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The Remaining Economic Life Time of a Semi-Submersible Crane Vessel

by

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'I'm not afraid of storms, for I'm learning to sail my ship'

Claudia Fitzgerald

Acknowledgments

My background as an engineer in the world of ship building has led me to find a research that studies the economical stand point of construction and or operation of ships. This has led me to the topic of life cycle engineering. LCC helps engineers think like MBA's but act like engineers (Emblemsvag, 2003). The study at MEL and the combination of this topic is very interesting for me and will be a good compliment to my previous study.

As engineer I was confronted with many challenges which I could not confront on my own. My gratitude goes to Prof. Aalbers for being my thesis supervisor and to take time to guide me.

Furthermore, without the help of all my colleagues I would not have managed this research, special thanks to Mr.Brunt, Mr.Solleveld, Mr.Zijderveld, Mr.Kennis, Mr.Koopman, Mr.Hofland and all the staff at HMC that took time of their busy schedule to help me with this thesis.

At last I must thank my mom, my sister and my complete family, my friends and my MEL friends for giving me the support when I need it the most. Thank you.

Abstract

There are many expenses involved with the operation of a vessel including manning, fueling, and insurance and maintenance costs. In order to have a profitable ship operation the revenue generated should exceed these expenses. In recent years all of these expenses have increased mainly due to the high oil prices. However, the cost projections for a specialized vessel such as a semi-submersible crane vessel (SSCV) are not similar to other conventional vessels.

This thesis concerned the economical operation of a SSCV based on the technical state of the vessel. The current project at Heerema Marine Contractors entailed the development of a model that predicts when the vessel, from a technical stand point, no longer can generate the Economic Value Added (EVA) target desired by the company. With this tool the management can make strategic and operational decisions in the short and long term. Moreover, valuable information can be obtained to help managers make decision on maintenance, life time extensions programs, impact on investments of the economic an technical state of the vessels, and most importantly the optimum Cessation of Operation (COO).

To develop this model a Life Cycle Cost (LCC) method was performed from the economic stand point of the vessel. First data was collected and graphed over a period of time in order to establish the variables and parameters for the model. The technical model was made by a combination of Life Cycle Engineering and safety assessment of the vessel. The LCC analysis was then forecasted over a period of time and used to make an operating profit model.

The technical stand of the vessel should be in accordance with the classification society and HMC own standards. The classification societies have a specific standard that the vessel should meet in order to stay sea worthy. However, HMC wants its vessels to stay above this limit. As soon as the vessels technical state declined the company invests in replacements. Adding the operational expenses to the capital expenses over a period of time and keeping the specific technical state constant the economical performance of the vessel was obtained.

The operating profit model was made very simple in order to support future expansion. The operating profit model illustrates how the profits decrease when the repair and maintenance (R&M) expenses increase for a fixed revenue. The core model can support future expansion such as the amount of days worked, which makes the revenue generated per vessel dynamic over time; therefore, a better prediction of the EVA target can be obtained. The same model can also support the fixed and variable costs, which are correlated with the amount of days worked. At last the operating profit model can be further modified to find the EVA target over time.

The application of LCC to the offshore industry is relatively new resulting in various challenges giving rise to new ideas. The first challenge was to filter all the cost data available that leads to the maintenance of the vessel. The data collected should reflect the condition of the vessel. The major challenge was to link the economic model with the technical model in a logical and understandable manner. By linking the model to each other a better prediction of the earning capacity of the vessel was obtained. These challenges have inspired new ideas. Ideas such as a LCC

database which keeps all the cost data associated with maintenance of a vessel according to the specification of the classification society separately. Furthermore, the technical model should be updated whenever repairs and replacements occur on the vessel in order to predict the exact condition of the vessel more accurately. HMC can use these data to control all the costs related with the vessel till its cessation of operation.

The thesis research produced numerous conclusions and recommendations. For instance, it was found that the amount of working days correlated with the operational cost of maintenance. This finding is very logical considering the more the vessel works the more it deteriorates. From 2006 till 2008 the vessel Hermod had 1000 days in operation, during this period the repair and maintenance cost where sufficiently high to link the amount of days work to the expenses. The cost drivers associated with the vessel were also identified and for all the three vessels the engine room, the hull and the cranes were the major cost drivers. Furthermore, the cost patterns were deduced and the forecast was executed based on this observation. In the end, the model is able to give an indication of the operational profit of the vessel over an extended period of time. The EVA target for HMC can also be calculated using this model.

The preliminary results indicate that only the Balder will have a good economical performance towards the end of its COO which is approximately in 2021. The model indicates that before the Hermod is put out of commission in 2016 it will be loosing money on maintenance and repairs. The Thialf will also perform economically poor before its COO in 2031. The main reason for the vessel Hermod to perform poorly around the operation year 2014 is that the repair and maintenance expenses increase in order to maintain the vessel above the required technical conditions appointed by HMC.

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List of Abbreviations

ABS	American Bureau of Shipping
CAPEX	Capita Expenses
CEO	Chief Executive Officer
CFO	Chief Financial Officer
COO	Chief Operating Officer
COO	Cessation of Operation
DCV	Deepwater Construction Vessel
DP	Dynamically Positioned
EVA	Economic Value Added
HMC	Heerema Marine Contractors
IMO	International Maritime Organization
LCC	Life Cycle Costing
LCE	Life Cycle Engineering
MODU	Mobil Offshore Drilling Unit
NASA	National Aeronautics and Space Administration
OPEX	Operating Expenses
R&M	Repair & Maintenance
SSCV	Semi-Submersible Crane Vessel
WACC	Weighted Average Cost of Capital

Chapter 1 Introduction

Engineers are not used to controlling cost at a company. They are more involved with the calculation and planning of technology projects, process and operations. However, Life Cycle Costing (LCC) is a tool that can help engineers make decisions that improve the business operating profits. In a capital intense industry, such as the offshore industry, strategic decisions from a technical stand point can reduce the costs of operations. Engineers can predict and allocate expenses to areas of the vessel which are experiencing deterioration due to constant cost increases.

Chapter 1 gives an introduction of what are the objective of this research is and the methodology and research approach used in this thesis. Furthermore, the reason in using the component of life cycle engineering is explained. Chapter 2 will introduce the company and will to explore the motivation in starting this project and what for results is expected. Furthermore this chapter will introduce the offshore market to the reader. This thesis is part of an ongoing project at the company Heerema Marine Contractors (HMC) and it is covered in chapter 3. The entire project takes most of the life cycle engineering components into account to find the desired outcome. However, this thesis concentrated on the costing effect of ship maintenance, repairs and replacements. These costs give a technical glimpse of the vessel and can be used in the HMC project to predict when their vessel is no longer able to generated HMC desired income.

Besides introducing the project at HMC, the components of life cycle engineering will be explain in chapter 4. Life cycle engineering is a broad concept that has many components that cannot be researched by one person alone. In this thesis some of the major components will be explained. In chapter 4 these components such as life cycle costing and the life cycle stages of a product will be introduced together with an introduction of the LCC model.

Chapter 5 will discuss the findings from the data analysis made from the cost of maintenance and replacements investments at the equipment management department at HMC. The data collected is booked at HMC as operational expenses (OPEX) and capital expenses (CAPEX) and it is important to understand these costs better.

After a thorough analysis of the data collected, a cost model can be made to study how the increase of cost affects the economical performance of the ship. Chapter 6 will explain more about how the model is to be formulated and then modelled. The results obtained from this research will be explained in chapter 7 together with the findings of the model. The perspective of HMC will also be included in the findings because it leads to further research addressed in chapter 8. At the end of this thesis the conclusions and recommendations will further chapter 8.

1.1 Background and Objective

Life cycle engineering is most common in the car, military and aviation industry. It is often used to calculate the amount of years a product will last. With this information the car company can put a guarantee label on its product, military industry can predict reliability of its weapons and aviation can maintain reliable planes in the air.

This thesis explores how life cycle engineering can be introduced to determine how Heerema Marine Contractors can economically exploit its assets.

The Crane Vessel market is a capital intensive industry, with high operation and maintenance costs. The cost of maintenance and operations would overtake the revenue capability of the assets at some point. This point in the future is important for Heerema Marine Contractors and it is the main research objective of this thesis. Hence this thesis question:

Can life cycle engineering be used at Heerema Marine Contractors in order to predict the economic profitability of their three specialized vessels in the future?

The research question was first dealt with in a theoretical approach to establish sufficient knowledge on this topic. This approach comprises of literature review from other industries using this technique and by interviewing leading authorities on this subject. The second part of the research is an empirical approach.

1.2 Research Methodology

The literature review will start by gathering and selecting materials regarding the theory of life cycle engineering. From the main topic other materials will be selected from other specific industry, such as car and plane industry. Books, articles, journals and internet sources will be accumulated containing life cycle engineering and its aspects. From this literature review the theoretical background of this thesis will be prepared.

The empirical approach is the collection and observation of cost data during a specific period of time to later be analyzed for the life cycle of the ships. The empirical approach is further broken down into two components during the analysis and interpretation of the data collected. The first part is a quantitative approach in which the cost data of the ship will be analyzed and modeled for the three ships separately.

During the interpretation of the results a qualitative approach will be used. This approach is important to bring the relationships of the cost over a specific period of time into perspective. Costs such as CAPEX must have had a reason for why they were implemented when they did. The experience of the engineers and cost controllers at HMC would be very valuable during this stage of the research. For the reevaluation of the forecasting model this qualitative approached will take out the graph-peaks that occur in the previous periods and can give the model a better outlook. Depreciated CAPEX will later in the research be used to forecast the repair and maintenance (R&M) expenses.

1.3 Research Approach

1 Gathering Information

The first step in this project is to collect and condense as much useful information as possible. In this stage the use of books, essays, articles, and academic thesis are helpful. Life cycle engineering is a relatively new theory in the marine sector. It is applied more extensively in the automotive, aeronautics, and weaponry industry. However, creativity and ideas developed in one field can be applied in other fields as well.

2 Gaining Expert Knowledge

During this stage the company's expertise and work approach is used to facilitate the project. Here the knowledge of every individual in the company is considered. Furthermore, the knowledge must be captured in a form which can support discussions, thus, promoting co-ordination and development of a shared understanding (Wynn, Eckert, and Clarkson 2006). During this stage, interviews conducted with the ship managers are recorded and their input will help make this project successful. Furthermore, other departments at HMC will be interviewed to collected valuable knowledge, for instance on the business rules, the financial and accounting bookings, and the risk HMC takes in the offshore market.

3 Framework

The knowledge gained will then be translated to a restricted framework in which the project is to be achieved. This restricts the input of information, thus making the output more viable. Overload of information can lead to multiple correlations that could obscure the desired outcome of the project, in this case, the realization of the model. The framework contains the desired outcome, what the project intents to illustrate. In the framework the parameters are established to simplify the model.

