MASTER THESIS

MAINTENANCE AT THE DR. JULES SEDNEY PORT OF PARAMARIBO: IDENTIFYING AREAS FOR IMPROVEMENT

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Acknowledgement

This document contains the final chapter of my life at the University of Twente, with the goal of attaining my master's degree in the field of Construction Management and Engineering. As the title "*Maintenance at the Dr. Jules Sedney port of Paramaribo: Analysing current maintenance and the maintenance process"* suggests, this research was conducted in Paramaribo - my home city.

The research was carried out at the landlord of the port of Paramaribo, the Suriname Port Management Company where I was stationed in the Infrastructure Department. I would like to thank the company, my company supervisor (Aisa) and the personnel at the company especially those of the Infrastructure Department for their acceptance and help during my research.

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Summary

Because ports are considered an essential part of civil infrastructure it was an ideal situation to help the Suriname Port Management Company to improve maintenance at the Dr. Jules Sedney Port of Paramaribo in Suriname.

The objective of the research was "*to develop recommendations for HBS to improve current maintenance in line with the HBS maintenance manual and align the current maintenance process in accordance with literature"*. This objective was split into four separate parts namely:

1) To analyse the differences between the HBS maintenance manual and current maintenance.
2) To identify the reasons behind the difference between the HBS maintenance manual and current maintenance.
3) To analyse the difference in the maintenance process between a mature organisation and the current organisation.
4) To recommend ways HBS can improve maintenance in line with the maintenance manual and by aligning the maintenance process according to literature

A literature review was performed to gain more insight into maintenance management, factors affecting the implementation of a preventive maintenance program and to identify a framework for the analyses of the collected data. The data collection consisted of analysing literature, performing interviews, analysing company documentation and performing observations.

To reach the objectives of the research, the most suitable approach was performing gap analyses on current maintenance and the maintenance processes. By performing a gap analysis, the differences could be identified between the desired or ideal state and the current state.

For this research two gap analyses were performed. The first analysis (comparison 1) relates to sub-objective 1 namely to identify the differences between the HBS maintenance manual and current maintenance. The maintenance manual was regarded as the ideal state and the main points and maintenance of several assets were used as a reference to compare to current maintenance. The main points and assets focused on are:

1) Maintenance organisation
2) Database
3) Norms and criteria
4) Inspections
5) Quay
6) Concrete piles underneath the quay
7) Concrete transition slab
8) Storm water drainage
9) Bollards
10) Fenders
11) Electrical installations
12) Water supply and firewater system
13) Fences
14) Draught of quay

After identifying both the ideal state and the current state several gaps were revealed. Gaps were present in the maintenance organisation, the database, norms and criteria, inspections and maintenance activities. The current maintenance organisation is different than the one prescribed in the maintenance manual and the research revealed that the database is limited, and norms and criteria currently used are based on the experience of the personnel and not on recorded information. When it comes to maintenance of assets and performing inspections there are differences between performing inspections, inspection method and reasons why inspections are performed, differing considerations regarding the importance of inspections and maintenance, and different maintenance actions, methods and timing of maintenance.

The identified reasons behind these gaps causing a difference between the maintenance manual and current maintenance are a lack of knowledge, limited resources, absent maintenance policy, contractual -and organisational problems.

The second analysis (comparison 2), based on sub-objective 3 aimed to identify the differences between the maintenance processes in a mature organisation and the current organisation. The mature organisation was regarded as the ideal state and was identified based on information gathered from literature. The current state consists of the current organisation supplemented with the maintenance manual.

The comparison revealed several similarities and differences in the maintenance processes between the current organisation and the mature organisation identified through literature. Similar steps are followed in all the processes, but a difference is the level of detail and documentation provided in the current organisation which is substantially less than what is prescribed in literature. Currently a lot of emphasis is placed on the experience of the personnel because of the limited information documented. Another difference includes the absence of several steps in the assessment phase of maintenance which make it harder for the Suriname Port Management Company to assess and improve the maintenance process.

With the company aiming to implement more preventive maintenance actions, it was important to identify which factors affecting the implementation of a preventive maintenance program were present within the company. Both positive and negative factors are present with factors such as training for personnel, a short organisational structure and good communication system aiding implementation. Factors inhibiting successful implementation are a lack of an implementation plan, custom made maintenance program (until the maintenance manual is updated) and a lack of performance measurements. An important factor which cannot be forgotten when successfully implementing a PM program is the support of management.

After performing this research, several recommendations are made based on short-term and long-term improvement of maintenance within the company. Summarised, the recommendations for short-term improvement of maintenance are that the company must perform inspections. The inspections can either be performed by personnel or by an external consultant. In case personnel is used, these must receive additional training to perform inspections. Another recommendation is that a database must be developed. The company should implement standardised data collection methods for this database. The database should consist of data from all objects which require, affect or are affected by maintenance. A final recommendation for short-term improvement is that current procedures, maintenance activities, and standards and criteria should be registered, reviewed and added to the maintenance manual resulting in an updated maintenance manual.

The long-term recommendations relate to the development of a maintenance policy with an evaluation of the Infrastructure Department part of this policy. The company should decide which path is to be followed regarding maintenance including who should perform maintenance. Another recommendation is the creation of an implementation plan when implementing the maintenance policy and aligning the current maintenance process to the processes performed by the mature organisation with the constant improvement of maintenance especially taken into account.

1. Introduction

"Satisfactory lifetime performance of civil infrastructure is of critical importance to sustained economic growth and social development of a modern society". This is a statement in a paper by Frangopol & Liu (2007) which highlights the importance of well-maintained infrastructure. Deterioration of infrastructure will eventually lead to increased costs for consumers and will have social and economic consequences in case of catastrophic failure. Well-maintained civil infrastructure can increase a country's competitiveness and resilience to unfortunate circumstances like natural hazards and manmade disasters (Frangopol & Liu, 2007).

To better understand the research, two definitions will be defined in this introduction. The first one is maintenance which is the combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function (EN13306, 2010).

The second word is asset, which is defined in the Oxford dictionary ("asset | Definition of asset in English by Oxford Dictionaries," 2017) as (1) a useful or valuable thing or person (2) an item of property owned by a person or company, regarded as having value and available to meet debts, commitments, or legacies. In this case the asset will be described using the second definition.

An asset may be split up into separate components which differ in size, function as well as the cost related to them. To maintain these components several maintenance actions are taken. During the 20th century these actions have evolved, and maintenance has changed – from only corrective actions being performed – with precautionary maintenance being developed. Corrective maintenance consist of performing repairs or restoration after loss of function or a breakdown has occurred and precautionary maintenance consist of performing preventive, predictive, proactive or passive maintenance actions to prevent a breakdown of loss of function (Pintelon & Parodi-Herz, 2008).

Maintenance also consists of performing cleaning activities. Some of these activities are performed daily and some actions periodically. This all depends on what needs to be cleaned and maintained. Examples of this are daily cleaning of the floor, but also maintaining the grass lawn every 2 weeks or cleaning the drainage system once a year.

Because harbours are considered critical infrastructure, it is imperative that these are optimally maintained to ensure that they function as designed to sustain economic growth and social development of modern society. Maintenance plans and maintenance manuals are helpful tools for performing the necessary maintenance. This is the reason why Port Management Consultants BV was commissioned to write the HBS maintenance manual (2010) - "Onderhoudsmanual N.V. Havenbeheer Suriname" – for the Suriname Ports Management Company (N.V. Havenbeheer Suriname). The company wanted to keep the assets in a good state after starting a rehabilitation and upgrade in 2007 at the Dr. Jules Sedney Port of Paramaribo (further referred to as the port of Paramaribo).

1.1. Background

Paramaribo, the capital of Suriname, has a long history of maritime trade. As a plantation colony, the export consisted mostly of much sought after agricultural products – mostly coffee and sugar – towards Europe and the import of slaves from Africa. The port of Paramaribo was initially located at the centre of Paramaribo, but in 1964 this was moved 3 km upstream (to the south) where the new

port – "De Nieuwe Haven" (renamed the Dr. Jules Sedney Port of Paramaribo in 2016) – was constructed (*Suriname Ports Handbook 2013-2014*, 2012).

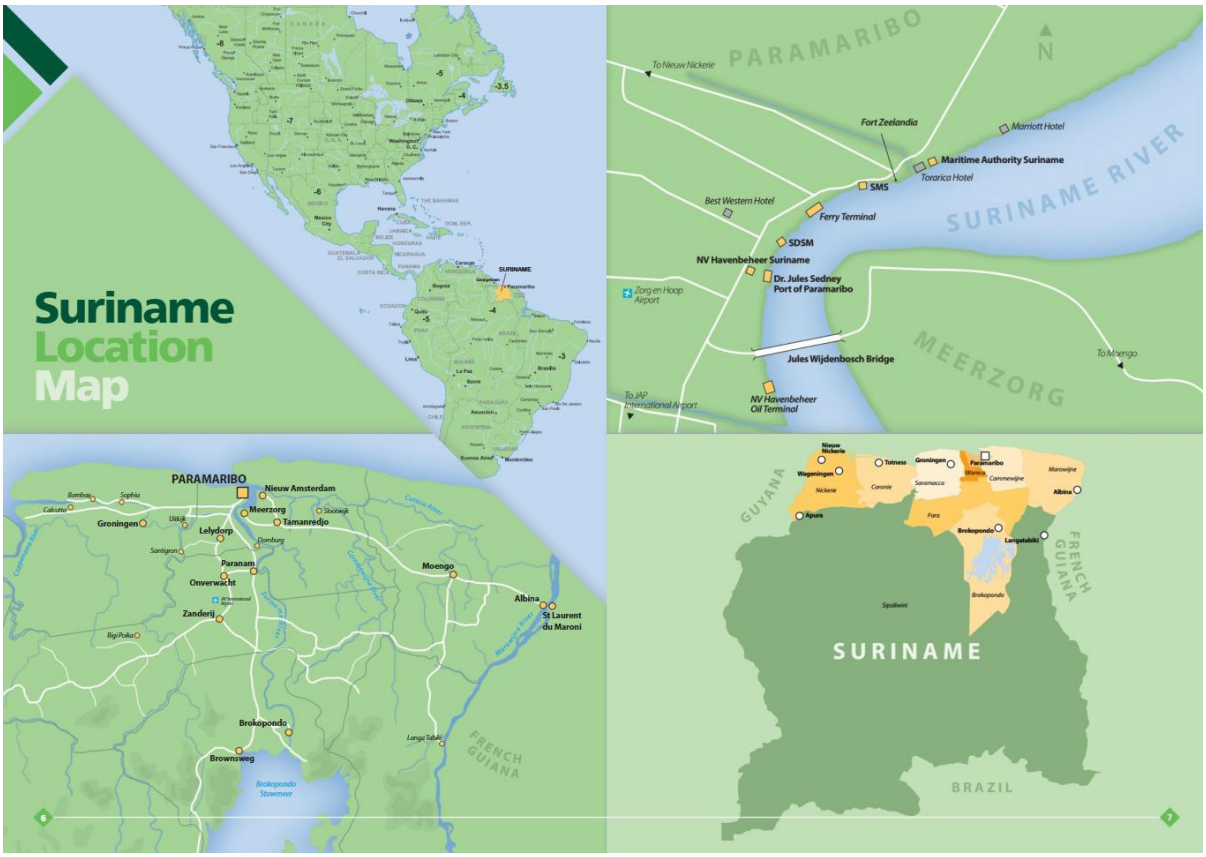

Figure 1.1 – Suriname and the Dr. Jules Sedney port of Paramaribo. Reprinted from Suriname Ports Handbook 2018-2019, 2017, Essex, Land & Marine Publications Ltd. Copyright 2007 by Land & Marine publications Ltd.

The Suriname Port Management Company (HBS) was founded on 11 November 1971 and handed responsibility of the new port. The company is owned by the Government of Suriname but operates as a limited liability autonomous company (*Suriname Ports Handbook 2013-2014*, 2012).

The main responsibilities of the company are (*Suriname Ports Handbook 2013-2014*, 2012):

1) Operating and maintaining landside areas such as jetties, buildings and other port installations within the port areas of public waterways in Suriname.
2) Continuous improvement of services and facilities.
3) Managing and operating the dry areas of the ports of Paramaribo and Nieuw Nickerie, and the N.V. Havenbeheer Oil Terminal in Paramaribo.
4) Stimulating economic activity and job creation within the ports by optimising the services and business climate.
5) Ensuring that sufficient space is available for port activities and investing in the maintenance and renewal of the infrastructure.

In 2007 a rehabilitation and upgrade project of the harbour was initiated. This was done mainly due to three reasons: (1) to better accommodate Suriname's growing economy; (2) to better accommodate containers; (3) to improve the condition of the deck and quay (*Suriname Ports Handbook 2010-2011*, 2009).

Figure 1.2 - Port of Paramaribo (G. Sontowinggolo, personal communication, August 2017)

The project resulted in the rehabilitation and complete restructuring of the layout for the 55,000 m^2 area ("Surinaamse haven kan weer dertig jaar mee," 2011) with the rehabilitated port officially opening in April 2010. By 2012 the total area of the harbour had increased to 182,000 m^2 with an extension of the quay – to a total length of 600 metres – part of the program (*Suriname Ports Handbook 2013-2014*, 2012).

1.2. The problem

At first glance it appeared maintenance at the port had room for improvement. It appeared preventive maintenance was not performed, whereas this is the strategy prescribed in the HBS maintenance manual. In most cases maintenance of the company's assets is performed when the assets are in danger of failing (failure-based maintenance), in lesser cases when a certain deteriorating condition has been noticed (condition-based maintenance) or when a complaint has been registered.

By assigning Port Management Consultants BV with the development of the maintenance manual, HBS attempted to make a first step in optimizing maintenance of their assets. Until recently however, this maintenance manual seems to have been largely neglected.

To improve its implementation, HBS needed to first identify what gap exists between the current maintenance practices and maintenance as specified in the HBS maintenance manual. Without having identified this gap, it may prove difficult for HBS to align practice with this manual. This could mean that parts of the manual should be adapted to existing practices, or alternatively that existing maintenance practices should be changed to be more in line with the prescribed maintenance in the manual.

Because no information was available regarding the maintenance process at the port it was unclear if improvement was needed and especially in which areas. A gap analyses was also considered the best strategy to identify these areas and thus a comparison was made regarding the maintenance processes performed by the current organisation and those performed in a mature organisation.

1.3. Research objective and research questions

The research objective describes the reason behind the research. Understanding the reason behind this provides insight regarding the work that needs to be done. The research questions guide and structure the process of collecting and analysing information to help attain the purpose of your study (Hartmann, 2017).

1.3.1. Research objective

The research aims to improve maintenance within HBS. To achieve this, the research objective can be noted as:

To develop recommendations for HBS to improve current maintenance in line with the HBS maintenance manual and align the current maintenance process in accordance with literature.

This research objectives can be split in four parts:

1) To analyse the differences between the HBS maintenance manual and current maintenance.
2) To identify the reasons behind the difference between the HBS maintenance manual and current maintenance.
3) To analyse the difference in the maintenance process between a mature organisation and the current organisation.
4) To recommend ways HBS can improve maintenance in line with the maintenance manual and by aligning the maintenance process according to literature.

1.3.2. Research questions

To reach this objective, several research questions and sub questions are formulated. These are:

1) To analyse the differences between the HBS maintenance manual and current maintenance.
   a) How does the maintenance manual prescribe maintenance to be?
   b) How is maintenance currently performed?
   c) What are the differences between the HBS maintenance manual and current maintenance?
2) To identify the reasons behind the difference between the HBS maintenance manual and current maintenance.
   a) What are the reasons behind the difference between the HBS maintenance manual and current maintenance?
3) To analyse the difference in the maintenance process between a mature organisation and the current organisation.
   a) How does literature describe the maintenance process within a mature organisation?
   b) How is the maintenance process within the current organisation?
   c) What are the differences between the maintenance processes within a mature organisation and the current organisation?
4) To recommend ways HBS can improve maintenance in line with the maintenance manual and by aligning the maintenance process according to literature.
   a) What steps can be taken to bridge the gap between maintenance prescribed in the HBS maintenance manual and current maintenance?
   b) How can the current maintenance process evolve towards that within a mature organisation?

1.3.3. Contribution of the research

This research contributes in different ways to the scientific community, the company and society. The contributions are as follows:

- Scientific contribution - This research will aid in generating empiric knowledge of existing maintenance practices in Suriname and compares these against the state of the art in literature.
- Company contribution – The research helps the company move towards better maintenance by identifying, understanding and bridging the maintenance and maintenance process gap.
- Societal contribution – In an indirect way, the research aids in improving port infrastructure. Good infrastructure increases the country's competitiveness in the global economy while deteriorating infrastructure raises consumers costs, especially in case of failure.

2. Literature review

This chapter discusses the theoretical background of this study and is divided into four sections. The first section gives insight into what maintenance is, the different maintenance types and maintenance strategies. Using this information, a conclusion can be drawn into what maintenance types and strategies are performed at the port.

In the second section the theory regarding maintenance management is discussed with the aim of analysing the current maintenance process and identifying the gap between literature, the maintenance manual and the current situation.

The third section provides insight into the implementation of preventive maintenance (PM) programs. This information is used to analyse the current situation while looking at enabling factors for successful implementation of a maintenance program.

In the last section a data analysis framework is illustrated.

2.1. Maintenance strategies

Maintenance is defined as the combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function (EN13306, 2010).

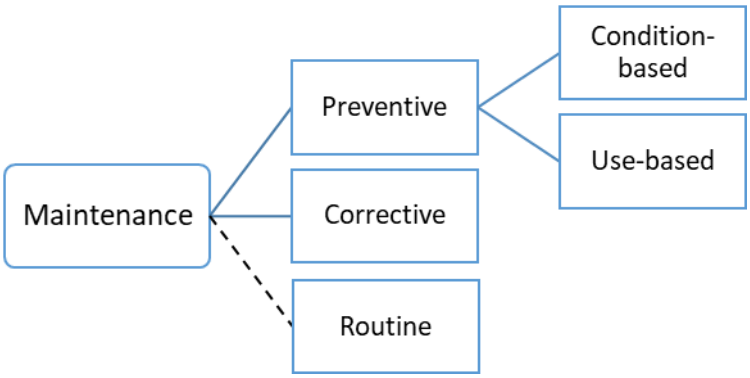

Figure 2.1 - Maintenance strategies

Van Der Toorn (1994) has divided maintenance according to strategies and split precautionary – referred to as preventive maintenance further on – maintenance into two parts. An important point he makes is that the repair costs will occur in all the maintenance strategies, but that the choice of which strategy to choose is primarily based on the extra costs. The extra costs differ per chosen strategy and consists of costs in addition to the cost of repair. The three maintenance strategies including the different costs are:

1) Failure-Based Maintenance: maintenance actions undertaken after failure has been noticed. The total cost of failure-based maintenance is the total cost of repair (or replacement) plus the total cost of consequences of failure, divided by the expected (average) lifetime.

2) Use-Based Maintenance: maintenance actions are taken after a certain use (time, distance, load history, etc.). The cost of use-based maintenance is given by the cost of repair (or replacement) plus the risk of failure up to the time when action is taken, divided by the expected lifetime, which is nearly the cycle of the planned repair.

3) Condition-Based Maintenance: maintenance actions are taken after a certain (unacceptable) condition limit is exceeded and noticed (by inspection, monitoring, performance, fuel and oil consumption, etc.). The cost of condition-based maintenance is the total cost of repair (or replacement), the expected inspection costs plus the total of risk failure and divided by the expected lifetime.

A very important factor in condition-based maintenance is the noticing of a condition limit. This can be done using several methods. The first method stated is performing an inspection. An inspection is a check for conformity by measuring, observing, testing or gauging the relevant characteristics of an item (EN13306, 2010). These are generally carried out before, during or after other maintenance activity (Crespo Márquez, 2007). In some cases, a simple inspection checklist is used which combined with human senses such as visual inspections, listening to strange noises, etc. can detect potential problems, but in other cases data, knowledge and equipment is necessary to predict when failure might occur (Pintelon & Parodi-Herz, 2008).

One form of maintenance not categorised in a strategy but performed in the company nonetheless is routine maintenance. This consists of regular or repeated elementary maintenance activities which usually do not require special qualification, authorization(s) or tools. Routine maintenance may include, for example, cleaning, tightening of connections, checking liquid level, lubrication, etc. (EN13306, 2010).

Given the above, the different maintenance strategies used in the maintenance manual and those currently used at the port can be determined.

2.2. Maintenance management

Maintenance also has an organisational part which can be summed up as the maintenance management function. Haroun and Duffuaa (2009) provide the following information regarding this:

"The maintenance management function consists of planning, organizing, implementing and controlling maintenance activities. The management organizes, provides resources (personnel, capital, assets, material and hardware, etc.) and leads to performing tasks and accomplishing targets. Once the plans are created, the management's task is to ensure that they are carried out in an effective and efficient manner. Having a clear mission, strategy, and objectives facilitated by a corporate culture, organizing starts the process of implementation by clarifying job and working relations (chain of command, span of control, delegation of authority, etc.)."

To manage maintenance effectively the department must meet the goals of the company. This department, summarised as the maintenance organisation is highlighted in the maintenance manual with Haroun and Duffuaa (2009) stating that the maintenance organisation is an integral part of the maintenance management function. Capacity of maintenance, the organisation of the maintenance department (centralised or decentralised) and how maintenance will be performed (in-house or outsourced) are essential factors in a maintenance organisation.

According to Haroun and Duffuaa (2009) there are several factors impacting a maintenance organisation and its position within the whole organisation namely:

- the type of business;
- the company objectives (these are for example: minimizing costs, providing a specific quality level of service, a safe and clean environment);
- the size, structure and culture of the organisation; and

- the range of responsibility assigned to maintenance.

To manage maintenance properly Crespo Márquez (2007) proposes the following sequential steps for asset maintenance: asset maintenance planning, scheduling maintenance operations, managing maintenance actions execution (including data gathering and processing), assess maintenance and ensuring continuous improvement. Duffuaa & Haroun (2009) describe the same steps (figure 2.2), but use different names for scheduling (organizing), execution (implementing) and maintenance assessment (controlling). These four steps are used for the analysis of the research data.

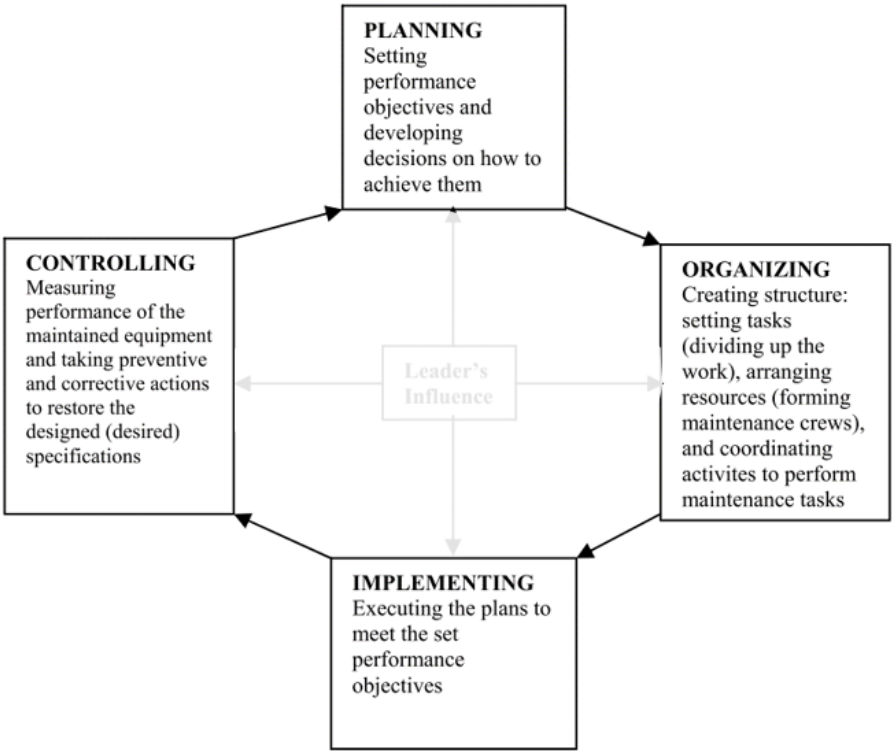

Figure 2.2 – Maintenance control as a function of the management process. Reprinted from Maintenance Control BT - Handbook of Maintenance Management and Engineering by S. Duffuaa and A. Haroun, 2009, London: Springer London. Copyright 2009 by Springer-Verlag London Limited

2.2.1. Maintenance planning

Maintenance planning – which is the management activity in preparation of the maintenance plan – is essential in performing an effective maintenance operation. Maintenance planning can be divided into short-term, (daily or weekly) medium-term (1 month – 1 year) or long-term plans (1 year – 5 years) (Duffuaa & Raouf, 2015). For the efficient planning of future maintenance activities and resources, good estimates of the future maintenance workload are of the utmost importance for the preparation of the future maintenance tasks (Duffuaa & Haroun, 2009). Crespo Márquez (2007) considers several aspects important to facilitate correct planning of maintenance such as the determination of asset priority, maintenance task identification, maintenance task analysis and maintenance resource identification (capacity planning).

Asset priority can be done using quantitative or qualitative techniques. Quantitative techniques can be used best when data on historical failure rates is available. In case of a lack of this data the organisation can use qualitative techniques such as a gross assessment. After the assets have been prioritised, the maintenance strategy must be set up for these assets (Crespo Márquez, 2007).

Maintenance task identification is composed of a number of processes which result in the choice between performing corrective or PM tasks (Crespo Márquez, 2007).

According to Crespo Márquez (2007) the specific information and resources necessary to perform maintenance are determined in the maintenance task analysis.

Carrying out an effective maintenance operation requires efficient planning of maintenance activities and resources. Since planning is performed to prepare for future maintenance tasks, it must be based on good estimates of the future maintenance workload. The resources required for maintenance are determined when planning the maintenance capacity. An important resource is skilled labour. The number of skilled personnel and their workload is a common problem encountered while scheduling the maintenance capacity. The key is striking a balance between the work to be done and the amount of skilled labour needed (Crespo Márquez, 2007). Although calculating the number of skilled personnel is possible Haroun and Duffuaa (2009) state the following regarding the capacity of skilled personnel:

"In order to have better utilization of manpower, organizations tend to reduce the number of available craftsmen below their expected need. This is likely to result in a backlog of uncompleted maintenance work. This backlog can also be cleared when the maintenance load is less than the capacity."

The steps proposed by Crespo Márquez are necessary to obtain the maintenance plan which according to EN13306 (2010) consists of a "structured and documented set of tasks that include activities, procedures, resources and the time scale required to carry out maintenance".

2.2.2. Maintenance scheduling

After maintenance planning, the next step is scheduling maintenance. Scheduling refers to the process of placing the tasks specified in the maintenance plan into a timeframe. Availability, acquisition and assigning of resources, linking different maintenance tasks, preparation of the different tasks, and the internal and external limitations and constraints are considered. Maintenance should be scheduled using a priority system (figure 2.1) to ensure that the most urgent, costly and important maintenance activities are performed first (Al-Turki, 2009; Crespo Márquez, 2007; Duffuaa & Raouf, 2015).

Table 7.1 Priorities of maintenance work

Priority		Time frame work should start	Type of work
Code	Name		
1	Emergency	Work should start immediately	Work that has an immediate effect on safety, environment, quality will shut down the operation
2	Urgent	Work should start within 24 h	Work that is likely to have an impact on safety, environment, quality, or shutdown the operation
3	Normal	Work should start within 48 h	Work that is likely to impact the production within a week
4	Scheduled	As scheduled	Preventive maintenance and routine. All programmed work
5	Postponable	Work should start when resources are available or at shutdown period	Work that does not have an immediate impact on safety, health, environment, or production operations

Figure 2.3 - Priorities of maintenance work. Reprinted from Planning and control of maintenance systems: Modelling and analysis, by S. Duffuaa & A. Raouf, 2015, Cham; Springer Cham. Copyright 2015 by Springer International Publishing Switzerland.

2.2.3. Maintenance task execution

After maintenance has been planned and scheduled, the execution of activities must take place. These tasks must be performed carefully with attention paid to the technical aspects, safety and environmental procedures. Information such as inspection data, work time, tasks carried out and resources must be recorded which can be used for managing the maintenance process and solving problems of similar nature (Crespo Márquez, 2007). To collect this inspection data, inspections must be performed.