4 Modular Approached

During this stage the model has to be structured. The best approach according to Professor Michael Pidd of the Department of Management Science at Lancaster University is to keep the model simple, start small, add to it as it progresses, and divide the model. He states that a simple model can support complicated analysis but it is a mistake to make the model more complex than the technology it is mend to help. Modes from other industries can be useful and applicable references during the modular structure stages. During this stage, it is important to benchmark the model to other models in various industries. This will give the model additional value during the realization and implementation stage.

5 Tasks and Duration

After selecting a few models that can be used, the task of the model will be determined. The following questions are to be addressed. What is the intention of the model? What is the task outcome? What are the sets of actions that the model will perform? Furthermore, the duration is determined. The duration basically states how long the model is to be simulated or calculated. Many choices are considered for the duration and used to compare results.

6 Data Collection

Data collection must be efficient and in alignment with the project framework and parameters. Too much data will make the model sensitive to mistakes and will decrease it reliability. Data collection should never have an influence on the model. The model must remain independent of the data used to determine, in the case of Heerema Marine Contractors, the cost efficiency of maintenance projects. The model and analysis used in the project determines which data is to be collected.

7 Process Variables

Process variables indicate data that is constantly changing with the process. The most common process variable is the 'cost'. For instance, the 'cost' to repair a ship is constantly changing because of the amount of work done, the cost for labour, and even the adaptation of charges due to inflation. The cost data over the years is always changing, and the process variables of the project must be established. The current study investigates if the cost of maintenance and operation at Heerema Marine Contractors is much higher than investing in a new ship. Due to the nature of this project, establishing the process variables is important to guarantee a more accurate result because of the dynamic behavior of the model.

8 Model Realizations and Implementation

In this phase the chosen model will e tested by putting in all data collected. The realization of the model will only be achieved when continued testing displays the outcome to be as close to the target possible. This can be a very difficult step during the project. The early benchmarking with other models should help give value to the output of the model. During the implementation stages, the logic behind the outcome must be scrutinized once again to see if the results reflect the real situation as close as possible.

9 Modification and/or Adjustments

Any calculations must be double-checked for eventual mistakes that could have occurred during the whole project. If the model or method followed must be modified or adjusted and the spiral of optimization will begin.

10 Management Judgments

A decision model is a useful device however it cannot incorporate all the nuances of a complex decision (Hunt & Butman, 1995). The last step in approaching the function objection of this research will be determined by the expert judgment of the people more familiar to the ship. The cost analysis can easily be explained by the different managers of the ship in question. Every ship at HMC has its own manager and their judgments of the model and cost analysis will be very valuable to the success of this project

1.4 Why LCC

When assessing the historic development of the world economy a few trends can be witnessed. Increasing cost of living, continuing cost growth for many products, decreasing consumer's buying power, tougher competition due to more competitors are all economic trends in the past years. With a new down cycle in the economy today these trends are emphasized even more. Due to these trends an awareness and interest was created in total system and product cost (Fabrycky & Blanchard, 1991). For a company such as HMC a LCC analysis would clarify some of its cost especially those that are not readily evident, such as operational and support costs.

The main theories on LCC include the total evaluation during the whole life time of the system the cost of research and development, the cost of production and construction, the cost of support and operation, and the cost of disposal. However, in the current research only the support and operation costs were analyzed in order to establish how these costs interact with the economic developments, total operational time and deterioration of the ship.

After analyzing historical accounting data the high cost contributors can be identified, cause-and-effect can be defined and valuable information can be gained and utilized for the purpose of improving the system which in this case is the semi-submersible crane vessels (SSCV) (Fabrycy & Blanchard, 1991). In these economic downturn these information of the company's assets will be valuable and crucial in later business decisions.

Chapter 2 The Offshore Industry

2.1 The Offshore Market

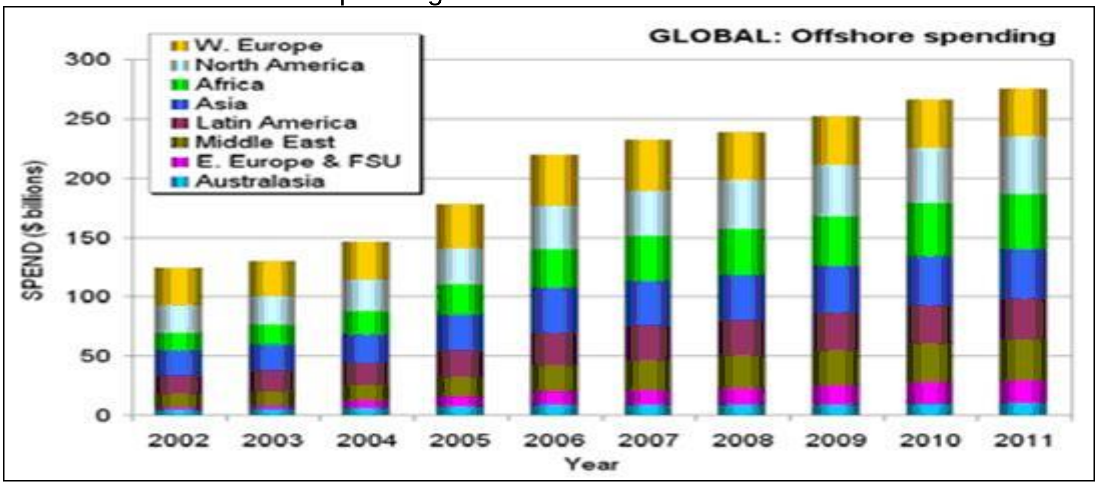
The world economic development is closely linked to the offshore industry. Our appetite for energy has drive companies to explore the bottom of the ocean for natural resources around the world. The high prices of oil have made this business very lucrative in recent years, and have allowed companies to revolutionize the exploration of oil. With new technologies natural resources such as gas and oil can be exploited in oceans were it was once impossible to do so. Areas such as at the Atlantic basin, the coast of Brazil and Africa, and ice-covered oceans close to the Arctic Circle are currently being tapped for oil and gas.

The current market is consists of five segments, the floating production, subsea, offshore pipelines, fixed platforms and deep & ultra deep water market. HMC has the equipment and the expertise to operate in all the five segments markets. This provides them an edge compared to other companies in the offshore market. They can provide their services over all five sectors which include the capability to lay pipe at the bottom of the ocean, heavy lift, installation and removal of platforms and subsea equipment.

The five segments in recent years have experienced a high growth rate mainly because of the growing energy needs form emerging countries such as China and India. In the floating production market the capital expenditure is expected to grow with an annual growth rate of 4.3% over the next four years (ISL, 2008).This trend is visible in table (1) by energyfiles ltd. that records and predicts the future spending in the offshore market.

In the coming years the ISL is forecasting that 175 units will be installed. This forecast is positive news for the core business at HMC. Certainly if these projects do not encounter any delays soon they will require other companies that provide services in heavy lifting for the installation of the platforms. With HMC being one of the fewer companies that can offer this service they have to prepare their assets to take opportunity of the market growth.

Table 1: Global offshore spending



Source: energyfiles Ltd.

The subsea market follows the build and installation of equipment for exploitation of natural resources on the bottom of the ocean. This market has grown rapidly mainly because of new technology being developed to sustain the pressure of the ocean.
The subsea market has also grown in recent years this is driven by the rapid development in the subsea technology. The subsea market is the market in where specialized equipment is build and installed at the bottom of the ocean. For the coming four years the expenditures in this section of the offshore market is predicted to double (ISL, 2008). The major activities will take place in the Gulf of Mexico and Africa both are familiar territories for HMC. Furthermore, due to the technical development companies will be able to explore into deeper waters. Consequently, the growth in this market can only be hinder by energy policies. HMC has the assets to provide services in ultra deep waters.
The subsea market has also a positive spillover effect on the pipeline market. The subsea installation will need pipelines to conduce the oil and gas extracted from the bottom of the ocean. That will translate into growth and is forecasted to increase over the next years.

The fixed platforms market is the original and oldest indicator on how the offshore market is developing. By observing the forecasted expenditures on platforms the total market forecast for the offshore could be made. Presently the offshore industry has evolved to include the other sectors of the market such as subsea and deepwater. The fixed platform markets has experience over the years a steady growth, however since 2008 the capital expenditure in this sector has witnessed a peak. This peak according to ISL is due to the decommissioning of existing platforms. Furthermore the market is forecasted to have more peaks due to the high demand of oil and gas, making investing in the offshore industry very lucrative.

The deepwater market has a total effect in the whole offshore industry. It drives the subsea and pipeline market to continuous growth. Without exception all of the top ten international oil and gas companies regard deepwater exploration and production as a key element of their strategic development for the coming decades (ISL, 2008). With most oil and gas companies taking the deepwater sector of the market as an integral part in their business transactions/ or something makes HMC a key player in the offshore industry. Their assets are equipped to work in deepwater and can provide all of the service needed during construction and installation of equipment in these waters. Companies are expected to invest more than $100 billion dollars over the next five years in deepwater. Total offshore expenditure shows a steady rise from $123 billion in 2004 to $148 billion in 2008, with forecasts continuing to increase to $161 billion in 2013 (Offshore Magazine, 2009). This forecast for the coming years is very positive for the business area of HMC.

All and all, the complete offshore market is experiencing high growth rate. With HMC being equipped with ships that can provide service for marine installation and decommissioning they can take advantage of this growth. Because this industry is very capital intensive they would need to have a good control of their cost to maximizing their profits during these positive years making LCC a very important part in the company.

2.2 Heerema Marine Contractors

The Heerema Group has a long history of building offshore drilling platforms for the gas and oil industry that dates all the way to the 1950s. The company today is comprised of Heerema Marine Contractors and Heerema Fabrication Group. Together the Heerema Group can provide the design, fabrication, transportation, installation, and removal of facilities for the offshore industry. The Heerema Marine Contractors specializes in the transportation, installation and removal of oil and gas production units. To realize all of its offshore projects HMC provides management, logistics, planning, engineering, and work preparation to its client. HMC owns and operates three Semi-Submersible Crane Vessels, two large tug boats, and numerous barges.
HMC is an international organization with offices located all over the world. The company's corporate vision is to become the best marine contractor in the world. Therefore, an analysis like LCC can keep them on the forefront of the market by providing their services at any time.

As a successful company in its field, HMC has gathered a wide range of knowledge and experience throughout the years and can now offer their clients all the service needed during their offshore projects, from heavy lift, float over to deep water installation. Consequently, HMC has all the means to become the best company in offshore construction company in the world.

2.3 HMC Organization

HMC has a leadership team that leads the company on their strategy path. The leadership team consists of the chief executive officer (CEO), the chief operating officer (COO), the chief financial officer (CFO), and the executive vice president commercial. They are being advised by a specific advisory board. From the leadership team the guidance for the implementation of the company's strategy is passed via a chain of commands to the different department managers. The department managers adhere to the company's vision and strategy in the operation phase.

The culture at HMC is one of an international organization that performs their business in English in order to take advantage of talents worldwide. At HMC, employees are expected to be creative, driven and flexible (Heerema Marine Contractors, 2009). This international environment is conducive for conducting research such as this current LCC. Furthermore, the organization facilitates collaboration between departments and every project is backed by all the departments of the company/ the different departments eagerly contribute their knowledge and expertise to the projects conducted at HMC.

The research on life cycle costing is part of a vital project at HMC that could only be completed due to superior organization of the company. The cost data was obtained from the equipment management department that handles the cost of maintenance of all the vessels. The revenues data and model was provided by the sales and business department. The risk analysis was provided by the advisors of the legal department and the workday's data was provided by the planning department. The results of this project can help the technology and operation departments in the future. This gives an example on how all the departments must work together to achieve a more reliable result which is also promoted by a good organizational scheme and the company's culture.

Furthermore during the data collection extra knowledge can be obtain from knowledgeable individuals with years of experience. As suggested by the theory established by Wynn, Eckert, and Clarkson (2006) this extra knowledge gathering can create new discussions, and promote co-ordination and develop a shared understanding of the concept and goal of the life cycle project.

2.4 HMC Assets

As previously stated HMC owns and operates three of the worlds biggest SSCV, two large and powerful ocean-going tugs and numerous barges than can carry heavy loads. As a marine contractor specialised in installing and decommissioning of oil platforms HMC needs these assets to be in good condition in order to take advantage of job opportunities. The project started at HMC will concentrate on their biggest assets the SSCVs however it will be implemented on all their assets afterwards. However during implementation one must realized that the tugboats are very different qua size, total cost of maintenance and classification society regulations. The concept of the LCC will remain the same but the outcome must be interpreted differently. Before the LCC is performed a better understanding of HMC assets must be made. In this project the SSCV's will be the only assets being used for the LCC analysis.

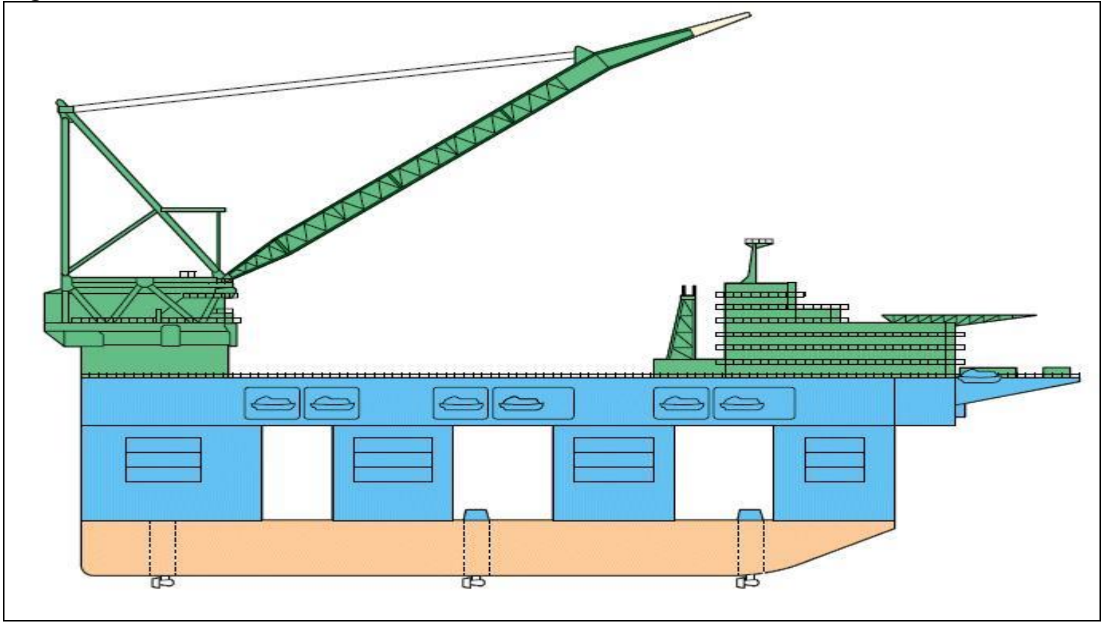
2.4.1 Semi-Submersible Crane Vessel

A semi-submersible crane vessel has large pontoons-like base and these are connected via their columns to the deck of the ship. At first view these vessels do not look like a typical ship. However, their construction makes them the ideal equipment for heavy lifting. The pontoon and legs of the vessel can be submersed during operations, this is called ballasting (adding water ballast into the hull).This increases the stability of the ship during rough sea and improves the ability of the ship to do heavy lifting. Because these types of ships are less sensitive to sea swells they can operate in areas such as the North Sea especially during the winter months when the conditions are harsh. This gives HMC the ability to take jobs all year around in areas where mono-hull ships cannot easily operate.

What makes these vessels unique is the DP (dynamically positioned) system installed on them. The DP with the help of thrusters located at the bottom of the ship allows perfect manoeuvrability and fixed positioning guided by satellite. This system allows them to work in a fix position without using anchor lines. Anchor lines hinder a ships ability to work closer to the oil platforms where heavy lifts are needed. Furthermore, anchor lines limit the depth of water that can be worked in and cannot be used in operation where there are pipelines and cables on the seabed. In figure (1) show a cross sectional view of a SSCV.

These assets are the core of HMC business. HMC owns and operates three of the biggest SSCV in the world making them market leaders in this sector due to the handful number of SSCV's in the world.

Figure 1: SSCV cross section



Source: www.globalsecurity.org

SSCV - Hermod

The semi submersible crane vessel (SSCV) Hermod was built by the Japanese yard Mitsui Engineering & Shipbuilding Company Ltd in 1978. This thirty year old ship has an overall length of 154 meters with a width of 86 meters and a draft ranging between 11.5 – 28.2 meters. Furthermore, the gross tonnage of the ship is 73,877 tons and its cranes can lift in tandem 8,100 tons. All the propulsion systems on the Hermod are electrical and it has seven main diesel generators of 2,765 kW each that provide the power for the ship. This power configuration gives the Hermod a transit speed of 6 knots. Detailed information on Hermod is listed in appendix 1.

SSCV - Balder

The Balder is the sister ship of the Hermod and was also built at the same yard and delivered the same year as the Hermod. The main difference between them is that the Balder was later in its life outfitted with more equipment in order to function as a deepwater construction vessel. This vessel can install foundations and moorings at the bottom of the ocean and can lay pipe-lines and flow-lines as well.

SSCV - Thialf

The Thialf is the biggest vessel in HMCs fleet with a length overall of 201.6 meters a width of 88.4 meters and a draft that ranges from 11.8 to 31.6 meters. It is also fitted with sufficient equipment to make it a multipurpose ship that can install foundations, moorings and topsides, and can also lay pipelines on the bottom of the ocean. The cranes on the Thialf can lift up to 14,200 tons in tandem. The ship has a gross tonnage of 136,709 tons. This ship was also built in 1985 at the same shipyard as the other SSCV's. The extended specifications are listed in appendix 1

2.4.2 Classification of SSCV

The main purpose of the LCC is to identify the technical state of the vessel, in order to see when it is not economical to continue maintaining and repairing the SSCVs. Maintenance on these vessels are done routinely in order to prevent major breakdowns. Furthermore, HMC does all the maintenance necessary to remain in class. Remain in class means that the vessel approved by a classification society during design and construction is still sea worthy. No major upgrades or modification can be performed on a ship without consulting the classification society where the ship is register. The seaworthiness is than certified by the society. This certificate must be renewed every year, and deterioration on a ship will hinder the renewal.

There are many classification societies in the world and the main ones are Lloyds register, American Bureau of Shipping, Bureau Veritas, and Det Norske Veritas. The vessel Hermod and Balder has certification from the Lloyds register and the vessel Thialf is register with the American Bureau of Shipping. The selection of the classification society is mainly the free choice of the owner. A reason behind the ABS classification of the Thialf can be due that the ship a joint venture was of HMC and the American company J. Ray Mc Dermott. After the joint venture was over HMC stayed with this society because it’s easier than switching to another one.

The rules applied to these vessels in both societies are very similar and they followed the classification regulation for a Mobil Offshore Drilling Unit (MODU). A MODU is a generic term for jack-ups, semi-submersibles, and submersibles units, mainly used as drilling platforms. The MODU rules covers the auxiliary machinery, control engineering systems, electrical installations, fire and explosion protection, jacking system (not applied for these vessels), masts, derrick posts and crane pedestals, materials, propulsion machinery, process plant, piping system, stability together with damaged, steering gear, structural strength, mooring equipment, and weather-tight/watertight integrity. The cranes on the vessel are classified separately under the society’s code for lifting appliances in a marine environment. Furthermore, the rules are divided in five class notations to make the rules more manageable. The class notations are as follow; ship units, barge units, self-elevating units, semi-submersible units, and support vessels. The main difference between these three SSCVs is that the Thialf is classified as a barge and semi-submersible unit and the Balder and the Hermod as a combination of ship and semi-submersible unit. This changes the rules a bit for the certificate rules and surveys.

During the life time of these MODU the society required various surveys which can be periodical, annual, docking, in water, special and continuous survey. The main difference of these surveys when compared to a mono-hull ship is that even docking surveys are necessary they can still be performed in water. However, the ship will have more regulations to comply with. Because of this rule the SSCVs at HMC hasn’t been dry docked in the last ten years for surveys.

The types of survey must be taken into account when they decrease the amount of days the vessel can be available for work. Also during the cost analysis the peaks can be explained by surveys periods that required heavy investment in order to remain classified, for instance hull and deck coat painting. Because these units are over thirty years old during special surveys the thickness of the hull must be measured and can drive costs of maintenance high due to the necessary step to stay seaworthiness. If the hull of the vessel is deteriorating the cost to stay seaworthy will be high and will stay relatively high and must be kept in mind when performing the cost data analysis.

All and all cost to keep these MODUs in working condition and most importantly in safety standard is closely linked to calcification society's rules and regulations. Beside the rules for the structure that will have multi surveys done in its life time a sea going vessel will adhere to rules for safety at sea, special for seafarers and the environment. This is because a marine or offshore engineering product is usually a large, expensive and complex engineering structure and a serious failure could cause disastrous consequences (Wang, Yang, Sen & Ruxton, 1996). Other code regulators such as the IMO on an international level and the US coast guard on a national level have their codes that one must oblige to. These codes can also drive the operational cost up, especially if repairs and or maintenance are required to guarantee safety at sea. Safety and cost are obviously two conflicting objectives, with higher safety leading to higher cost (Wang, Yang, Sen & Ruxton, 1996). From an engineer's stand point and without analyzing any data yet this hold true. Safety can never be compromise to reach a low investment cost and high security level. And from initial design standpoint it is generally impossible to have a design which could maximize safety (i.e., minimize risks) and minimize the life cycle cost simultaneously (Wang, Yang, Sen & Ruxton, 1996). In the case of all the regulations and safety codes in place for a MODU it is basically impossible to compromise between safety and minimization of life cycle cost. In order words this cost will continue to increase in will determined the total cost of maintaining a ship.