Data can either be internal or external to the company. Internal data is data such as engineering designs, maintenance, finance, legal, etc. External data includes information such as the material information from vendors and information from service agents in case maintenance is outsourced. Data can also be collected in terms of its use. In this case data can be either technical, economical, commercial, etc. (Murthy, Karim, & Ahmadi, 2015). The data can be used for planning, monitoring, benchmarking and evaluating the various operations involved in the maintenance of an object, building models to assist the decision-making processes, and for continuous improvements to the operations.

All this data can be stored in a database. The database should consist of data from all areas that affect or are affected by maintenance. Because data is coming from different sources, it is important to establish what kind of data will be collected, who will collect what data and who will do the data analyses and modelling (Murthy et al., 2015). This common maintenance database is necessary to define, identify and integrate all kinds of data needed to plan, carry out, follow up and improve maintenance. Kans & Ingwald (2008) argue that the shared information is relevant to support decision making especially in case of PM. The data required is much larger compared to reactive maintenance. This data must be structurally defined, identified and retrieved.

2.2.4. Maintenance assessment/control

Essential in maintenance management is assessing or controlling the process. Analysing the maintenance process can be viewed as part of the control function of maintenance management. Maintenance control refers to the resources, activities and procedures needed for work control, quality and process control, cost control, and an effective reporting and feedback system (Duffuaa & Haroun, 2009). Crespo Márquez (2007) states that maintenance must be assessed to test maintenance efficiency and effectiveness. Objective standards must be used by the organisation for collecting, analysing, and interpreting data. Actual performance must be measured of which the results must be compared with the specified standards to support corrective actions and improvements (Crespo Márquez, 2007; Duffuaa & Haroun, 2009). Likewise, the use of job standards will specify a qualified workers productivity according to standard performance in similar functions. This is also necessary for evaluating the performance of facilities, and for predicting, planning, scheduling, and controlling work, costs, and operations (Duffuaa & Raouf, 2015). Continuous improvement must be the goal of the company.

When PM is performed, the assessment should cover the effectiveness of maintenance, technical aspects of the maintenance task, adequacy of resources and operating, safety and environmental procedures. In case of corrective maintenance, the cause of failure must be investigated as well and used to identify preventive and corrective actions (Crespo Márquez, 2007).

To summarise the maintenance management section of this report, the four phases of the maintenance process – planning, scheduling, execution and control – are necessary to properly manage maintenance. The planning phase consists of task identification and task analysis which are both important when analysing the current situation to identify what maintenance strategy is used and to plan for the execution of maintenance.

For the scheduling phase the addition of priorities is important to identify how maintenance is scheduled. In this phase the availability and distribution of resources are essential while preparing for the execution of the different maintenance tasks.

Important aspects of the execution phase are performing the maintenance tasks taking technical aspects, safety, environmental procedures into account in addition to gathering information such as inspection data, work time, tasks carried out and resources. The information gathered in the execution phase is necessary to control the maintenance process and work towards improving all four phases of this process.

2.3. Maintenance implementation

Because the research at the Suriname Port Management Company (HBS) centres around the HBS maintenance manual and its implementation, it is important to study the literature to interpret the data and to reach conclusive findings.

There are several reasons why companies change their maintenance practices and in this change several factors have been noticed that hamper or foster this process. Moubray (as cited in Eti et al., 2006) states that improving maintenance procedures usually requires: “a change of attitude; and getting maintenance personnel to apply the resulting proposed changes, one at a time, ensuring each time that an improvement occurs.” while Kotter (as cited in Bengtsson, 2007) adds that successful implementation is based on following a multi-step process to create power and motivation to overcome the conservatives, and strong leadership. It thus becomes important to identify the steps which hamper or support the improvement of maintenance.

A point to take into account noted by Moubray and Starr (as cited in Bengtsson, 2007) is that condition-based maintenance should be used when it is appropriate and not as a general maintenance strategy. This can also be applied to preventive maintenance which should be used when it is appropriate and not as an overall maintenance strategy.

2.3.1. Common problems during implementation

Several problems have been identified that occur during implementation of PM. The most common problems identified by Bakerjan (as cited in Bamber, Sharp, & Hides, 1999) during the implementation of a Total Productive Maintenance program (TPM) being a lack of management support and understanding, a lack of sufficient training and the failure to allow sufficient time for the evolution of maintenance. Even though TPM focusses on maintenance at production facilities, the problems experienced are similar to those occurring during implementation of PM in general.

Other researchers have categorised the problems differently than Bakerjan but have found similar problems that are linked to a lack of management support (Davis as cited in Bamber et al., 1999; Higgs et al., 2004; Ireland & Dale, 2001). Two reasons include management lacking a complete understanding of the real goals of the PM program but thinking of it as just a tool to save money

(Bamber et al., 1999) and lacking determination during the implementation of the program (Davis as cited in Bamber et al., 1999). Other reasons include problems with the acceptance and support by personnel for the new maintenance strategy (Higgs et al., 2004; Tsang & Chan, 2000), implementation of a standard program instead of a custom made program (Davis as cited in Bamber et al., 1999; Higgs et al., 2004), and programs that have problems such as being too high on managerial or engineering level that lack to involve all the structures within the organisation which lead to a loss of involvement of various personnel (Davis as cited in Bamber et al., 1999).

Sufficient training – to keep up current skills and introduce new skills – is necessary because not just a change in maintenance strategy, but a complete change of maintenance culture is needed for successful implementation of a maintenance program (Bamber et al., 1999). The use of inexperienced consultants/trainers, possibly combined with an absence of education and training for the people responsible for the support of the program, also leads to problems for implementation. The teams responsible for maintenance will eventually lack the necessary skills and experience (Davis as cited in Bamber et al., 1999) but these are precisely the important actors in the implementation because it's success depends heavily on the skills of the technicians (Higgs et al., 2004). A change in strategy has proven to be a problem for engineers, especially for the older generation as changes in entrenched practices are considered to be extremely difficult (Higgs et al., 2004).

The time needed for the successful implementation of a PM program is often overlooked by company management (Bakerjan as cited in Bamber et al., 1999). This implementation often involves changing entrenched practices, and changing entrenched practices takes time. The level of difficulty in a complete change instead of gradual change must be taken into account (Higgs et al., 2004).

All in all, the literature has identified the following factors that hamper successful implementation of PM programs:

1) Insufficient management support and understanding;
2) Lack of training;
3) Not calculating enough time for implementation.

2.3.2. Factors leading to successful implementation

From the studies done on the implementation of PM several key factors have been identified that lead to successful implementation. The most important one is having an implementation plan which is both practical and adjustable. The implementation plan must be practical so it is clear to everyone involved in the process and easier to implement but changes must also be possible in case a strategy proves less effective than hoped (Davis as cited in Bamber et al., 1999; Ireland & Dale, 2001). Relevant measures of performance must be used to continually monitor improvement in different areas with the aim of achieving the greatest benefits. These benefits should be continuously communicated to everyone involved in the program to aid in the acceptance of the program (Davis as cited in Bamber et al., 1999; Ireland & Dale, 2001). (Bengtsson, 2007) and Tsang and Chan (2000) indicate that conducting pilot projects is helpful to verify, fine tune and adjust the implementation before starting on a larger scale.

Management accepting that the implementation of a PM program will take time is also important. Changing the attitudes and values of employees requires time to spread across a company (Davis as cited in Bamber et al., 1999; Tsang & Chan, 2000). The company management must keep in mind that estimates for complete implementation range between 3-5 years (Bamber et al., 1999). This makes it important that the management is determined to keep going forward with the changes (Davis as cited

in Bamber et al., 1999) especially if these changes have already proven to be an improvement. Management support is crucial since they must support coordinators with time and resources, back them when necessary and enforce the policies put in place for the implementation (Davis as cited in Bamber et al., 1999; Tsang & Chan, 2000).

Management can also support the implementation by developing the organisational structure limiting the management layers – in case several layers exists and this proves to be a problem during implementation – so that the maintenance manager/coordinator can communicate in a much more direct way with senior management and changes can be executed faster (Ireland & Dale, 2001). The training of this manager and coordinators is important because they must promote and support the PM activities daily (Davis as cited in Bamber et al., 1999). Communication between personnel at different levels – top-down and bottom-up – in the maintenance process is important for the success of the implementation. This communication is important for the removal of doubts regarding the changes as well as, promoting trust, understanding, and collaboration between different levels of maintenance and departments (Bamber et al., 1999; Bengtsson, 2007; Ireland & Dale, 2001; Tsang & Chan, 2000). The communication can be performed using multiple channels such as newsletters, bulletin boards, videos, training and even before and after pictures of situations (Holder as cited in Bamber et al., 1999). The frequency depends on how the information is processed by the personnel because a clear understanding is necessary of the process, goals and needs, but should be frequent and provide information regarding all the changes.

To summarise, the factors identified as positive for the successful implementation of PM programs are:

- Implementation plan - custom PM program, sufficient implementation time, implementation strategy.
- Management support - well trained champions to manage the implementation, resources, determination
- Short management levels
- Performance measurement
- Training
- Communication

Ultimately, the analysis of the maintenance process is done with the aim of identifying which factors exist in the current situation. When more information is known about these factors, HBS can work towards successful implementation of the HBS maintenance manual.

2.4. Data analysis framework

The literature above is integrated into a framework (figure 2.4) combining maintenance management and implementation factors. The HBS maintenance manual

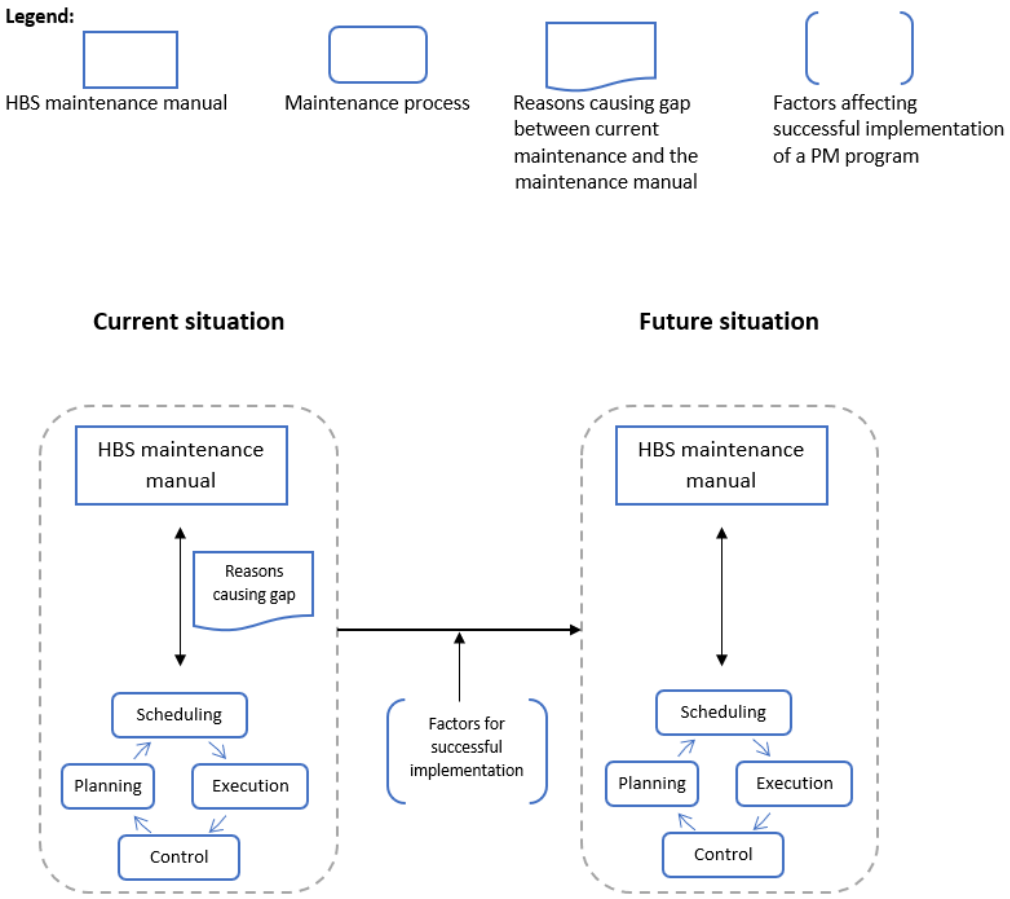

Figure 2.4 - Data analysis framework

Table 2.1 - Data analysis framework legend

Current situation	Situation the moment the research was performed
HBS maintenance manual	Maintenance manual developed by Port Management Consultants BV (2010)
Reasons causing gap	Unknown reasons causing the difference in maintenance between the HBS maintenance manual and current maintenance
Planning	Task description and task analysis
Scheduling	Scheduling prioritisation and scheduling tasks
Execution	Maintenance execution
Control	Assessment of maintenance
Factors for successful implementation	Factors affecting successful implementation of a maintenance strategy as defined in chapter 2.3
Future situation	Considered the desired situation for this research

3. Research design

The research methodology describes how the research was conducted. The goal of this methodology was to help the researcher perform the research as smooth as possible while considering risks and other potential factors that could hinder the progress of the research. A research design is a blueprint or plan for the collection, measurement, and analysis of data, created to answer your research questions (Hartmann, 2017).

3.1. Research methodology

The method of research was a gap analysis conducted in a case study. A gap analysis is a tool to assess the current situation by comparing it to an ideal/desired situation (Nolan, Anderson, Nolan, & Anderson, 2015). In this research two separate gap analyses were performed namely to analyse the difference between the HBS maintenance manual (referred to as maintenance manual) and the current situation (comparison 1) and to analyse the differences between maintenance processes in a mature organisation and the current organisation. By identifying the differences in these two comparisons, the company can discover in what areas attention must be focused to improve and bridge the gaps (Maletič, Maletič, Al-Najjar, & Gomišček, 2014).

Steps in a gap analysis include (Nolan et al., 2015):

1) Decide the topic you're going to do the gap analysis on.
2) Identify where you are right now.
3) Identify where you'd like to be over a specific time frame.
4) Identify the gap between where you are and where you want to be.
5) Determine how the gap should be filled.

These steps (Nolan et al., 2015) are adapted for this research with gap analyses performed in the two abovementioned cases. Figure 3.1 shows these adapted steps placed in a research model followed by an explanation on how the research was performed.