HMC business rules required that the vessels condition to be none less than 65 percent considering new vessel condition as 100 percent. In other words besides classification rules and regulation HMC also control their vessels technical standards by imposing this minimal safety and operational requirement. By following their own business rules HMC is not compromising between the minimal technical state of the vessel and the costs of maintaining theses, meaning that the costs will continue to increase in the future.

2.5 Economic Value Added (EVA®)

HMC is a company that reports its earnings in EVA® making them a so called EVA® company. This system is very similar to other economic models to measure performance of a company. The main difference is that it brings the hare holder also in this model and this is further explained in this chapter. The final result of the project at HMC must reflect the EVA® target of the company and it is important to understand how this performance model works. Furthermore, the EVA® is measure of the performance of the company and this must be broken down to reflect the performance of each vessels.

EVA® was developed and deployed by Stern Stewart the founder and chairman of a consultancy company established in 1982. He set out to explain many ideas in financial policy and strategies. Shareholding value is important for a company and it could only be achieved by making complex financial theories workable and valuable for senior management. The focus of EVA® is to create value for the company to generate more benefits. EVA® is a trademark of the Stern Stewart Company and it is often referred to in the educational world as economic profit. At HMC this is the chosen way to evaluate the company's potential and welfare. That is why it is necessary to understand how EVA® works.

2.5.1 Economic Value Added: General Idea

This economic profit is a performance metric that can measure a company's earnings or return on capital. This performance metric is based on the principal of the discounted cash flow model that states that the value of a company is the same as the present value of its future cash flows. The main distinction is that the economic profit model is broken in invested capital and the future economic profits of the company. Because of this the economic profit will return profits earned above the cost of capital.

Furthermore, the market value of the company can be viewed as the present value of the future economic profits. This explains the relationship between the two parts of the economic profit model. The calculation of the economic profit is based on three simple ideas, that cash is a better performance indicator that some expenses are really long- term investments, and that equity capital must be accounted for because this is not free. Using these three ideas the model takes the EBIT (earning before interest and tax) and coverts it to net operating profit after tax. During the net operating profit after tax (NOPAT) calculation, the interest expense is added back to the EBIT together with the adjustments that is intended to covert accrual to cash and to classify some expenses as investments. Afterwards, the taxes that, for instance, HMC pays with cash from its net operating profits are deducted to find the NOPAT.
Finally the economic profit can be obtained by subtracting the invested capital times the weighted average cost of capital (WACC) from the obtained NOPAT of the company. The formula for the economic profit is as follow:

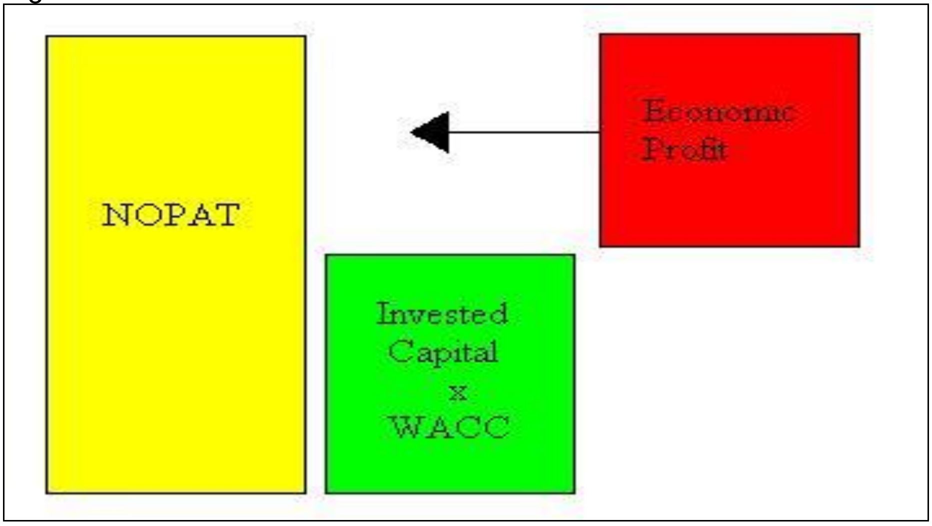
Economic Profit (also the EVA®) = NOPAT – (invested capital x WACC)

This formula is further explained in figure (2).With this calculation the profit that HMC needs to make to satisfy the lenders and shareholders who have rented capital in the company can be found. It is a measuring model that can show the shareholders of HMC how profitable their investments are. This is one reason why it is use today at HMC. Another reason to use this performance metric is the nature of the oil and gas industry, which are very capital intensive.

The economic profit is not very different than other traditional cash flow theories. It uses the same principals and theories however with key adjustments that can be stipulated per company. This makes it more practical for companies such as HMC.
Because HMC uses EVA® to measure their performance, this needs to be included in the analysis of their total cost of maintenance and operations. Simply put, the LCC and the EVA® target of HMC will be put in a model and when the cost of maintenance makes EVA® less than what shareholders desire HMC can adapt their business plan.

According to Mr. Stewart EVA® target can be raised by four different ways. One of these ways is the improvement of the operating efficiencies on its existing capital (Stewart 2009). This in turn will raise the return on capital. The LCC model intents to help the efficiencies of the maintenance cost for HMC, and can elevate their EVA®.

Figure 2: Economic Profit Added



Source: Stern Steward & Co

Chapter 3 HMC Internal Project

3.1 The Project at HMC

Any successful company in the world manages their cost carefully and plans its strategy according to the economic trends such as continuing increase in costs. Costs such as living expenses and travel expenses, have increased over the years and the same trend is projected for the coming years. To run a successful and profitable business such as HMC, good planning is needed, and good planning can only be formulated with good analysis of the whole business.

Considering cost management, a company must analyze its historical cost data and make a forecast to have multiple scenarios outcome for the future. Therefore, HMC required a method for determining when the company's assets are no longer capable of generating their target revenue. To achieve this goal we started a project to develop a structured method to analyse the remaining technical and economical life for the Thialf, Hermod and Balder.

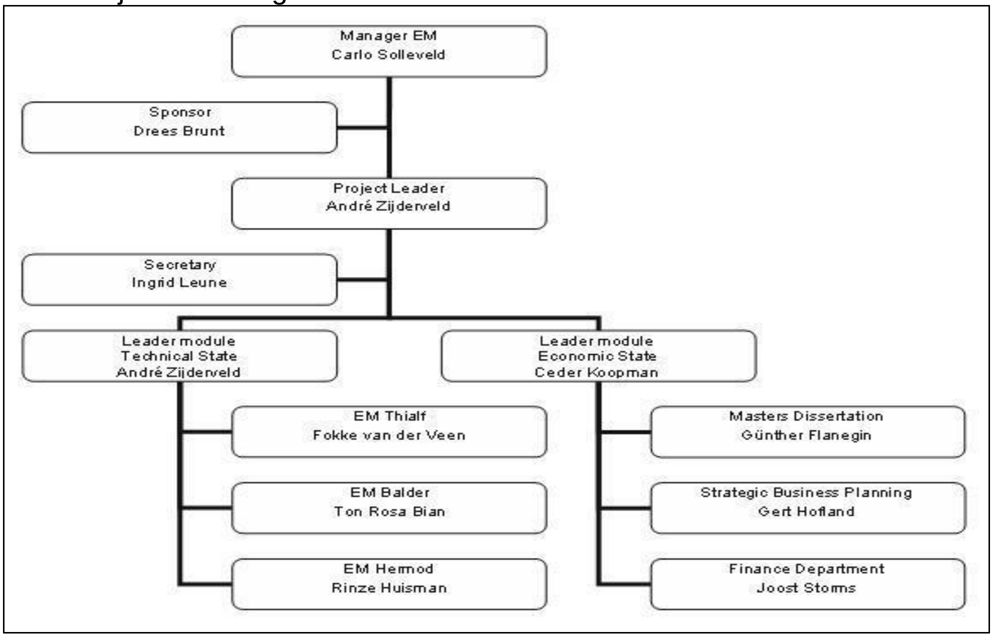
The main objective of this project is to provide the HMC management team with information to support future decisions on nature, magnitude and scheduling of maintenance programmes versus new investments. The information will be used to see how the increasing cost of operation in the equipment and maintenance department affect the EVA target of the company.

This project is very innovative in nature and was set up as multi-departmental project. By doing so, HMC can cultivate the expertise of a numerous individuals in the organization. Furthermore, making a prediction model for the future is more of an art form than science (Pidd, 1999). The interpretation of the findings is up to all the persons involved in this project. Figure (3) show an organizational chart of the persons involved in this project.

To simplify the total project it was divided in an economic part and a technical part. The economic state of the vessel can be defined as the difference between the income generating capacity of the vessel and the integral cost to maintain and operate the vessel. The cost data over a period will be analysed and forecasted in a model that states constant revenue to determine the cost efficiency of the vessel. The technical state of the vessel will be modelled where the results can be expressed in a time period where the vessel can not be operational and when the income generating capacity becomes zero.

The desired outcome of the whole project at HMC is to develop a tool that merge the economic state of the vessel with its technical state. In this whole project my thesis falls in the economic analysis and modelling of the R&M costs (OPEX and CAPEX). To estimate the future cost of maintenance, a LCC analysis will be performed and will be further developed to fit HMC needs regarding this project.

Figure 3: Project team organisation



Source: HMC internal data

3.2 Project Definition

To achieve the project at HMC a cost estimation of the repair and maintenance must be made. A LCC for these costs will give an outlook of the condition of the assets. This is the main reason for LCC estimation. For a successful implementation of the LCC estimation the expectations must be defined and understood in the company. The main expectation is that LCC views all the costs booked according to accounting protocol at HMC, in other words it is a picture of how the cost moves per year. Furthermore, the forecast of the historical LCC trends must be well understood. In this project historical data are used to make predictions for the future. This model gives a glimpse in the future, and other information such as technical state of the vessel must be used during decision making at HMC. In the early stage of the project it is not completely or fully understood, and this must be taken in consideration during data and knowledge collection.

In order to achieve the desired outcome for the current project, this must be divided into manageable components. This was done at HMC to facilitate the planning, to have a good scheduling, to control the data available and to improve on the technical content. The division of this project can be seen in figure (4).

Chapter 4 Life Cycle Engineering and its Components

4.1 Life Cycle Engineering

The engineering of technology systems is a complex undertaking that has many factors dictating its success. To realize a project the following steps are taken: The client wants a specific technology to achieve a desired outcome, the engineers design the best possible technology to achieve this outcome, and the economists determine the total cost of having this technology made. For the client the cost of production, maintenance, and operations will determine if this technology is feasible. Life Cycle Engineering can help determine the relationship between the building cost and maintenance cost by identifying the life expectancy of this technology.

4.2 Life Cycle Model

Identifying the life expectancy for a technology system is not an easy task. A complex technology system has many elements that determine its life expectancy such as materials used, construction, correct design for its environment, and operations regularity. In order to have a high level of reliability for the stipulated life cycle of the technology, a model is designed using specific parameters and within a specific framework. The framework and parameters to be applied to the model will be based on a sound theory.

A life cycle economic model is the visualization of the data collected at Heerema Marine Contractors (HMC). The desired result for this model is the understanding of how the cost of maintenance, repairs, and operations affect the overall performance of the company.

4.3 Life Cycle Engineering of Ships

In the technology system model a ship is as complex as they can get. A ship is a collection of engineering systems clustered together. For some ships the level of complexity is even higher, these ships are constructed to carry out a specific task; for instance, a pipe laying vessel, crane ship, and/or a heavy lift ship, with their names stating their function. Heerema Marine Contractors have three very specialized vessels. The name of these vessels defines their functions; Semi-Submersible Crane Vessels. For a company such as Heerema the cost efficiency of maintenance and replacements are important when viewed against the EVA target of the vessel.

The life of a ship can be established by the following; the functional life, the physical life, the technological life, the economic and social life of the vessel. The functional life is the period that the vessel is expected to continue working; in this case, this can almost be omitted because the vessel will not lose its functions for years to come. Its physical life is the important part here, because it is the technical state of the vessel, which will predict its life expectancy. Its technological life can be shortened if new technology is invented that will make the SSCV’s obsolete. In the case of these vessels, it does not look like a new type of ship will put them out of date. The economic life of the vessel is the period in which it becomes too expensive to operate and other cheaper solutions are available. Here the LCC will shed light on the final model at HMC. Finally, the vessel's social life is basically when the society does not deem it necessary to have these types of vessels anymore. The only way that this will determine the end life of the vessel is when oil or gas becomes socially and/or morally wrong to use.

Life cycle engineering can determine when the cost of repairing and extending the physical life of a ship is higher than the cost of acquiring a new ship; therefore, determining the total cost efficiency for the company. The best practice would be to adapt or improve the models used by other technology producing industries to fit the needs of the marine industry. The LCE assessment was made by the equipment management department and the vessel managers. It consists of a visual assessment in percentage of the state of the vessel. The initial stand point is the new state of the vessel at a hundred percent. Then the model shifts percentage wise all the way to zero indicating the end of the life time of the vessel. From the input of the equipment managers and onboard engineers a table of the technical state was made. The table consists of the call centers used by the cost controllers at HMC and is also used during the economic analysis. Furthermore, four categories of the technical state were defined. These are, excellent 100% to 80%, acceptable 80% to 60%, not-acceptable 60% to 40% and reject-able less than 40%. A color was given to each category in order to highlight the trouble areas of the ship. In figure (2) the outcome of this analysis for the vessel Hermod can be seen. This analysis was made for all the three vessels and it shows the areas that need immediate improvement.

A part of the life cycle engineering has to do with the life cycle costing of the ship during its operating life time. However, the actual costs are difficult to calculate for a ship because the deterioration of a ship depends on several parameters that cannot be accurately predicted. For example, the waters in which the ship operates greatly influence the costs involved in ship maintenance and repairs, that is, heavy waves cause more sagging and hogging than other conditions. Overall, the quality of the workmanship during construction of the vessel is of great importance to the life expectancy of the ship. These parameters are too difficult to predict accurately during an LCC analysis and further qualitative research would be needed to fit the model. However, by combining the analysis with the LCC, HMC will have a better tool to base their future investment decisions. The specific areas that need investments can be compared with the cost trends of the vessel over a specific period. In figure (4) the areas that need more improvements for the vessel Hermod can be seen, these are the engine room and the power generation. The complete technical state matrix of this vessel can be viewed in appendix 2.

Figure 4: Technical state vessel engine room and power generation Hermod

E - Engine Rooms	Safety	Availability	Workability	Reliability	Average %
Fuel System	65	70	70	70	68.75
Lub Oil System	80	80	80	80	80
Seawater System	70	80	75	70	73.75
Fresh Water System	80	80	80	80	80
Compressed Air System	70	90	90	90	85
Bilge System	70	75	60	70	68.75
Sanitary System	70	60	40	50	55
Steam Systen	30	30	30	30	30
~~HVAC System~~					0
Steering Gear	60	60	40	50	52.5
Provisions Cooling/ Freezing Syst.	70	80	80	80	77.5
Sewage System	60	60	60	60	60
Starting Air System	70	90	80	70	77.5
Control & Monitoring Sytems	60	60	60	60	60
					66.82692308

J - Power Generation / Distribution	Safety	Availability	Workability	Reliability	Average %
Main Diesel Engines	40	70	60	20	47.5
Main Generators	40	70	60	40	52.5
Main / Aux Distribution Board	40	70	60	50	55
Transformers	40	60	60	40	50
Cabling	40	40	40	40	40
Emergency Power System	60	60	60	70	62.5
UPS	70	70	70	70	70
Alarm System	70	70	60	70	67.5
					55.625

Source: HMC internal model

4.4 Life Cycle Costing

Life cycle engineering, as previously stated, considers the life expectancy of every component that goes into the making of a specific technology, for example a plane or a ship. It takes into account how the components deteriorate during their life time, and assessments can be made to predict maintenance or replacement of different components. However, all these activities during the active life of the technology cost money. Life cycle costing identifies all the cash flow throughout ownership, operation, maintenance, and disposal of the equipment. For HMC this cash flow are important to determine the economic profitability of their specialized ships over the rest of the equipment life span. HMC has a specific EVA (Economic Value Added) target that it wants to achieve. If the earning capabilities of its assets cannot achieve the targeted EVA, they will need to consider the disposal of these assets.

Life cycle costing can ideally be applied to capital intensive industries such as the marine offshore industry, which requires investment decisions in advanced. Furthermore, it can determine the sensitive areas that need more investments. Here is where life cycle costing and life cycle engineering intertwine. Life cycle engineering determines the sensitive areas that are more prone to wear and tear, and life cycle costing determines the effect of these in economic terms. Besides maintenance costs the life cycle costing takes into account the total operations costs. From this life cycle costing the economic state of the vessels can be found. In order to get a positive EVA the economic state of the vessel must be related to the market forecast.

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4.5 Quality through LCC

HMC's vision for the future is ***"by any measure to be and to be recognized as the best offshore construction contractor in the world".*** In order to be the best in any market sector, a company should provide good quality products and/or service for the right cost. Quality assessment varies from company to company and from industry to industry. A computer for instance will have a higher level of quality than a garden tool. The quality that HMC can offer is reliable equipment with a specific open window to accept any job.

Life cycle engineering can determine the size of the window in which a ship is available for work. The high availability is one component to achieve the status as the best offshore construction contractor in the world. Life cycle costing will indicate how much money is required to maintain this high level of availability during the life span of the equipment, in this case the SSCV (Semi-Submersible Crane Vessel). It is logical to think that as a ship goes through its maturity process it will deteriorate more and more. Because of this the cost to maintain the same level of reliability will increase over the years, lowering the ship's profitability.

Furthermore, LCC can manage the maintenance and repair spending, prioritizing areas that need improvement to maintain operations. This can help companies avoid over-spending on areas that already have a high quality and further improvement will not result in operational cost savings.

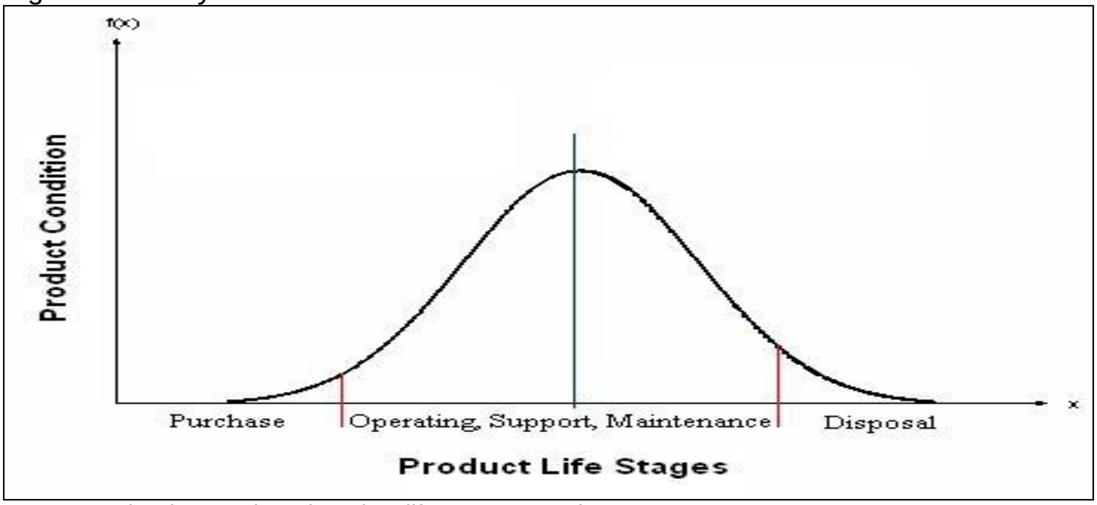
4.6 The Life Cycle Stages

Similar to human beings, a product has various stages in its lifetime; for instance, growth, maturity, and decline. A vessel goes through five main stages in its lifetime from the operator's perspective. The five stages according to Emblemsvag (2003) in its book Life Cycle Costing are identified as follow:

1. Purchase (or commission) of a ship
2. Operating of the ship
3. Support of the ship
4. Maintenance of the ship
5. Disposal of the ship

These life stages are also considered at HMC for the life cycle costing. Figure (5) shows a simple graph that depicts the life stages and life expectancy of a vessel. A vessel's life expectancy is a normal symmetrical distribution due to the nature of its life cycle. It is an interpretation of the life cycle expectancy theory. This theory suggests that the condition of a product inclines for the first part of its life until it reaches its peak condition, which is an indication of its mid life. Thereafter, the condition of the product declines until it reaches the disposal stage at which time the product is no longer functional. The decline stage of the product is considered as the deterioration phase. The life expectancy of the product can be extended by decreasing the rate of its deterioration.