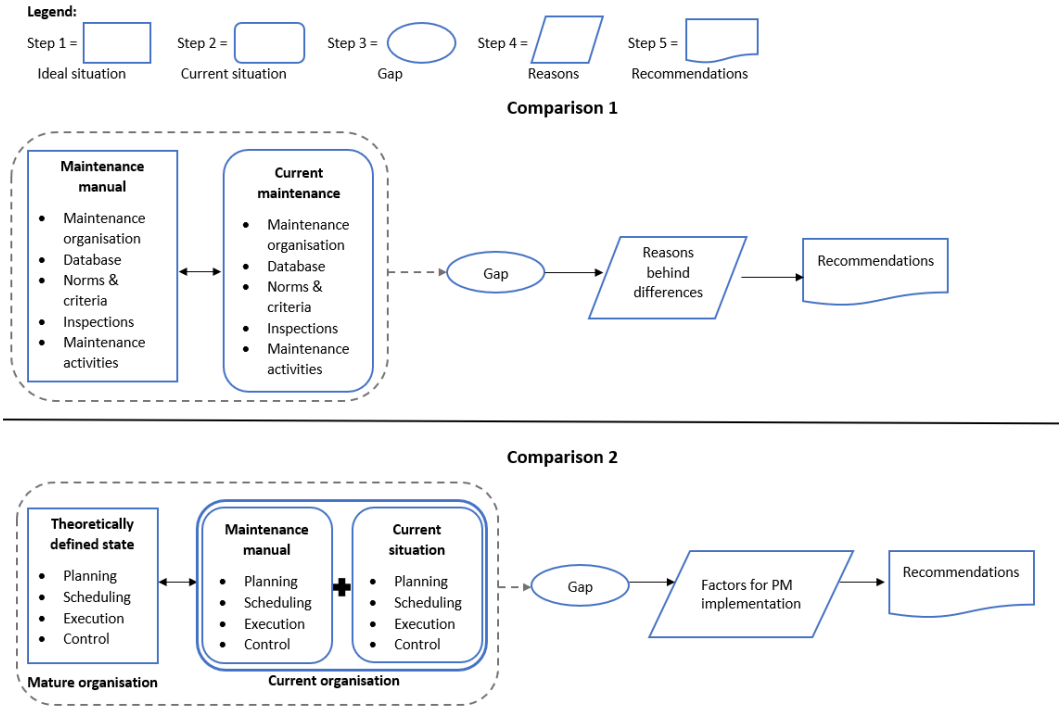

Figure 3.1 - Research model

Step 1 – Identifying the ideal/desired state

For comparison 1 the HBS maintenance manual is regarded as the desired state. This is used because the company wishes to further implement the maintenance manual and perform maintenance according to the information described in it. Using this as a benchmark, research was conducted to establish the gap between the information in the maintenance manual and current maintenance.

For comparison 2, the literature on maintenance management is regarded as the theoretically defined state for the maintenance processes in a mature organisation and used as the benchmark. The gap is thus identified by comparing the maintenance processes in a mature organisation to those in the current organisation.

Step 2 – Identifying the current state

Interviews, analysing documentation and performing observations were the methods used to identify the current situations in both comparisons.

For the interviews several persons were identified. These include persons or departments who are responsible for maintenance at the port or have an interest in the results of this analysis. Table 3.1 shows the relevant persons and the reasons why they are considered relevant. The interviews were divided into two rounds of which the questions in the first round (see appendix 1.1 for first round interviews questions) were used to collect data to identify current maintenance.

In comparison 1, the current state of maintenance was identified performing the interviews with questions based on the information retrieved from the maintenance manual. This information was used as a guideline, to identify how maintenance was performed on the objects listed in the maintenance manual and to determine the state of the main points noted in this manual. Because the data analysis framework lists that the comparison is between the maintenance manual and the current situation, only the items identified in the manual are used to identify the current maintenance.

For comparison 2, the questions from the first round of interviews, relevant documentation and observations were used to identify the maintenance processes performed by the current organisation

are identified as the current state. The maintenance processes performed by the current organisation consists of the current maintenance process and the maintenance processes identified in the maintenance manual. These are viewed together because this information is already available to HBS and can thus be compared to the maintenance processes in a mature organisation.

Table 3.1 - Respondents

Person	Interest
Infrastructure Department staff	Better implementation of the maintenance plan
Infrastructure Department field personnel	Better efficiency regarding maintenance
Safety Department	Safe working conditions and regulations
Operations Department	Steward of facilities
Consultant (external)	Project supervision at port
Contractor (external)	Maintenance contract at port

Step 3 - Identifying the differences
After the current maintenance practices and processes are identified the comparison can be made. Using the data analysis framework, comparison 1 was done to establish the gap between the maintenance described in the maintenance manual and current maintenance.

In comparison 2 the maintenance processes are identified by comparing the maintenance processes in a mature organisation to those performed in the current organisation. Starting by defining the maintenance strategy per asset, the data analysis framework is used to identify the differences following the sequential steps of planning maintenance, scheduling maintenance, maintenance task execution and maintenance assessment/control.

Step 4 – Identifying the reasons behind the differences and factors for improvement
In the data analysis framework several factors and reasons are noted which are important to the differences identified. These are addressed in this step, starting with performing a second round of interviews to identify the reasons behind the gaps between the maintenance manual and current maintenance. The interviewees – the same persons as in interview round 1 – were asked questions (see appendix 1.2 for the second-round interview questions) related to the identified gaps to collect the needed information.

For comparison 2 a different step was done than comparison 1 because the reasons behind this gap are not sought but an analysis was done. The analysis consisted of comparing data collected from the answers provided in the interviews, the observations and company documents to identify which factors affecting the implementation of a PM program – as identified in the literature review – are present in the current organisation.

Step 5 – Bridging the differences and improving maintenance
After analysing the different reasons for the gap – between the maintenance manual and the current state – and factors affecting the implementation, the last step using the data analysis framework is using the information acquired from the second round of interviews, the maintenance manual and literature to make proposals to assist in the improvement of maintenance at the Suriname Port Management Company.

3.2. Scope of the research

While the maintenance manual focusses mostly on assets that were part of the rehabilitation project, some points regarding maintenance are highlighted as well. The highlighted point: creating a maintenance organisation, creating a database, establishing norms and criteria, and implementing visual inspections are focused on in this research. In addition to these points, the assets important to the functioning of the port are focused on as well by examining the maintenance activities and the maintenance processes related to these assets.

To summarise, the items included in the study are:

1) Maintenance organisation
2) Database
3) Norms and criteria
4) Inspections
5) Quay
6) Concrete piles underneath the quay
7) Concrete transition slab
8) Storm water drainage
9) Bollards
10) Fenders
11) Electrical installations
12) Water supply and firewater system
13) Fences
14) Draught of quay

4. Identifying the gaps between the HBS maintenance manual and current maintenance

In this chapter the comparison of the HBS maintenance manual to the current maintenance practices is presented. The chapter is split into two sections with the comparison between the maintenance manual and the current maintenance presented in the first chapter and the reasons behind the identified differences presented in the second section.

4.1. Comparing the maintenance manual to current maintenance

In this section the maintenance manual is compared to the current maintenance which is maintenance as currently performed by Suriname Ports Management Company (HBS). The comparison is performed based on the main points and maintenance activities prescribed in the maintenance manual. After each item is listed, the gap between the maintenance manual and current maintenance for that item is presented.

Starting with the main points noted in the maintenance manual, the sequence of identifying the gaps is the following:

- Maintenance organisation
- Database
- Norms and criteria
- Inspections
- Maintenance activities

4.1.1. Maintenance organisation

Maintenance manual

The maintenance manual has a section regarding the creation of a maintenance organisation. Proposed is a small independent maintenance organisation within the company. This maintenance organisation should consist of inspectors for maintenance and supervisors of work performed by third parties as most work should be outsourced. The organisation is tasked with providing budget figures to the Financial Department of HBS in addition to overseeing that the allocated budget is not exceeded.

A proposal of three trained inspectors is made who should be part of the Infrastructure Department. Possibilities are that inspectors take turns performing inspections in different parts of the port or have inspectors who have specific knowledge regarding civil engineering, technical and electrical installations, and the environment.

Current situation

Currently the Infrastructure department is responsible for maintenance and thus the maintenance organisation. The department is in charge of performing maintenance, carrying out small construction projects, producing budget figures and working according to the acquired funds. The department consists of two sections namely the *Facility Services* and *Planning and Construction*. Facility services is charged with the upkeep of the grounds, cleaning of the port including the buildings, and maintenance of the drainage system. The Planning and Construction section is charged with the planning of maintenance activities, performing maintenance and small construction projects at the port. This

section is divided into an electrical, welding and a construction division with the electrical division performing maintenance on the electrical installation, the welding division performing maintenance on mechanical items and the construction division charged with maintenance of building of civil engineering objects.

Gap

Between the proposed maintenance organisation in the maintenance manual and the current maintenance organisation, there is a gap in regard to trained inspectors because these are currently not present.

Another difference is noticeable in the setup of both organisations. While the maintenance manual prescribes that maintenance be outsourced with the maintenance organisation overseeing the execution, the current maintenance organisation is also tasked with executing small construction activities.

4.1.2. Database

Maintenance manual

A main point in the manual is the creation of a database. There is no specification of what the database should contain other than items such as year of construction, design information and calculations, design drawings, and as built drawings.

Current situation

There is no database, but a limited amount of information is stored. Information such as technical drawings exists but are sometimes outdated. The information is also not stored centrally and there is no standardized format for collecting, interpreting and storing information. Further information such as calculations and other information relevant to maintenance is poor.

Gap

Even though the information regarding the database is limited in the maintenance manual, a general assumption can be made for the gap and that is the overall lack of documentation. This lack of documentation is supplemented by an absence of standard formats for the collection, interpretation and storing of information. Specific information such as year of construction, technical drawings, technical information and calculations does not exist for most objects.

4.1.3. Norms and criteria

Maintenance manual

The maintenance manual has no norms and criteria, but it highlights that HBS must create norms and criteria.

Current situation

Currently there are some criteria used – but not written down – for when maintenance activities are performed but this is not the case for most assets. An example of criteria followed which is not recorded is criteria regarding the cleaning of the stormwater inspection pits. Other criteria are provided in the maintenance actions section where the differences between the manual and the current situation are identified.

Gap

Although the maintenance manual has no norms and criteria, there are several being used by HBS. The problem is that these are not recorded but passed on orally and based on experience.

4.1.4. Inspections

Maintenance manual

The manual states that a system of visual inspections must be created by HBS and in the maintenance activities section of the manual some inspection cycles and guidelines are presented differing per object.

Current situation

There is no system for performing visual inspections, but several inspections are performed. At the moment there are inspections performed for cleaning of the port and the drainage system, the fenders, the lighting on the port, the emergency generators and the depth in front of the quay. These inspections differ in frequency and detail from the maintenance manual though. Inspections of other assets noted in the maintenance manual are not performed.

Gap

There is a gap in regard to the inspections which are performed and the way these are performed. The objects which are inspected are mentioned in the paragraph above, but inspections on the other objects are not performed.

4.1.5. Maintenance activities

In this section of the chapter the maintenance activities for specific objects are compared. These are:

1) Quay
2) Concrete piles underneath the quay
3) Concrete transition slab
4) Storm water drainage
5) Bollards
6) Fenders
7) Electrical installations
8) Water supply and firewater system
9) Fences
10) Draught of the quay

Because the information in the maintenance manual is specifically related to an object, the comparison is presented in tables. The first column of these tables indicates the action points stated in the manual or performed currently. These action points are noted as written in the maintenance manual and differ per object. The column maintenance manual indicates the time, frequency or activity that should be performed according to the manual. The column current situation shows the time, frequency or activity as currently performed. The column satisfactory refers to the conclusion that the performed actions are satisfactory or not. If the maintenance is satisfactory a check mark (√) is shown and in case of insufficient maintenance a “X” is shown. In case no information or activity is performed, a string of dashes (------) are placed in the column.

Quay

The quay is one of the most essential parts of the port since this is the area where the ships connect to land and is used to transfer the different objects between land and ship. Maintenance of the quay (table 4.1) is listed in the maintenance manual consisting of different action points.

Table 4.1 - Quay maintenance comparison

Action point	Maintenance manual	Current situation	Satisfactory
Inspection	Daily	Cleaning: daily Other activities: -----	√ X
Cleaning	Continuously remove rubbish and sand.	• Manual: Removal of litter, left-over bulk material, empty rubbish bins. Terminal operators are responsible for removing the waste in the terminals and waste generated when loading and unloading cargo. Waste is disposed of at official landfill. • Mechanical: Monthly cleaning using sweeper or vacuum truck. If necessary extra cleaning is done.	• √ • √
Removal of water	Use vacuum truck to remove water puddles to prevent/limit floor drains.	Drains drilled into floor. No action on water puddles.	X
Surface cracks	1. Register and monitor cracks. 2. Repair if necessary (procedure provided).	1. Inspect cracks after occurrence of an incident. 2. Refer to a consultant to supervise repairs if necessary.	1. X 2. √
Expansion joints	1. Sweep, blow clean or vacuum joints. 2. Repair in case of damage (procedure provided).	1. Sweep joints clean. 2. -----	1. √ 2. X
Drains	Regularly clean floor drains and drains in front beam.	Weekly cleaning of drains in the front beam.	√
Quay usage	Minimum crane distance, container stacking, limits for maximum load provided.	Supervision on crane minimum distance and container stacking.	√

Gap

The first point listed in the manual is the performing of inspections. At the moment inspections are performed regarding cleaning, but not for the other action points. Users indicate that an extra inspection might be necessary to ensure that the quay remains clean. The maintenance manual does not list the specific cleaning methods however and these actions must be added to the manual to ensure that it is up to date.

Figure 4.1 - Mechanical cleaning using a vacuum truck (Source: HBS archive, 2016)

Problems with flooding and dirt are dealt with right away but water puddles remain on the surface. In the maintenance manual the use of a vacuum truck is recommended to prevent the use of vertical drains. These drains have been made however and increase the possibility of concrete decay if not maintained. The drains were drilled into the floor after construction and concrete cover for the rebar is less than necessary. The problem with the water puddles however is that equipment traveling through these puddles leave additional dirt behind. These areas thus have a higher concentration of sand which may result in additional wear of the concrete. While this poses a problem, wear of the concrete surface is not considered.

Figure 4.2 - Water puddles and sand on quay, January 2018.

A look at the maintenance of the expansion joints reveals that these are cleaned but their functionality and damage are unknown. In case they are damaged, the repairs will not be performed quickly enough, and this may lead to additional problems.

Continuing with the next point of inspecting cracks on the surface, the difference is that instead of continuously checking and monitoring cracks this is only done after an incident has occurred. Incidents can be a container or other object falling. Instead of repairing the damage as listed in the manual, a report will be made, and the rest of the process will be transferred to a consultant to supervise repairs.

The use of the quay is not a maintenance activity, but by making sure the quay is used according to the manual, this should aid in prolonging the life of this asset. There is no monitoring of reach-stackers, other heavy mobile equipment or loads on the quay and the weight of containers or other objects is not verified.

Concrete piles underneath the quay

Essentially the foundation of the quay, the concrete piles must remain in good condition to ensure the port remains operational. Maintenance of these concrete piles (table 4.2) aims to keep these piles in optimal condition to support the quay and the loads of the transferred objects between port and ships.

Table 4.2 - Concrete pile maintenance

Action point	Maintenance manual	Current situation	Satisfactory
Inspection	• 2/year • 1* 5 years	-----	X
Damage	Repair and replace damaged pile if loadbearing capacity is compromised	-----	X
Concrete decay	Repair using provided procedure.	-----	X
Preservation	Clean and apply coating every 5 years	-----	X

Gap

No maintenance activities or inspections have been performed since the rehabilitation of the port and no procedures in place to perform maintenance on these piles.

Concrete transition slab

The concrete transition slab is the area between the quay and the land-based areas of the port. The maintenance activities performed on the concrete transition slab (table 4.3) are the same activities that are performed on the quay and the gaps the same as well.

Table 4.3 - Concrete transition slab maintenance

Action point	Maintenance manual	Current situation	Satisfactory
Inspection	Daily	• Cleaning: daily • Other activities: -----	√ X
Cleaning	Continuously remove rubbish and sand.	• Manual: Remove litter, left-over bulk material, empty rubbish bins. Terminal operators responsible for removing waste in the terminals and waste generated when loading and unloading cargo. • Mechanical: Monthly cleaning using sweeper or vacuum truck. Extra cleaning if necessary	• √ • √
Surface cracks	1. Register and monitor cracks. 2. Repair if necessary (procedure provided)	1. Inspect cracks after occurrence of an incident. 2. Refer to a consultant to supervise repairs if necessary.	1. X 2. √
Expansion joints	1. Sweep, blow clean or vacuum joints. 2. Repair if necessary (procedure provided).	1. Sweep joints clean. 2. -----	1. √ 2. X

Gap

The noticed gaps are the same as the quay. Inspections are performed regarding cleaning but not for other actions. Cleaning is performed the same way as on the quay.

A look at the maintenance of the expansion joints reveals that these are cleaned but their functionality and damage are unknown. In case they are damaged, the repairs will not be performed quickly enough, and this may lead to additional problems.

Continuing with the next point of inspecting cracks on the surface the difference is that instead of continuously checking and monitoring cracks this is only done after an incident has occurred. Incidents can be a container or other object falling. Instead or repairing the damage as listed in the manual, a report will be made, and the rest of the process will be transferred to a consultant to supervise repairs.

The use of the quay is not a maintenance activity, but by making sure the quay is used according to the manual, this should aid in prolonging the life of this asset. There is no monitoring of reach-stackers, other heavy mobile equipment or loads on the quay. The weight of containers or other objects is not verified.

Stormwater drainage

The stormwater drainage is essential for keeping the port dry. Maintenance of the stormwater drainage (table 4.4) consists of maintenance of the surface and subsurface drains but maintenance of the oil separators and the drainage outlets are also taken into account because these complete the drainage system.

Table 4.4 - Stormwater drainage maintenance

Action point	Maintenance manual	Current situation	Satisfactory
		Open gutters	
Inspection	1/month	1/quarter	√
Cleaning	Cleaning must be performed monthly or as often as necessary (process provided).	1/quarter because not proven necessary to perform extra.	√
Damage	1. Missing grills must be replaced immediately, with the area cordoned off until the grill is replaced. 2. -----	1. In case of a missing grill, the consultant is notified. A contractor is instructed to provide a new grill under consultant supervision. Area is cordoned off until replacement. 2. In case of damage to a pit, damage report is made and the Infrastructure Department responsible for the repair. In case the department is not equipped to repair damage, task is passed to a consultant whom supervises a contractor. Area is cordoned off until repairs have finished.	1. √ 2. √
		Closed sewer system	
Inspection	2/year using mirrors or cameras.	• Ø 50 cm culverts: 2/year • Ø 100 cm culverts: 1/year	• √ • √

Cleaning	Remove sludge or other pollutants using gully sucker.	A gully sucker is used to clean the inspection pits when the dirt in the sand trap has reached a certain level.	√
Damage	If leak or sinking is noticed above ground, inspection must be performed. Expert contractor to perform repairs to prevent further damage.	Produce damage report and plan repair.	√
Oil separator			
Inspection	1/month	2/year	
Cleaning	1. Remove pollutants from trash rack and dispose of at official landfill. 2. Clean chambers using gully sucker as often as necessary.	1. Pollutants are removed from trash rack and disposed of at official landfill. 2. Cleaning is performed twice a year using a gully sucker.	1. X 2. √
Flap valves	1. Inspect valves and remove obstacles if necessary. 2. Repair valve if needed.	1. Valves are inspected and cleaned. 2. Repairs are referred to a consultant.	1. √ 2. √
Drainage outlets			
Inspection	1/day	-----	
Cleaning	Remove dirt and any obstructions.	Dirt and obstructions are removed.	
Damage	Replace damaged paint.	-----	

Gap

Open gutters

Even though there is a difference between inspection cycles for the open gutters, it has been proven that cleaning is performed correctly. The manual speaks of cleaning once a month or as often as necessary. Cleaning four times a year has proven sufficient to remove excess rainfall sufficiently.

Sewer system

The maintenance manual speaks of an inspection twice a year, but in the current situation the inspections are performed four times in a year. Because there is no data available when an inspection pit has been inspected and the level of silt accumulated, no detailed assumption can be made regarding which pits need to be inspected or cleaned more often.

The difference between the current and prescribed inspections, is that the sand trap is inspected in the current situation, but the manual only notes that the culverts must be inspected. The culverts are currently inspected whenever cleaning has taken place but instead of using the prescribed method of mirrors or a camera, a person is lowered through the manhole to perform this inspection. Inspections on the surface are not performed, with damage only noticed when these are significantly visible.

Figure 4.3 - Cleaning of stormwater drainage inspection pits using a gully sucker (source: HBS archive, 2017).

Oil separator

There are no inspections performed on the oil separator, but cleaning is performed two times a year with the outflow openings and the dirt racks cleaned as well. The maintenance manual lists that an inspection must be performed monthly, but it does not take place because it is unclear who is responsible for this.

Drainage outlets

The drainage outlets are not inspected daily, but cleaning is done when maintenance and cleaning of the flap valves and oil separator is performed.

Fenders

Fenders are installed along the quay for protection from berthing ships by absorbing the energy of these ships while berthing. Maintenance of the fenders (table 4.5) is divided into three parts namely maintenance of the fender panels, the rubber fenders and maintenance of the chains and anchors.

Table 4.5 - Fender maintenance

Action point	Maintenance manual	Current situation	Satisfactory
		Fender panels	
Inspection	1/week	Before and after mooring of a ship	X
Face pads	Periodically replace face pads completely or partially when damage exceeds 20%.	-----	X
Steel frame	1. Repaint damaged frame using paint suitable for an aggressive environment. 2. In case of extensive damage, remove fender and repair in the workshop (procedure provided).	1. ----- 2. -----	1. X 2. X
		Rubber fender	
Inspection	1/week	Before and after mooring of a ship	X

Damage	1. Identify cracks 2. Register small cracks and monitor for changes. In case of change, repair immediately. 3. Repair larger cracks. 4. Replace rubber fender if functionality is no longer guaranteed.	1. ----- 2. ----- 3. ----- 4. -----	1. X 2. X 3. X 4. X
Anchors & chains			
Inspection	1/quarter	Before and after mooring of a ship	X
Fixations	1. Tighten bolts and nuts. 2. Reconnect loose brackets. 3. Reconnect loose chains.	1. ----- 2. ----- 3. -----	1. X 2. X 3. X
Damage	1. Apply suitable paint to corroded parts. 2. Replace damaged paint.	1. ----- 2. -----	1. X 2. X

Gap

The gap in fender maintenance consists of a lack of maintenance and a lack of inspections. There is no inspection for the rubber friction panels, the rubber fender, the steel frame or the chains and connections unless damage has been noticed. Simple inspections to ensure that a ship can moor safely and that the ship has not damaged the fenders are performed by personnel from the Operations Department before and after a ship moors at the port. The inspections are performed while standing on the quay and thus limited by the visibility from this position.

In case damage is noticed, the Infrastructure Department is alerted so that they can perform a detailed inspection. In case of damage, a damage report is made, and the Infrastructure Department decides if they can perform the repair or if this must be outsourced.

Figure 4.4 - Fender with damaged face pads, January 2018.

Bollards

The bollards are used for mooring ships at the port. Maintenance of these bollards (table 4.6) is based around ensuring that these are fastened securely to the quay.

Table 4.6 - Bollard maintenance

Action point	Maintenance manual	Current situation	Satisfactory
Inspection	1/year	-----	X
Fixations	1. Check if bollards are fastened correctly 2. Check if nuts are fastened 3. Check if bolts remain anchored in concrete correctly	1. ----- 2. ----- 3. -----	1. X 2. X 3. X
Concrete cracks	Check for cracks in the concrete.	-----	X
Painting	1. ----- 2. -----	1. Repaint bollards after removing rust. 2. Repaint bollard numbers.	1. √ 2. √

Gap

The first noticeable gap is the lack of inspections to check on the fixations and damage to the concrete. The performed maintenance activities however are not listed in the maintenance manual such as repainting.

Figure 4.5 - Bollard and bollard number, January 2018.

The bollards have been repainted due to corrosion with repainting performed after the corrosion was removed. Repainting of the bollard numbers was done because of wear of the paint was noticeable.

Electrical installations

Maintenance of the electrical installations (table 4.7) include the maintenance of the electrical grid, the high masts, maintaining the emergency generators and the air-conditioning units.

Table 4.7 - Electrical installations maintenance

Action point	Maintenance manual	Current situation	Satisfactory
Inspection	1/week	• High mast lightbulbs: 1/month – 1/quarter • Emergency generators: 1/week	• X • √
Malfunctions	In case of malfunctioning lighting or electrical network, alert expert personnel for repairs.	In case of malfunctions or power failure the electricians are alerted but contractors can be used if needed.	√
Light bulb replacement	1. To prevent reductions in light output, change light bulbs frequently. 2. Change non-working light bulbs as soon as possible.	1. Replacement when malfunctioning is noticed. 2. Replacement when failure is noticed.	1. √ 2. √
High mast maintenance	Damage of the high masts or fittings must be repaired by expert personnel.	Damage to the highs mast or fittings is repaired by expert personnel.	√
Emergency generators	1. Simulate power failure 1/quarter. If system fails alert expert. 2. ----- 3. -----	1. Weekly check of fuel followed by testing generators. 2. Service by expert contractor 2/year. 3. Cleaning of generator platform and surrounding area: 1/quarter.	1. √ 2. √ 3. √
Obstacle monitoring	Cable trays and pipes network must remain free containers or heavy obstacles.	Certain areas of the port are monitored and remain clear of vehicles, containers or other obstacles.	X
Air-conditioning	1. ----- 2. -----	1. Cleaning 2. Minor repairs are performed by electricians and larger repairs are outsourced.	1. √ 2. √

Gap

Inspections

Visual inspection for the high masts includes checking which light bulbs are working. This is done by turning the lights on and checking if there is sufficient light. The inspections are to be performed monthly, with a minimum of one time per quarter. However, this target is not always reached due to a reduction in available personnel.

Malfunctions

The maintenance of the current electrical network consists mostly of reactive maintenance. In case a problem occurs, the electrical division checks if they can fix it or if a third party is needed.

Inspections are not sufficiently performed, and problems are not anticipated. A lack of communication between different users aided by the electrical division not anticipating increased use is one of the reasons for failure, with a frequently occurring problem being the tripping of breakers. Appliances are installed without checking with the electrical division to ensure that the system has the capacity to

handle these appliances. This results in the network overloading and as a safety measure, tripping of the breakers. Adapting the installation becomes necessary and is done by the electrical division.

High mast maintenance
The maintenance manual has a gap regarding how much light should be available for the different areas. The criteria at the moment is that lightbulbs are changed when more than half of the lightbulbs are not working or when there is a complaint of an area being too dark.

Emergency generators
The maintenance manual only mentions actions for when the system fails, but preventive actions to ensure that the generators keep working are not mentioned. The maintenance manual does not specify the weekly checks for the emergency generators.

Obstacle monitoring
A gap in the monitoring is noticeable with only the area at the western fence constantly monitored. Other areas that should be kept clear of containers or equipment are not always clear.

Air-conditioning units
Cleaning and small repairs are done by the electrical division while larger maintenance tasks and repairs are outsourced. None of these tasks are mentioned in the maintenance manual however as maintenance of the air-conditioning system is not part of the maintenance manual.

Figure 4.6 - AC unit filter cleaning, January 2018.

Water supply and firewater system

No information could be retrieved regarding the maintenance of the firewater system (table 4.8) hence the column for the current situation remains empty.

Table 4.8 - Water supply and firewater system maintenance

Action point	Maintenance manual	Current situation	Satisfactory
		Water supply	
Inspection	1/month		
Repairs	In case system fails, repair in expert manner.		
Water supply	Report to water utility company if problems with water supply occurs.		

Cleaning	1. Inspect water basin cleanliness. 2. Clean water basin if necessary. 3. Adjust filter system if water basin becomes dirty often.		
Firewater system			
Inspection	1/month by using fire hydrants.		
Repair	In case system fails, repair in expert manner.		

Fences

Fences have been installed on the borders of the port. Maintenance of these fence (table 4.9) consists of maintenance of the fence, the razor wire on top of the fence and maintenance of the gates.