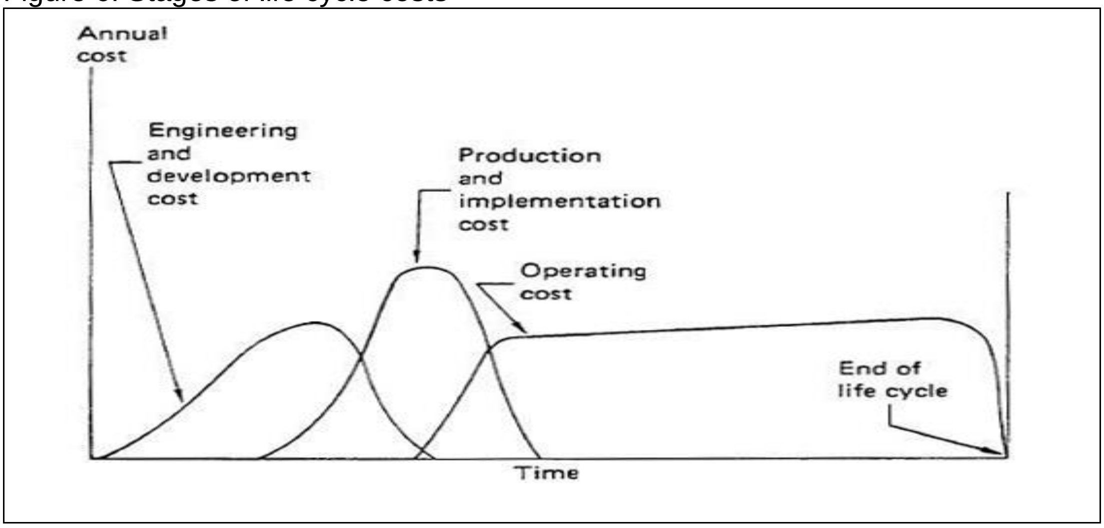
Figure 5: Life cycle distribution



Source: author impression of product life expectancy theory

Taking these stages into account, Woodward (1997) developed a model that illustrates the total life time of a product and the costs involved during each phase. Figure (6) shows Woodward's model (1997) which is based on the three major costs involved throughout a vessel's the lifetime.

Figure 6: Stages of life cycle costs



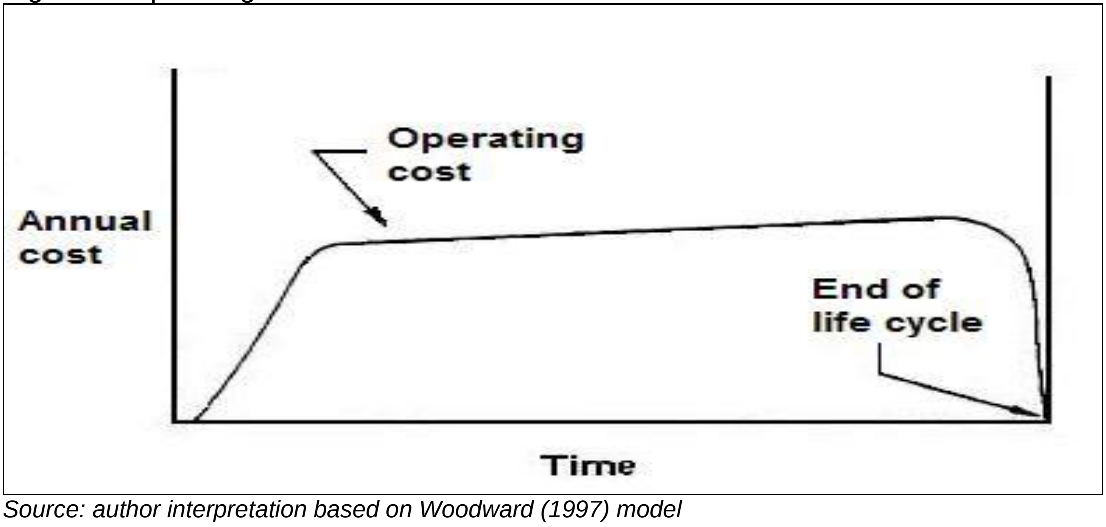
Source: Life Cycle Costing: D G Woodward

In the current research, the initial capital investment, the purchase of the ship and or the engineering and development costs, was not included for the assessment of the life cycle costs. The reason for not including the initial capital investment was mainly due to the fact that this data was not available. In addition, the initial investment was made more than three decades ago; therefore, one can assume that the initial investment has already been recouped by HMC. Furthermore, these costs were not considered important for this project because HMC is more concerned with the operating costs regarding the remaining life of the vessel, in other words where they are currently located on the life cycle curve. The production and implementation costs were also not included due to the unavailability of this data and due to the fact that the vessels are more than thirty years old.

A simpler model for the LCC has been developed, which is based on Woodward's (1997) model. This is illustrated in figure (7). The LCC analysis determines the cost of obtaining, maintaining and disposition of an engineering system for instance a vessel over its life time. HMC has already estimated the end of life cycle which will be incorporated in this model.

The operating LCC model can be divided in three sections; 1) the steep and rapid increase of costs because of construction (in this case the purchased cost for the vessel), 2) a constant increase in costs over time because of operation of the vessel, and 3) the rapid decrease in costs. The third section of the model does not indicate a rapid or instant deterioration of the vessel but reflects that no more capital is invested in the operation of the vessel till the end of its life cycle.

Figure 7: Operating LCC model



Source: author interpretation based on Woodward (1997) model

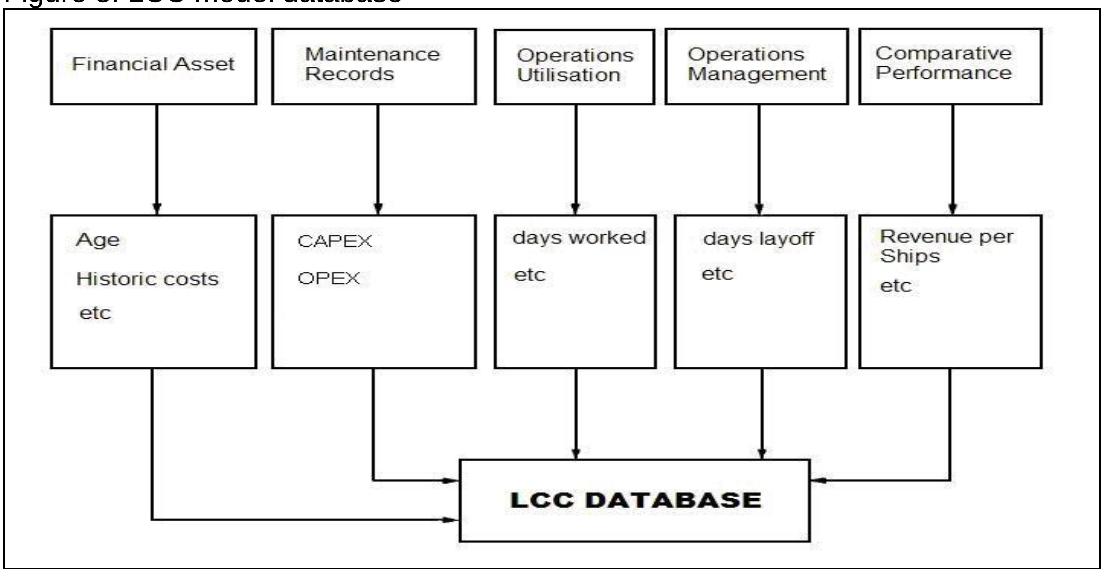
Finally, the disposal stage of the vessel was not used during analysis. This is to comply with HMC project description. At the moment HMC has not yet decided whether they want to continue investing in the vessel when they are close to reaching the end of their life cycle. The SSCV's owned by HMC are specialized ships that are very expensive to build. Their high price tag is due to the amount of labour that goes into these ships. According to Wijnolst and Wergeland (2009), 43% of the total cost of construction is regarded as labour costs for a very large crude carrier (VLCC). The rest of the costs are materials, equipments and components. Even though the SSCV is smaller than a VLCC it has a lot of surface due to its column-like legs, this will take a lot of steel material. Furthermore, a SSCV has many expensive components such as crane, thrusters, and numerous generators. Because of the high cost of building a vessel like this and the continuous changes in the offshore market one can not predict the exact life ending in the future of these vessels. For instance, if in seven years the market can generate high revenues but not enough for new construction, HMC can consider extending the operational life time of their vessel, such as the Hermod.

4.7 LCC Database

A life cycle data bank can keep track of all the costs during the life time of the vessel. A life cycle data bank will make it easier for a company to have a quick assessment on how their vessels are performing regarding the technical state. The data bank must get data inputs from the financial performance of the assets, maintenance records, operations utilization, operations management data, and comparative performance data. These major components will be added together to form a LCC data bank.

The main components are further divided into smaller components in order to separate all the data. However, by identifying all the costs that is needed for the LCC of the vessels in advance will make this easier to perform in the future. The LCC data bank theory was developed by D.G. Woodward in his 1997 paper and makes a good starting point for an HMC data base for its vessels' life cycles. In figure (8) a model of the data bank can be seen impending further implementation of HMC.

Figure 8: LCC model database



Source: Woodward 1997

This data base keeps all the input necessary for LCC together. By having this data base, the operator can see where the costs are allocated and by how much, making it easier for them to remember without relying on memory of what happened for instance five years ago with the vessel.

Chapter 5 Economic Analysis Cost Data

Before data is collected and analysed for the costs of maintaining these three vessels, the approached and methodology in which the data is to be collected and analysed must be determined. HMC has an enormous amount of data for the three vessels during a long period of time. Segregation of the data must be done in order not to get lost in data. The data collection was done following HMC accounting procedure and it is further explain in the chapter ship sub division

The data analysis was done by bringing the cost into graphical picture. From this graphical picture, common engineering knowledge was applied to high light area of the ships that are deteriorating. Increasing maintenance cost and peaks in the graph flagged areas that might suffer from wear and tear. After flagging these areas a qualitative research is done to further see what exactly is causing the rise in maintenance and replacement costs.

5.1 Ship Subdivision

A ship is a big and complex technology system, with many parts assembled together to form a unit. In order to distinguish all the parts that form a ship, the ship is divided by sections. The main subdivisions of a ship are, for instance, the hull, the engine room, the accommodation, main deck, loading gear, and navigational bridge. It is helpful to use subdivisions of the ship when doing maintenance and repairs. The engineers can focus on the area that needs to be repaired, and these areas can also be prioritised. Furthermore, some areas of the ship will require maintenance more frequently than others. For instance the hull has to be well maintain in order for the vessel to keep its seaworthiness a specially its certification from the classification society. Furthermore, equipments onboard that are regularly used will need to have its periodical maintenance, for instance the crane and engines.