Table 4.9 - Fence maintenance

Action point	Maintenance manual	Current situation	Satisfactory
Inspection	1/month	-----	X
Fence	1. Damaged connections must be repaired immediately 2. In case of corrosion: Remove corrosion, apply primer and finish with 2 layers of paint. 3. In case of damaged paint (wear or peeling): remove damaged paint, apply primer and finish with 2 layers of paint. 4. -----	1. Repair by welders when noticed. 2. In case of corrosion: Remove corrosion, apply primer and finish with 2 layers of paint. 3. ----- 4. Washing the fence.	1. √ 2. X 3. X 4. √
Razor wire	Depending on the damage, razor wire must be replaced.	Razor wire replacement after corroded to non-functioning level. Repair takes time.	X
Gates	1. ----- 2. -----	1. Maintenance of mechanical parts is performed by the mechanical division. 2. Maintenance of electrical gates is outsourced.	1. √ 2. √
Accident	Damage caused by collision must be repaired by steelworkers.	• Produce damage report and plan repair. • If collapse is possible or danger exists, repairs will be performed immediately. • Depending on severity, Infrastructure Department will perform repairs.	• X • X • X

Gap

The gap in inspections is considerable, with no inspections performed in the current situation. This resulting in loose joints and other damage only noticed by accident or when a maintenance activity is planned.

A considerable time gap exists before a maintenance activity is performed. Tackling corrosion is not done right away but only after numerous spots exist that have rusted. Weathering and peeling of the paint are not taken into account for maintenance, but washing the fence is done which is not listed in the maintenance manual.

Maintaining the razor wire is not performed adequately with damaged razor wire not replaced within an acceptable timeframe.

Figure 4.7 – Repainted fence and damaged razor wire, January 2018.

Looking at the maintenance manual for the procedure in the event of an accident, there is no significant gap noticeable with the current processes.

Draught of quay

Maintaining an adequate depth for the mooring ships is essential to the operation of the port because a reduction in the draught will block larger ships from reaching the quay. To ensure the quay remains reachable for vessels, maintenance actions (table 4.10) such as dredging must be performed.

Table 4.10 - Maintaining draught of the quay

Action point	Maintenance manual	Current situation	Satisfactory
Inspection	Regularly	1/year	√
Ensure sufficient draught	Removal of large obstacles.	Dredging the front of the quay when necessary (every 3-4 years).	√

Gap

Although measurements are conducted during the draught, these are not performed at the same time each year. If this would be done consistently at a set time, a better prognosis can be made for predicting when dredging will become necessary. The other action points noted in the maintenance manual are performed by the Maritime Authority Suriname. The Maritime Authority Suriname is responsible for guiding ships to the port in accordance with HBS.

Summary of maintenance action differences between the HBS maintenance manual and the current situation

Differences in the maintenance actions between the current situation and those prescribed in the maintenance manual can be summarised as follows:

- Differences regarding performing inspections, inspection method and reasons why inspections are performed.
- Differing considerations regarding the importance of inspections and maintenance of certain objects.
- Difference in maintenance actions, methods and timing of maintenance.

There is a difference when it comes to inspections such as the frequency of performed inspections. For example, the difference in the amount of inspections performed for the stormwater drainage currently exceeds the amount prescribed in the maintenance manual. Other differences are the inspections that are not performed, the inspection method used and the reason for an inspection. The maintenance manual states that inspections must be performed frequently to track the condition of an asset as well as ensuring that failure is not reached, but in the current situation the most common reason for performing an inspection is after a problem has occurred.

Another common difference is what actions are considered important. The manual has noted several maintenance actions as important, but currently other actions are taken into account when performing maintenance on these objects. An example of this is the inspection of the bollards, with the maintenance manual regarding inspecting the fixations as important while these are not considered currently. Another example is the inspection of the concrete piles underneath the quay which is stated in the maintenance manual but completely ignored currently.

Differences also exist when it comes to performing maintenance. Not only are several maintenance actions not performed, but of those carried out, most are executed after a substantial time has elapsed. The maintenance manual describes that maintenance must be performed when a certain condition has been reached – which can be regarded as condition-based maintenance – while maintenance is mostly performed near or after failure has been reached. While the maintenance manual is limited regarding execution procedures, methods of maintenance actions differ in the current situation such as how cleaning is done on the quay.

4.2. Identifying the reasons behind the gaps between the HBS maintenance manual and the current situation

In the previous section gaps were identified regarding the researched items between the maintenance manual and the current situation. The reasons behind these gaps are stated in this section of the report. with several differences noted when it comes to the following:

- Maintenance organisation
- Database
- Norms and criteria
- Inspections
- Maintenance activities

4.2.1. Maintenance organisation

The gap between the maintenance organisation in the current situation and the maintenance organisation according to go maintenance manual exist because HBS has made no changes to their company structures. This means that the same structure for the Infrastructure department has been maintained. A problem caused by this structure is the responsibility for performing inspections and maintenance.

4.2.2. Database

A lack of documentation can be accredited to the fact that this information was previously not requested within the company. As a result of this, the need for documenting all activities and making technical drawings did not exist. This has left a huge gap in available blueprints, which is being addressed by requesting the available documents stored at other departments, updating design blueprints and drawing new ones. The Infrastructure Department has started with several actions to generate the necessary data such as drawing and updating the electrical network. Other actions such as requiring department personnel to provide more detailed information and drawings when performing activities is also a measure taken to increase documentation.

Given the above, a database standard must still be created by the company with standardized forms and procedures to add information. With standard methods of information gathering, all parties can document, read and search through files in a more consistent and structured way. With a lot of information only available within the memory of personnel, steps must be taken regarding documentation to preserve and increase availability of information for HBS.

4.2.3. Norms and criteria

The criteria used – such as the criteria used for cleaning of the stormwater sewer – are based on the knowledge of the personnel. Because previous maintenance actions consisted mostly of replacing objects when failure had occurred, replaced items were just replicated. With failure as the dominant criteria, other criterion was not available or taken into account. The strategy at the moment is to implement small items to inspect. The knowledge at the moment is not sufficient to do detailed inspections, but by adding a different detail to an inspection every time is what is tried now.

4.2.4. Inspections

There are different reasons why inspections are not performed, of which one is the haziness as to whom is responsible for the inspections. In that case the inspection and maintenance are not performed unless a problem occurs. This haziness is caused by unclear interpretation of contracts, personnel shortages, unclear tasks, no knowledge regarding the performing of inspections and sometimes the lack of awareness.

Simple visual inspections – such as inspecting the fenders from the quay – can be performed, but detailed inspections are difficult with both the knowledge and technical details missing. Detailed drawings are missing so in order to perform detailed inspections, more information is necessary. In case detailed inspections must be performed, the task is transferred to a consultant, but it is unclear for personnel/staff what tasks are for the consultant and what is to be performed by the Infrastructure Department. Because of this, some tasks are automatically assumed to be part of the consultant's job, but there is no contract with them to perform these inspections.

Another reason includes the lack of equipment for performing inspections. For maintenance tasks that are performed in house, equipment is rented but this procedure takes time and reduces flexibility. An example of this is the absence of a boat to perform inspections from the water.

4.2.5. Maintenance activities

To identify the reasons behind the gaps in the maintenance tasks every asset was analysed separately. By looking at the assets separately all the specific reasons for the differences could be identified. These reasons are not elaborated but are presented in table 4.11. The first column shows the assets and the second column shows the differences between the maintenance manual and the current situation. In the third column the reasons causing the difference are presented. Because no information could be retrieved regarding the water supply and firewater system several dashes as placed to indicate that no gap and reason could be identified.

Table 4.11 - Asset specific reasons behind the difference between the HBS maintenance manual and current maintenance

Asset	Difference	Reason
Quay and Concrete transition slab	1. Inspection cycles regarding cleaning 2. Inspecting and maintenance of the newly drilled drains. 3. Inspecting for cracks 4. Inspection and maintenance of expansion joints. 5. Inspection on wear of the concrete. 6. Removing water puddles. 7. Monitoring that containers do not exceed the maximum allowed load.	1. Differing opinion between departments regarding amount of inspections. 2. Unaware of damage to the rebar of the quay. 3. Inspections on cracks are left to the consultant. HBS only checks in case there was an accident and in case damage has been registered this is passed on to the consultant to fix this with a contractor. These are not mentioned in the task description. In case these will be inspected, the criteria are also necessary to take into account. 4. Knowhow does not exist. Must be done by the consultant, but consultant has no contract for this 5. The assumption is that the consultant does this. The personnel are unaware that this is a factor for sustainability. 6. Puddles not considered a problem because the amount of water is not a nuisance. 7. No equipment available to check the loads.
Concrete piles underneath the quay	1. Inspecting the concrete piles. 2. Maintenance of the concrete piles.	Inspections and maintenance not performed by HBS because they are not equipped for this. There is no boat available and the knowledge needed for these inspections is absent.
Storm water drainage	1. Inspection of open gutters. 2. Inspection of damage to sewer system. 3. Inspection of the oil separator.	1. Unclear who should perform inspection in terminals. 2. Difference in inspection method. 3. Unclear who should perform this task.
Fender	1. Detailed inspection 2. Maintenance	1. No boat available to perform inspection from the river. 2. Maintenance department does not have the knowhow to perform these or does not know it is their task.

Bollards	1. Inspection on the fixation and damage to the concrete	1. The knowledge for performing the inspections is not available.
Electrical installations	1. Inspection on amount of light 2. Inspection on working lightbulbs 3. Inspecting to keep installations accessible. 4. Maintenance of the existing electrical network.	1. No test equipment available. 2. Not enough personnel available to perform inspections. 3. In case noticed that an installation is not accessible, necessary steps are taken towards removal of obstacles. In case this is in a terminal, terminal operator is contacted to enter the area and obstacles are removed. This takes time as access to the terminal is limited and problems need to be sorted out through terminal operator. It has not been a problem that installations are blocked, but there are no checks regarding the accessibility (must be accessible at all times). 4. Limited number of documents available, but blueprints of the network are being made and updated with details of installations added. Shortage of personnel, lack of testing equipment and haziness regarding task responsibility is impacting inspections and maintenance.
Water supply and firewater system	_ _ _ _ _ _ _ _ _ _ _ _ _ _	_ _
Fences	1. Inspections on the state of the fence 2. Maintenance of the fence 3. Repairing and replacing razor wire	1. While repairs are done, other items are inspected right away. 2. Organisational – personnel are routinely redirected to perform other tasks and delays occur in the previously assigned task. Delays caused due to time needed to relearn tasks which are not routinely performed. Delays caused due to bureaucratic processes between inspection and executing of maintenance. 3. Because of accidents the razor wire replacement has been placed on hold till all necessary precautions and training is in place. Previously a Job Safety Analyses (JSA) was not in place. Now these processes have been introduced.
Draught of quay	1. Frequency of measurements	1. The siltation of the quay is not that significant within a year so no extra measurements needed.

The information in table 4.11 leads to a general categorisation of reasons causing the difference between the maintenance activities noted in the maintenance manual and those currently performed. This categorisation is based on the reasons why certain activities are not performed and consists of:

- A lack of knowledge.
- A lack of resources.
- The absence of a maintenance policy.

- Contractual problems.
- Organisational problems.

The first reason identified, is a lack of knowledge which can be attributed to several inspections and maintenance activities not being performed. To clarify, personnel do not realise the importance of inspections and often do not know what to look for if they had to perform inspections on certain objects. An example of this are inspections of the expansion joints, the drains drilled into the quay floor and the concrete piles underneath the quay. Another reason which can be attributed to the lack of knowledge is that these inspections and the following maintenance actions are not regarded relevant and not high on the list of priorities. Actions such as inspecting the wear of the concrete, the fixations of the bollards, and maintenance of the expansion joints and concrete piles underneath the quay are thus being neglected.

A lack of resources is another reason why maintenance is not performed adequately or differently. As a result of the absence of a small boat, inspections on the fenders are only performed from the quay and inspections of the concrete piles underneath the quay are neglected, while testing of the light of the high mast is limited because of missing testing equipment and available personnel.

The absence of a maintenance policy has also been cited as a problem resulting in maintenance fixed around repairing what is broken, instead of preventing objects from reaching a state of failure. Personnel is trained for and accustomed to performing corrective maintenance instead of preventive maintenance (PM). Similarly, this lack of maintenance policy is attributed to personnel taking longer to get used to new regulations such as performing a job safety analysis (JSA) before the start of maintenance.

Another reason for the differences between the maintenance manual and current maintenance is the haziness in contracts. Problems regarding lease agreements at the port make it unclear who is responsible for maintenance and what specific actions must be performed. Terminal operators are in charge of the area leased from HBS, but it remains unclear who is responsible in that area for certain maintenance actions such as inspecting and cleaning of the stormwater drainage.

Organisational problems are the final reason behind the difference in maintenance activities with bureaucratic processes credited with taking-up a lot of time and thus preventing maintenance to be performed on time. This problem is further enhanced by a lack of documentation due to unavailable and outdated technical information for example missing or outdated blueprints of the electrical grid. Further problems include maintenance personnel finding it unclear whom is responsible for performing certain tasks such as cleaning of the oil separators or enforcing rules regarding the clearing of obstacles in certain areas.

All the reasons mentioned above have been categorised based on the identified reasons causing the gaps as shown in table 4.11. After the explanation of the categorisation these reasons can be placed in a table again. In table 4.12 these reasons are presented with the general reason causing the gaps shown in the first column and the second column showing the specific maintenance activities where differences have been noticed. In the third column the specific components or items affected by the gap in maintenance activities are presented.

Table 4.12 - Reasons behind the maintenance gap

General reason	Maintenance activity	Related component/items
Lack of knowledge	• No maintenance because actions not prioritised. • Lack of knowledge about importance of maintenance. • No inspections because no awareness of their importance. • Lack of knowledge about inspection criteria.	• Maintenance of expansion joints. • Maintenance of concrete piles. • Inspections of: – Concrete piles – Cracks on concrete floor – Drilled drains in concrete floor. – Concrete wear. – Fixation of bollards and damage to concrete.
Lack of resources	No maintenance actions and inspections because of limited resources.	• Testing equipment for checking of weight and light intensity. • No boat for inspection of fenders and concrete piles. • Limited personnel for inspections and maintenance.
Maintenance policy	• No PM policy. • Personnel trained for corrective maintenance. • Timeframe for implementation of new regulations.	• Mostly corrective maintenance. • Implementation JSA.
Contract problems	• Contracts unclear regarding responsibility of maintenance. • Specific maintenance actions explicitly in contracts.	• Inspections in the terminal. • Inspection of drainage network.
Organisation	• Haziness regarding which department or division of the department is responsible for certain tasks or inspections. • Unavailable and outdated technical information. • Delays due to bureaucratic processes. • Reinforcement of regulations.	• Cleaning of oil separators. • Lack of data such as blueprints of the electrical grid and installations. • Bureaucratic processes. • Keep areas obstacle free.

5. Identifying the gaps in maintenance processes between the current organisation and a mature organisation, and the factors affecting the implementation of a preventive maintenance program

In the first section of this chapter the comparison between the maintenance processes in the current organisation and a mature organisation are presented. The current organisation consists of the maintenance manual and the current situation and the mature organisation regards the theoretically defined state.

In the second section the factors affecting the implementation of a preventive maintenance program are identified.

5.1. Comparing the maintenance processes within a mature organisation to those in the current organisation

After analysing the current situation with the HBS maintenance manual, the maintenance processes are compared in this section. The comparison – regarding the phases of planning, scheduling, execution and assessment – is made between the current organisation (current maintenance process and maintenance manual) and a mature organisation (referred to as the theoretically defined state). For each situation the comparison is made between.

Even though the comparison is between the two defined organisations, the tables show the three separate states. This has been done to clearly show the areas where the maintenance manual or current maintenance has shortcomings compared to the mature organisation. The dashes in the tables show the steps where a clear gap is noticed.

5.1.1. Planning

Mature organisation

The planning process is divided in task identification and task analysis and the specific characteristics of the theoretically defined state are presented in the first column of table 5.1.

Task identification

According to Crespo Márquez (2007) task identification can either be preventive maintenance (PM) or corrective maintenance (CM).

Task analysis

Task analysis consists of several steps (Crespo Márquez, 2007; Duffuaa & Raouf, 2015) and these are presented in the first column of table 5.1.

Current organisation

Task identification

Both in the current situation and the maintenance manual CM and PM strategies are used. In most cases, current maintenance is corrective, but the cleaning of the drainage system is an example of PM being performed. The maintenance manual is mostly designed based on a condition-based approach with inspections needed to know the state of an object, with the intention of performing maintenance when necessary.

Task analysis

Task descriptions in the maintenance manual are very brief and do not provide information regarding the level of detail for a skilled maintenance worker. A short description of what needs to be considered when performing inspections is available with inspections considered essential in deciding when maintenance must be performed

In the current situation a lot of the maintenance procedures and task descriptions are based on memory and experience of the personnel because a very limited amount of information is recorded.

Medium term planning is made for routine maintenance and PM tasks, but CM is mostly planned shortly before this is necessary. Frequency of the tasks depends mostly on the state of an asset so in case damage has been noticed or if a problem persists, maintenance will be performed.

The time for maintenance activities is planned based on the available personnel, taking their skill level into account and experience of similar tasks. Experience of the personnel is very important because work plans are very limited. Tasks are performed mostly based on experience.

A job safety analysis (JSA) is performed when maintenance must be performed. In this JSA the safety of the tasks is reviewed, and measures are planned to limit risk.

In case tools, parts, materials, consumables and support equipment are needed, a cost calculation will be added to the job planning because these will need to be acquired or rented. In some cases, the maintenance tasks will be outsourced because of the cost of acquisition. Acquiring test equipment is lacking in some cases however.

Maintenance planned as emergency maintenance when a problem has occurred and must be fixed right away such as the failure of an air-conditioning unit or other electrical problems. Other maintenance prioritised as routine maintenance or scheduled because there is no need for an immediate repair.

The maintenance manual states that a database should be set up, but currently this does not exist, and a lot of extra work is necessary because information is not registered. This leads to measurements to be taken each time whereas if this information was stored it would be sufficient in some cases to just verify the previous recorded measurements.

After all the information has been gathered a work order is made and send up to the head of the department, and in case necessary up to management for approval. After approval has been granted or when other maintenance activities must be planned, resources are redistributed to start work.

Table 5.1 - identifying the differences in the planning phase

Theoretically defined state	HBS maintenance manual	Current maintenance
Task identification		
PM or CM	1. Routine maintenance 2. Preventive maintenance 3. Corrective maintenance	1. Routine maintenance 2. Corrective maintenance 3. Preventive maintenance
Task analysis		
1. Determine maintenance task (with the level of detail required for a skilled maintenance person);	1. Brief description of maintenance tasks based on routine, major and calamity maintenance with	1. Task descriptions based on experience because most procedures not registered. Description of outsourced

2. Frequency of the task (based on a relevant measure such as elapsed time, operating hours, number of operational cycles or distance); 3. Establishing number of personnel, skill level and time required to perform the task; 4. Develop a work plan with maintenance procedures required; 5. Review safety procedures; 6. Procedures for handling, transportation and disposal of hazardous materials; 7. Special tools, test equipment and support equipment required; 8. Plan which spare parts, materials and consumables to be used or replaced; 9. Prioritising maintenance tasks (emergency, urgent, routine, and scheduled); 10. Observations and measurements to be made; 11. Calculating the costs of the work; 12. Filling in work order; 13. Review jobs already scheduled that are behind schedule (backlogs) and develop plans for controlling it; 14. Predict the maintenance load using an effective forecasting technique; 15. Checkout procedures to verify proper operation and successful completion of the maintenance task.	inspections cited as important before performing a task. 2. Frequency of inspections and routine maintenance. 3. ----- 4. Procedures described briefly for some maintenance tasks, but not very detailed and for a limited number of tasks. 5. ----- 6. ----- 7. ----- 8. ----- 9. Description of points to take into account and continuously measure when performing inspections. 10. Use database for relevant information. 11. ----- 12. ----- 13. ----- 14. ----- 15. -----	maintenance tasks stated in the contract. 2. Frequency of routine and PM tasks stated in medium to long range planning. Planning for CM tasks when task must be done. 3. Personnel assigned based on job specification, skill and time required for the tasks. 4. Maintenance procedures mostly based on experience and not written down. 5. Safety procedures reviewed in JSA. 6. Procedures for handling, transport and disposal of materials. 7. Register necessary tools, specialty and support equipment. If not available prepare for acquisition or rent. 8. Register necessary parts, materials and consumables and prepare paperwork to acquire them. 9. Maintenance tasks consists of emergency, routine and scheduled tasks. 10. Performing measurements and observations to gather information. 11. Cost calculations are made before maintenance is performed. 12. Work orders are made. 13. Resources and plans reviewed in case these are needed for another task. 14. ----- 15. -----

Gap

Task identification

No gap identified.

Task analysis
The current organisation has a problem regarding the documentation of the number of personnel and skills needed for a task, safety information, information regarding tools, support equipment, materials, parts. This information is not written in the maintenance manual but also not recorded currently. Maintenance planning is mostly done based on experience and procedures are limited with those available not detailed. A step completely missing in the current organisation the use of effective forecasting techniques for predicting the maintenance load, and checkout and verification procedures to ensure successful maintenance completion do not exist. There are checklists proposed to verify that maintenance has been completed successfully, but these have not been implemented yet.

5.1.2. Scheduling

Mature organisation

Scheduling prioritisation
The division of the priorities for scheduling according to Duffuaa and Raouf (2015) are presented in the first column of the scheduling prioritisation section in table 5.2.

Scheduling tasks
The scheduling of maintenance consist of several steps (Crespo Márquez, 2007; Duffuaa & Raouf, 2015) which are presented in the first column of table 5.2 in the scheduling tasks section.

Current organisation

Scheduling prioritisation
The maintenance manual makes no clear prioritisation but there is a timetable for when inspections should be planned. A schedule can be derived from this planning with the prioritisation allowing for inspections to be performed as scheduled. In case the need for maintenance exists, this can thus range from emergency to postponable maintenance with the decisionmakers provided with sufficient time to follow a degrading situation and plan maintenance.

Current maintenance is prioritised differently based on the differing maintenance strategies. Routine maintenance is performed as scheduled, unless the need arises that extra cleaning is needed for example.

For PM long term scheduling is common with tasks such as mechanical cleaning planned for the whole year with dates scheduled for execution. This is also the case for maintenance of the drainage system, unless the need exists – depending on the results from the inspection – that extra cleaning or no cleaning is necessary.

When it comes to CM the scheduling differs between urgent, normal and postponable. Prioritisation is done depending on the criticality of maintenance with scheduling to repair a damaged gate receiving a higher priority than repainting a corroded bollard.

Scheduling steps
The maintenance manual has no information regarding which steps must be taken for scheduling maintenance but for the current maintenance process several steps are followed.

HBS has procedures for acquiring the necessary materials or parts and stores these in the stockroom or on site. The same process is used for tools and support equipment with those not available bought or rented. Transportation is provided with several vehicles available to the department, but external

transportation is arranged in case this is necessary. This is also the case when external resources or support is needed.

The scheduling of maintenance is performed in collaboration with other departments or parties at the port so that minimal nuisance is caused or to alleviate problems the other parties might have. Safety and environment procedures are considered when a JSA is done, and this is checked with the Health, Safety, Environment & Quality (HSEQ) Department. Maintenance backlogs are considered when scheduling because the possibility exists that resources need to be pulled from a different job, due to the need of another task receiving a priority. It is an occurring problem that resources must be redistributed to other tasks.

Training is provided to personnel ranging from training for maintenance tasks to general wellbeing of the personnel. Not only specifically related to maintenance tasks, but also safety and procedures.

Table 5.2 – Identifying the differences in the scheduling phase

Theoretically defined state	HBS maintenance manual	Current maintenance
Scheduling prioritisation		
• Emergency • Urgent • Normal • Scheduled • Postponable	• Most actions prioritised as scheduled. • In case a problem occurs, scheduling can range from emergency to scheduled.	• Routine maintenance prioritised as scheduled. • CM scheduled as urgent, normal or postponable. • PM prioritised as scheduled.
Scheduling tasks		
1. Identifying and assigning personnel; 2. Acquiring materials and spare parts from external sources or inventory; 3. Ensuring that tools, transportation, lifting and support equipment are available; 4. Preparing required operating, maintenance, safety and environmental procedures and work plans; 5. Identifying and reserving external resources; 6. Aligning the schedule with other departments to limit workflow; 7. Information regarding backlogs; 8. Providing necessary training	1. ----- 2. ----- 3. ----- 4. ----- 5. ----- 6. ----- 7. ----- 8. -----	1. Personnel identified and assigned to specific maintenance tasks. 2. Materials and spare parts acquired for maintenance task and stored. 3. Tools, transportation and support equipment arranged. If not available within HBS, acquisition from third party is possible. 4. Safety & Environmental procedures considered in JSA, but maintenance procedures mostly based on experience and not listed in detailed. 5. Identifying external resources and starting acquisition. 6. Maintenance scheduled with different/relevant parties at the port. 7. Backlogs rearranged if resources are redirected. 8. Training provided to maintenance personnel.

Gap

Scheduling prioritisation

Maintenance is scheduled according to all priorities and no gap noticeable.

Scheduling steps

The maintenance manual provides no information regarding how maintenance should be scheduled, but the current maintenance process contains all the steps listed for a mature organisation.

5.1.3. Execution

Mature organisation

In literature Crespo Márquez (2007) defines several tasks for PM and CM execution. The tasks presented in the first column of table 5.3 are similar for PM and CM, but in CM there is the addition task of fault identification.

Current organisation

When comparing the maintenance execution processes, it is noticeable that the maintenance manual does not contain a lot of information. The manual provides a brief description but leaves out details into the execution of these tasks with a division into routine, major, calamity maintenance and inspection guidelines made.

In the current situation maintenance execution is mostly based on the experience of the personnel because there are also no detailed descriptions of maintenance tasks.

The steps of acquisition of spare parts, materials, tools and support equipment are followed as well as providing transportation. The previous steps, and procedures such as demarcating and clearing the worksite of people and obstacles are not noted in the manual but are performed, as well as reopening the site after use.

When maintenance is performed, the time is registered if the work takes longer than planned, but further information is not regarded as important. Observations and measurements are sometimes written down and information for future use is based on the memory of personnel involved.

Fault identification is the last step according to literature and this is performed in case of frequent and persistent problems. An example of this is identifying the reason behind a frequently malfunctioning electrical subsystem.

Table 5.3 - Identifying the differences in the execution phase

Theoretically defined state	HBS maintenance manual	Current maintenance
• Preventive maintenance: 1. Gathering technical data and task description; 2. Obtaining spare parts and tools and support equipment; 3. Travel to worksite; 4. Preparation of the worksite such as equipment shutdown, isolation and lockout procedures; 5. Active maintenance time; 6. Observations and measurement; 7. Testing and checkout; 8. Clearing of worksite; 9. Recording necessary information. • Corrective maintenance (same steps as PM and): 10. Fault identification, in order to identify the location and nature of the failure and the necessary refurbishment or replacement of components.	1. Brief description of maintenance tasks divided into routine, major, calamity and inspection guidelines. 2. ----- 3. ----- 4. ----- 5. ----- 6. Inspections should be performed, and changes monitored until action is required. 7. ----- 8. ----- 9. ----- 10. -----	1. Brief task descriptions made, but tasks performed based on experience. 2. Spare parts, materials, tools and support equipment provided. 3. Transportation available for travel to worksite. 4. The worksite is cleared from people or obstacles and demarcated to create safe working area. 5. Maintenance is performed, and time is recorded occasionally. 6. Observations and measurements only written down in select circumstances. In most cases workers memory is the only "record". 7. Testing performed for the electrical grid and equipment. 8. Worksite is cleared and reopened for use. 9. Limited information registered regarding maintenance activities. In most cases the information recorded is that the job is finished. 10. If persistent problems, fault identification.

Gap

In both the current situation and in the maintenance manual there is no detailed description of the maintenance tasks. Other gaps are the lack of information recorded when performing maintenance, the limited testing – to ensure correct operation after maintenance completion – and absence of a lockout procedure.

5.1.4. Control

Mature organisation

According to literature several steps in the control phase (Duffuaa & Haroun, 2009; Duffuaa & Raouf, 2015) are presented in the first column of table 5.4.

Current organisation

The maintenance manual states standards for maximum loads and crane use on the quay and mentions the creation of a database for information such as blueprints and technical information. Another point mentioned is the establishment of standards and criteria.

In current maintenance there are no recorded objectives or standards, but the maintenance personnel use several criteria for performing certain tasks. An example is the criteria for cleaning the inspection pits of the drainage system. Furthermore, there are no records regarding the state of assets or standard these assets are required to be. This information should be part of the database stated in the manual.

Measuring actual performance is a step not performed currently and because of a lack of job standards it is difficult to measure how workers perform compared to workers doing similar tasks. This is missing from the maintenance manual as well. Only some information proposing that a maintenance organisation should be in charge of overseeing maintenance and budgets is available.

Because of a lack of information, performance measurement and job standards, it is unclear if corrective action is taken to improve maintenance.