Besides the frequency of the maintenance patterns, the different areas express the reliability of the ship. There are some areas of the ship that without proper maintenance or repair would jeopardize its integrity and can lead to declassification.
The three ships at HMC are categorized in twelve sections, in order to better manage the maintenance and repair costs. These categories are stated as follows:

- A Accommodation
- B Anchor & Mooring Systems
- C Ballast System
- D Cranes
- E Engine Room
- F Hull & Vessel Construction
- G J-Lay / MLD / A&R / PEL
- H Navigation & Communication
- J Power Generation & Distribution
- K Propulsion & DP Systems
- L Safety Equipment
- M Non-Floating Equipment

The life-cycle costing can be determined from all these categories. However, the main reason for this project at HMC is to determine the profit generating capacity of the ships in a future time. For this project the areas of the ship that will hinder the navigation and operation of it will be considered and taken into account during the LCC. The criteria used to select the subdivision for the LCC is very simple. The part of the ship that, when broken, hinders the navigation and/or operation of the vessel. The following subdivisions were selected:

- A Accommodation
- D Cranes
- E Engine Room
- F Hull & Vessel Construction
- G J-Lay
- J Power Generation & Distribution
- K Propulsion & DP Systems
- L Safety Equipment
- M Non-Floating Equipment

These categories will be used for the three ships with the exception of category G (J-lay) that is only available on the Balder. The next step after identifying these sections is to make a historical cost analysis and to recognize the areas with higher costs and the origins of these costs. In this thesis the cost relationship of each area to one another will not be analyzed mainly because the result will not show where the available budget will go. The intension of the cost analysis is to see individually how the cost of maintenance and repair rises over a specific period of time. Furthermore, with this analysis the cost drivers can be obtained and these will be used during the cost modelling as variables.

5.2 Cost Drivers

As mentioned before the selected sections of the ship were taken into account when the data analysis was performed. The data used for the three SSCV's were the R&M costs (OPEX) and the replacement investments (CAPEX) from 1999 to 2008. For both these costs data an analysis was performed. The R&M costs were kept separately because it is a better indicator of how the costs act on the ship with the years.

The intention of analyzing the R&M costs is to determine the expenditure stand of the ship which can be interpreted as the technical stand of the ship. The more expenditure it takes in R&M for a certain area of the ship will show the areas that are deteriorating with time. During this cost analysis the technical stand will be evaluated by another HMC department and will be compared to each other to see if the fluctuations of the R&M cost coincided with the current technical situation of the ship.

Besides the R&M cost the replacement investments will be analyze. With this analysis the areas that need frequently renewing can be pin pointed. These CAPEX investments will further identify which section of the ship are the drivers of the total cost of operating a ship on the technical level. After separating and study the R&M cost and replacement investments of the above mentioned ship section, these two are combined to finally establish which cost are the cost drivers that would be set as variables for the determined cost model.

5.2.1 Cost Drivers Hermod

The top R&M cost drivers for this ship are put in order of their impact here:

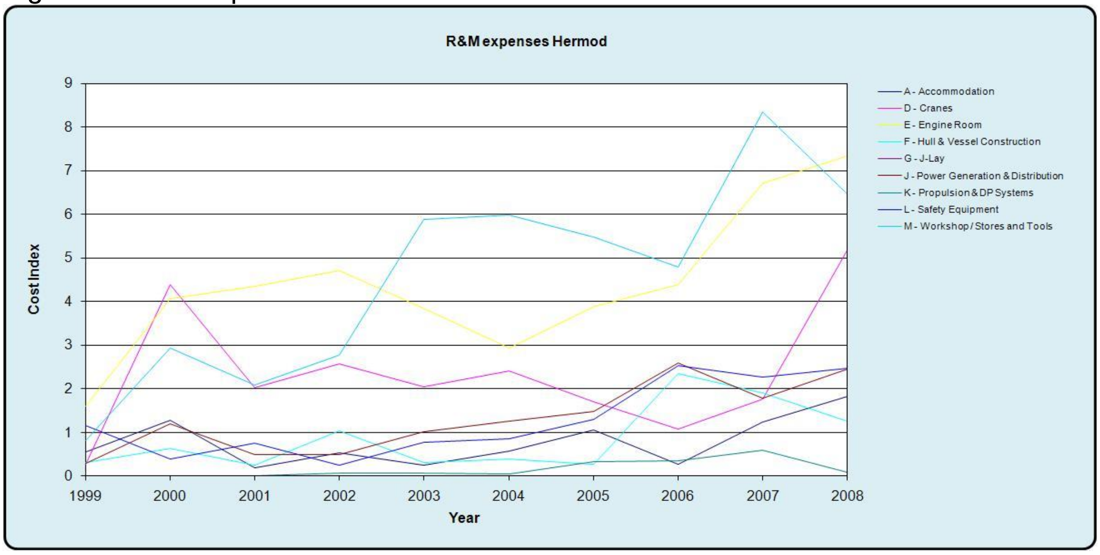
1. Engine room
2. Cranes
3. Hull & Vessel construction
4. Power generation
5. Non-Floating equipment

Even though in the analysis the non floating equipment has a higher R&M cost than cranes, hull & vessel construction and engine room its impact is not very decisive to the state of the ship. Furthermore, there is a strong correlation between the amount of days work and the cost of the non floating equipments. This can be considered as very proper because the more days the ship work, the more materials it will need to keep working.

The engine room on the other hand does not show this correlation, and gives the impression that the cost to maintain the engine room in good state will keep increasing. The hull of the vessel, cranes and the power generation costs of maintenance are also on the rise. Their path of growth suggests that these areas experience deterioration and more maintenance is needed to maintain them in working condition. The hull which is an integral part of the vessel due to strict regulations by classified societies such as Lloyds' register can be considered as a major cost driver for this vessel. If the hull is not maintained properly the sailing permits for the ship can be revoked and the amount of working days will decrease, resulting in decrease in revenue due to opportunity lost. Each minute out of service is therefore going to result inconsiderable financial loss to the system user (Asiedu & Gu, 1998).

These five sections of the ship are the main cost drivers for the ship Hermod. The other costs are very linear and don't suggest a negativity on the earning capacity of the ship. These cost drivers are the main target during the modeling however the total cost of the R&M should not be neglected. In figure (10) the graphical analysis of the R&M expenses can be seen. This graph was made with a cost index in order to study the actual growth per year.

Figure 9: R&M expenses Hermod



Source: HMC internal data's

5.2.2 Cost Drivers Balder

The top R&M cost drivers for this ship are put in order of their impact here:

1. Engine room
2. Cranes
3. J-Lay
4. Power generation
5. Non-Floating equipment

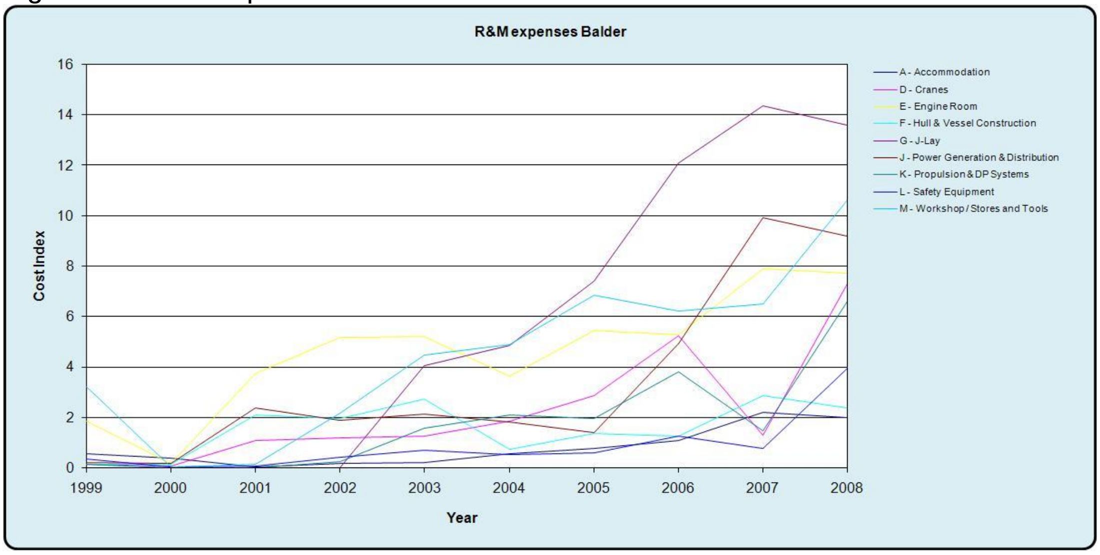
Just as the Hermod the non floating equipments cost are high but do not give a negative impact on the state of the ship. Furthermore, here the high cost of these can be explained by the amount of day per year that the ship works.
The state of this vessel qua cost areas are very similar to its sister ship the Hermod, the main differences are that this ship has equipments for pipe laying and that the hull doesn't required many random maintenance.

The J-lay is a leading cost driver since the past three years. This is due to the conversion that happened only a few years ago. The R&M cost are high because of this new technology that requires continuous maintenance to keep it operational. The historical data suggest that these costs will continue growing due to the high usage of this equipment.

In this ship the engine room, the cranes and the power generation are other cost drivers which all are showing growth over the years. From these three cost areas the engine room shows more deterioration due to the high R&M cost per year. The crane costs are increasing but are not really showing the deterioration of this equipment, this trend could be later explained with the capital expenditures for the ship sections.

These main cost drivers will further be analysed and will be determined in the LCC model. The other cost areas will still be used in the total cost analysis. By keeping the cost drivers at the beginning of the LCC we can see which area of the ship will need urgent capital injections now and in the future. In figure (10) the graphical analysis of the R&M expenses can be seen.