Table 5.4 - Identifying the differences in the control phase

Theoretically defined state	HBS maintenance manual	Current maintenance
1. Establish objectives and standards; 2. Measure actual performance; 3. Compare results with objectives and standards (job standards); 4. Take corrective action.	1. Standards for maximum load and crane use. Collect data for database. 2. ----- 3. ----- 4. -----	1. Objectives and standards not written down but based on experience. 2. ----- 3. ----- 4. -----

Gap

There is a gap in objectives and standards. There are standards and objects applied when maintenance is performed on certain objects, but these are not recorded but based on experience. Other standards and objectives do not exist and must be developed.

Other gaps relate to measuring the actual performance and comparing job standards as these do not exist in the current organisation.

A final gap relates to performing corrective actions as no records could be found regarding these procedures.

5.2. Identifying the factors affecting the implementation of a preventive maintenance program

Because the research focusses on improving maintenance at the port aided by the maintenance manual, the identification of factors impacting the implementation of a PM program was done. The analysis was done to identify which factors mentioned in the literature – as affecting the implementation of a PM program – are present in the current situation. These factors are described

in this chapter starting with the factors in place that aid successful implementation, followed by the factors that must be addressed for a successful implementation.

5.2.1. Factors aiding successful implementation

Personnel is receiving training regarding maintenance, safety and other activities, but for a successful implementation the training must be build up in such a way that it aids in maintenance as well as personnel understanding the road ahead. Only with this understanding the program will be successful. Maintenance personnel may otherwise fear for their jobs, think they will have to work much harder and work against a successful implementation. Some entrenched practices – such as waiting till corrective maintenance must be performed – must be changed with changes based on cost-customer based analyses.

HBS has a good system of communication through the bulletin board and there is a monthly port magazine. The magazine is a good medium to provide intermediate results and general information regarding the implementation and changes in maintenance.

The organisational structure at HBS is already short with the maintenance manager directly structured in the second layer under top management. The lesser the layers between top management and the maintenance manager have proven to be key in successful implementation of PM programs.

5.2.2. Factors inhibiting successful implementation

An important factor for successful implementation is that management understands the goals of the PM program. Without complete understanding their support might not be sufficient. Up till now management has lacked seriousness regarding the implementation of PM. This can be seen in the implementation of the maintenance manual which has not happened. Until recently personnel were even unaware of the existence the manual. But changes are happening with management taking steps of reshaping maintenance and implementing steps highlighted within the maintenance manual.

Management support also relates to the availability of resources for the implementation of a PM program and is critical in implementation and must support the process extensively and be determined that success will be made. Completing a successful implementation of the maintenance manual and maintenance improvement will take time and management, but it remains unclear how much time management will take into account.

There is no implementation plan and a custom-made PM program is also necessary. The current maintenance manual must be updated to better suit the company. Several maintenance activities are missing from it but performed nonetheless and these must be added. Criteria is also missing from the maintenance manual but in reality, there are criteria being used by the Infrastructure Department. These criteria must be recorded and updated to better suit maintenance and be added to a new program.

In addition to the implementation plan the lack of performance measurement also is a factor inhibiting the maintenance process. Improvement is difficult when there are no clear measuring points to improve on.

6. Conclusion and recommendations

In this chapter of the report the conclusions of the research and some recommendations for the improvement of the maintenance are provided.

6.1. Conclusion

After conducting an initial survey of the situation, it was determined that the best course of action was performing gap analyses. The gap analyses where performed by performing two comparisons. The comparisons consisted of several steps of which the first step was identifying an ideal state. The second step was identifying the current state and the third step was performing the comparison to reveal the differences. After these differences were identified the reasons behind the differences in comparison 1 were sought, and factors affecting the implementation of a maintenance program were identified in comparison 2. The final part of these analyses was providing recommendations for improvement which are provided in the recommendations sections of the report.

The first section of this research was centred around the comparison of the HBS maintenance manual and the current situation. This comparison reveals that the maintenance manual prescribes maintenance actions to be preventive, with a lot of emphasis placed on performing inspections to know when the condition is reached when maintenance must be performed. In current maintenance, limited emphasis is placed on performing inspections and tasks consist mostly of routine and Corrective Maintenance (CM) with most assets reaching or nearing a state of failure before maintenance is performed. In spite of this generalisation, Preventive Maintenance (PM) is performed on some objects such as cleaning the stormwater drainage and the maintenance of the emergency generators.

This comparison also reveals that a gap exists in the items highlighted in the maintenance manual namely the creation of a database, setting norms and criteria, and performing inspections. Currently there is no database, but a limited amount of information does exist. The maintenance personnel perform tasks using unwritten norms and criteria based on experience due to the absence of documented norms and criteria. The manual prescribes the performing of inspections, but these are only performed for some assets, differing in moment, method and detail from the manual. For most assets, the inspections are only performed after an incident has occurred.

In addition to the above, there are also differences in maintenance actions. Currently maintenance is performed at other moments and using other methods than those described in the maintenance manual. Five reasons identified which cause this difference are a lack of knowledge, limited resources, absent maintenance policy, contractual -and organisational problems. Due to the lack of knowledge, personnel are not aware of the importance of the actions highlighted in the maintenance manual. Limited resources result in certain tasks not being performed until there is no other choice and a lack of a maintenance policy meaning that the focus of maintenance is on corrective actions. Contractual and organisational problems lead to responsibility issues and do not enhance maintenance to be performed until problems have occurred.

The second comparison in this research was performed to identify differences in the maintenance management processes between a mature organisation and the current organisation. The most striking difference is the limited information provided in the current organisation by the maintenance manual. The maintenance manual should be the guideline of the organisation but provides no

information when it comes to the planning, scheduling and assessment of maintenance. In contrast to the maintenance manual, the current situation is not as detailed as the theoretically defined state prescribes the process to be, but there are several similarities.

Documentation is currently limited, and actions are only briefly described. An example of this are the task descriptions, with tasks performed based on routine actions and experience whereas literature prescribes them to be written in detail with information regarding tools, support equipment, materials and parts available. Within the mature organisation, a lot of emphasis is placed on documenting information, using this documented information, following procedures and using forecasting techniques.

In addition to these gaps, the assessment of the maintenance procedures cannot be completed in the current organisation due to a lack of objectives, standards, performance measurement and use of job standards which make it harder for continuous improvement of the maintenance process.

The implementation of the maintenance manual can never be successful if issues regarding management support, implementation time, performance measurement and an implementation plan with an updated maintenance manual are not addressed. Although the company does have a good system in place to communicate to their personnel and the personnel is receiving training, this must be better streamlined for the implementation to be successful.

In addition to the abovementioned conclusion, conclusions can be drawn regarding the contribution of the research as well. In chapter 1 of this report several contributions were provided for the research. Looking at the scientific contribution it was stated that the research would aid in generating empiric knowledge of existing maintenance practices in Suriname and compares these against the state of the art in literature. With the research completed the findings reveal that maintenance at the port consists mostly of CM, but PM is also performed. The comparison reveals that there are several differences between the current organisation and a mature organisation as identified in literature. Main points include differences in documentation and the way maintenance is planned, scheduled and assessed with assessment revealed as the process which is taken into account the least.

For the company the contribution of the research was to improve maintenance by identifying, understanding and bridging the maintenance and maintenance process gap. The abovementioned conclusion reveals the gaps between maintenance and the maintenance manual as well as the gaps between the maintenance process in the current organisation and a mature organisation. The gaps acknowledge that change is necessary for maintenance to improve and the identified reasons behind the gap and the factors affecting the implementation of a preventive maintenance program should aid in bridging this gap and allow the company to improve maintenance.

Finally, the societal contribution was also considered by adding that improving port infrastructure increases the country's competitiveness in the global economy while deteriorating infrastructure raises consumers costs, especially in case of failure. The research revealed some important assets important to the functioning of the port. By identifying the gaps in their maintenance, the company can now work on improving maintenance and ensure that these assets as well as the other assets are kept in a good condition and safeguard the continuous operation of the port.

6.2. Recommendations

To improve maintenance at the Suriname Port Management Company (HBS), several changes are necessary regarding the maintenance process, maintenance activities and the maintenance manual. These changes can be divided between short-term and long-term improvements.

6.2.1. Short term improvement

Starting with the short-term improvements, several recommendations can be made relating to performing inspections, creating a database, updating and using the maintenance manual.

Inspections

For maintenance to be sufficient, it is important that inspections are performed to identify if deterioration of an asset is taking place. By performing these inspections, the deterioration can also be monitored, and maintenance can be performed when necessary.

To perform these inspections HBS must either train their personnel to perform these inspections or hire a consultant. In case HBS performs the inspections, personnel must receive training regarding inspection and maintenance awareness as well as what to look for when performing inspections.

Database

Another recommendation regards the database. This common maintenance database is necessary to define, identify and integrate all kinds of data needed to plan, schedule, carry out, follow up and improve maintenance. The database should consist of data from all objects which require, affect or are affected by maintenance such as design information, blueprints, technical information, inspection records and information, maintenance records and information, etc.

HBS management must either install a small team or outsource the tasks of creating this database and teaching personnel how to use it. For this database, a standard must be created for gathering, storing and analysing data.

In addition to the database a thorough inspection of the assets of the port must be performed by an external party with sufficient knowledge of maintenance of the port assets. This inspection is needed to know what the current state of assets is and to add this information to the database. A comparison can then be made to the state HBS wishes its assets to be and maintenance planning can be started accordingly.

Maintenance manual

In addition to the database, the currently performed tasks, used standards and criteria must be recorded and reviewed. Management must appoint someone within the company who has sufficient knowledge of maintenance or a consultant to perform this information gathering and review.

Information such as details for maintenance execution must be added with the different necessary tools, spare parts, materials and support equipment. Maintenance of the bollards, cleaning methods of the quay and other areas, weekly emergency generator checks and criteria for minimum paint coating thickness must also be recorded. The inspection criteria must be updated with standards provided for test equipment – which must be acquired and used accordingly.

After the review, the recorded information must be added to the maintenance manual. This will result in an updated maintenance manual with all information regarding maintenance available.

6.2.2. Long term improvement

When looking at the long-term changes, several recommendations can be made regarding a maintenance policy and the implementation of this policy and the maintenance manual.

Maintenance policy

A first recommendation is that the company starts with creating a policy regarding maintenance. This policy is necessary to ensure that HBS has a clear vision and works towards optimally maintaining the assets under their management. When HBS is clear about the direction it wishes to follow then further steps can be taken. In this policy the company must divide objects based on the maintenance strategy.

For some assets the strategy can be PM while for other assets a CM strategy is the better choice. Maintenance of the drainage system and the quay are typical assets where a PM strategy is necessary to ensure that these remain in optimal condition whereas replacing lightbulbs after failure is a good CM strategy.

An important aspect which should be clearly stated in the policy is that inspections should be performed regularly. These inspections aim to identify the condition of an asset with the aim of performing maintenance before a certain condition is reached.

A final part of this maintenance policy is performing an evaluation of the Infrastructure Department, resulting in an updated structure. HBS should clearly define who will be responsible for maintenance by choosing between outsourcing, in-house maintenance or the current hybrid system of outsourcing some tasks while performing others in-house. If the maintenance policy stipulates that the hybrid system will continue to be used than it is important that the department should stick to the core tasks addressed in the policy by evaluating which tasks should be performed by HBS and which should be outsourced. Continuous training of the personnel is essential in that case and should also be stipulated in the maintenance policy.

Implementation plan

For the implementation of the maintenance policy and the maintenance manual, it is essential that an implementation plan is made with management taking sufficient time into account for the changes which can range between 3 to 5 years according to literature. Because of the changes happening, communication with the personnel is essential for the successful implementation. The port magazine and monthly information sessions are perfect for communication about the program with the personnel, but these must be increased and include videos. Visual aids are perfect for educating and informing the personnel about the implementation, improving understanding of the program and to showcase the results. The full implementation should only be done after the maintenance manual has been updated.

A part of this implementation plan should be the realignment of the current maintenance processes with those in the mature organisation. Measuring actual performance and adding job standards are needed to measure the improvements in maintenance with management seeing to it that constant improvement occurs. These changes can be made using pilot projects. By performing pilot projects, the problems can be identified, and improvements made before complete implementation. This should limit the amount of problems occurring during implementation and make the transition smoother. A pilot project can be the implementation of effective forecasting techniques to predict when maintenance will be necessary. The cleaning of the sewer system can be improved by registering the silt level in every inspection pit. Using this information, calculations can be made to predict when

cleaning will be necessary. This will also lead to the identification of areas where extra surface cleaning will be necessary to limit the amount of sand reaching the drainage system.

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Appendix Interview questions

Two rounds of interviews were conducted. The first round of interviews was to gather information regarding the current state of maintenance and the second round of interviews was to understand the reasons behind the identified gap.

Appendix 1.1. Questions round 1

Three primary questions were asked followed by follow up questions (table A 2-1). The primary questions related to maintenance of every asset. The questions were:

1. What maintenance activities are performed?
2. When is maintenance performed?
3. What criteria are used to perform maintenance?

Table A 1 - Follow up questions

	Asset	Follow up questions
1	Quay and concrete transition slab	1. What is the procedure when damage occurs? 2. How often is a certain maintenance activity performed?
2	Concrete piles underneath the quay	-----
3	Storm water drainage	Are there problems regarding flooding?
4	Fenders and bollards	What is the procedure when damage occurs?
5	Electrical installations	What is tolerable for non-working lights, electricity, and etcetera?
6	Water supply and firewater system	-----
7	Fences	1. What criteria are used regarding the state in what the fence must be at all times? 2. What is the procedure when damage occurs?
8	Draught of quay	1. What is the minimal draught? 2. Is an inspection performed and how often?

Appendix 1.2. Questions round 2

The second round of interviews was done with the questions (table A 2-2) aimed at understanding the reasons behind the gaps between current maintenance actions and maintenance prescribed in the maintenance manual.

Table A 2 - Questions round 2

Asset	Question
General	1. Why do you think the maintenance manual has not been implemented? 2. Why are there no norms and criteria? 3. Why aren't inspections performed? 4. Why is there no database?
Quay/transition slab	1. Why aren't there inspections for cracks? 2. Is wear of the concrete taken into account?
Concrete piles	Why isn't maintenance performed?
Bollards	Why aren't the fixations and concrete inspected?
Electrical	1. Why aren't the installations kept accessible? 2. Why isn't the current network monitored better?
Fences	Why isn't maintenance performed right away?