Figure 10: R&M expenses Balder



Source: HMC internal data's

5.2.3 Cost Drivers Thialf

The top R&M cost drivers for this ship are put in order of their impact here:

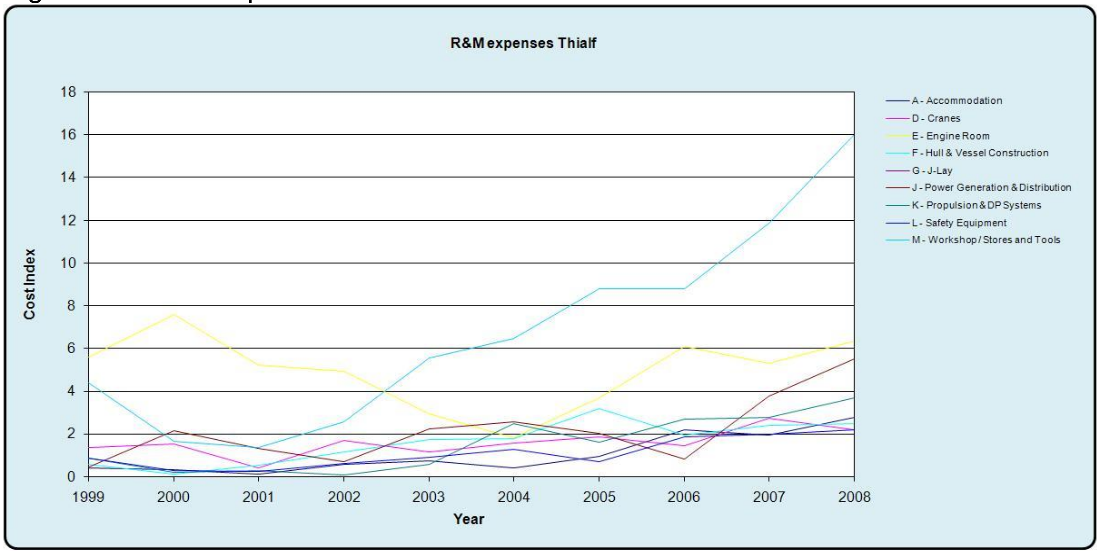
1. Hull & Vessel construction
2. Power generation
3. Non-Floating equipment

Again the R&M cost for non floating equipment is higher than all the other cost, but doesn't relate to the technical state of the vessel. Furthermore, also for this ship there is a strong correlation between the total days work in a year and the cost. However it is still a main cost drivers and its effect on the total cost to operate a ship cannot be denied.

Another main cost driver here is the engine room. This cost has been high over the past years, with a dip in cost in 2004. This dip can be explained through qualitative research. However, the R&M cost for the engine room are the second highest operation cost for the Thialf, suggesting deterioration in this area of the ship. Besides the engine room the power generation R&M cost has also been increasing over the years. So far it is not a driver of high cost, but historical data suggest that it will in the future. A better perspective of the increase in costs over the years can be seen in figure (11).

The hull of the Thialf is also deteriorating due to the steadily increasing cost to maintain it. Further, research in the technical state and capital investment will determine the true deteriorating state of the hull. All these cost drivers for the Thialf are to be analyzed with LCC to see how these cost acts on the earning capability of this ship.

Figure 11: R&M expenses Thialf



Source: HMC internal data's

5.3 Analysis Replacement Investments

The data used for the three SSCV's were the R&M costs (OPEX) and the replacement investments (CAPEX) from 1999 to 2008. For both these costs data an analysis was performed. After analyzing the R&M costs (OPEX) separately the replacement investments (CAPEX) was analyzed using an identical procedure. During the analysis the depreciation of the replacement investment was not used. By keeping the replacement investment as cash injections in the maintenance cost a graph can be made and this can later be qualitative be checked with the technical state of the ship. The replacement investment cost can indicated which areas of the ship are deteriorating and needs heavy investment to bring to an operational state. The visualization of this project shows the peaks in investments. These peaks can indicate that a breakdown has occurred and investment was needed or large maintenance project was planned and it shows as a high peak in the graph. In both scenarios the state of the vessel regarding the area of the ship researched can be brought into focus through LCC.

After analyzing the CAPEX for the replacement investments for the three ships, this will be depreciated according to the HMC accounting procedure. The depreciation table will give a better indication on the total cost for operating a ship and will further used during the revenue model. Furthermore, the depreciation table of the capital investments per ship will give a good indication on the growth factor of the total costs per year.

5.3.1 Analysis Replacement Investments Hermod

From the replacement investment analysis the main cost drivers were obtained for the Hermod. The main cost drivers for this ship are the cranes and the hull & vessel construction. These cost drivers have been increasing rapidly over the last few years. The steady increase in the cost regarding the hull & vessel construction indicates that the hull is deteriorating. Since 2002 the investments in the hull has increase steadily and has quadrupled over the last six years. In this study, this cost driver was isolated and was researched in depth during the LCE of the Hermod. The graph in figure (12) shows the time period of high investments in a specific part of the ship.

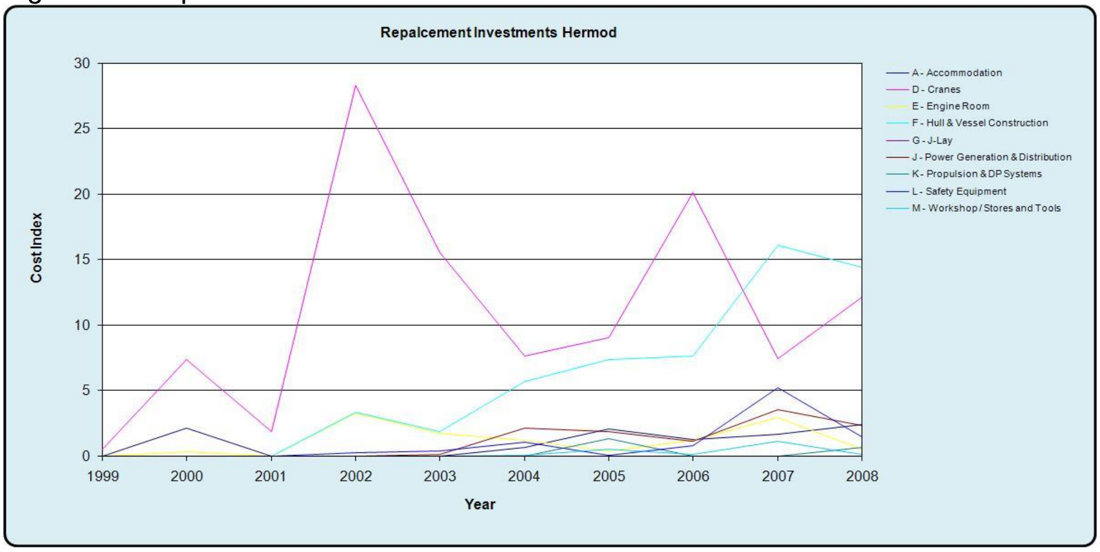
According to the manager in charged of foreseeing the R&M cost for the Hermod this cost analysis is very closed to the truth. The hull has been deteriorating and new coating to protect this was needed and this coating is very capital intensive. One must imagine coating a ship like the Hermod which has an enormous surface. Furthermore, the coating of inner tanks is time consuming pushing the expenses even more.

The cranes on the Hermod also push the total maintenance cost of this ship up. The investment to update the cranes uses the majority of the maintenance budget at HMC. The peaks in the analysis indicate major upgrade and or overhaul. After improving the cranes with major upgrade capital investment, the R&M expenses gets lower. From the data analysis we can see that two peaks have occurred in the last ten years. One of the peaks (in 2006, see figure 12) is mainly due to investments in buying a new crane for the ship, this investment can be booked as initial capital, because of this we can take this peak out during forecasting. The other peak in 2002 was a major overhaul of the main hoist crane control. This part of the crane is essential to have a efficient working crane without breakdown. The main hoist control is the electrical system that controls the crane; if this deteriorated the crane will not work. The peak generated by this investment will not repeat it self for at least ten years.

From a cost analysis stand point these two peaks suggest that they will repeat them self in the future. For a better forecast of the whole engineering system the technical analysis must coincide with the LCC. Further LCE will achieve the desired outcome, which is to find out when is the ship no longer able to generate a high EVA target without overspending on new or overhauled cranes. In simpler terms HMC doesn't want a deteriorating ship that has to much cost to maintain with a brand new crane on top of it. An LCE analysis will avoid this sporadic investment.

Moreover, there are major repairs for the Hermod on schedule to be performed in the period of June 2010 en June 2011. This major repair means that the ship would have to be docked at a shipyard and would be out of service for a specific period. The income of this vessel will drop significantly if this action is performed to long. Furthermore, new peaks will be seen in the replacement investments analysis. According to EM planners at HMC the main cost drivers of total EM cost found from historical data will take most of the budget during the docking period. In the forecast this must be updated to get a better few after 2011, before this year the cost projection forecast can give a general idea how much they would need to invest.

Figure 12: Replacement investments Hermod



Source: HMC internal data's

5.3.2 Analysis Replacement Investments Balder

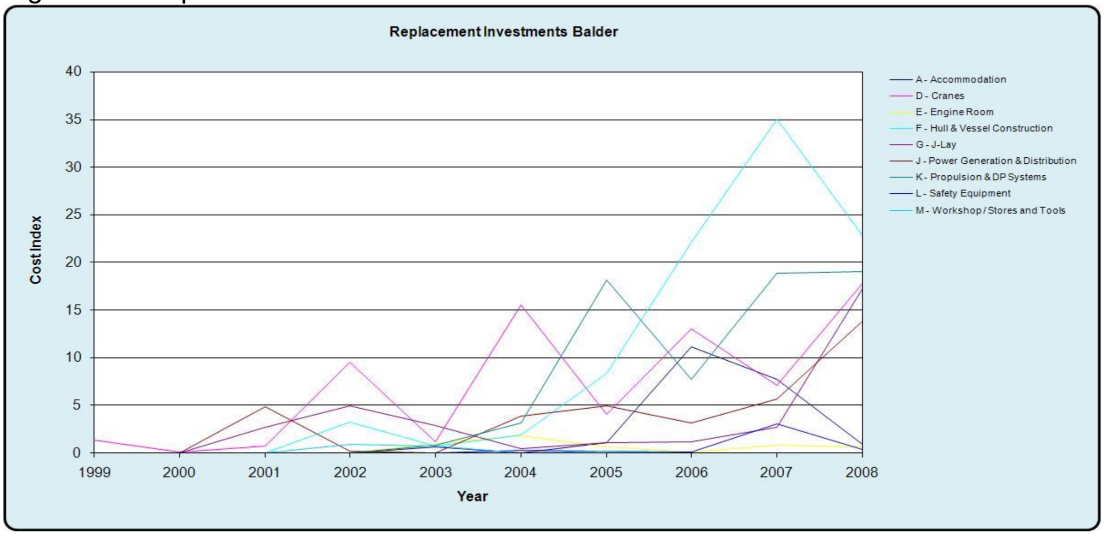
During analysis of the historical repair and maintenance cost data for Balder the cost drivers were identified as the hull, crane and propulsion & DP system. However, heavy capital investment was made during the period analyzed to convert this ship into a Deepwater Construction Vessel (DCV) capable of lay pipelines and flow lines on the bottom of the ocean. Because of this conversion the J-lay system became another cost driver on this ship. The capital invested in the conversion of this vessel will be regarded as acquisition cost, in other words the initial cost of capital, just as buying a new ship. Cost associated with the conversion should not be taken into account during forecasting because the conversion to DCV will only happen once.

From the analysis we can see that the crane had major cash injection every two years since 2002. The replacement investment data suggest that the cranes on the Balder are experiencing wear and tear. This wear and tear is also suggested by the operational cost of the cranes. This cost driver is important during the technical analysis to further determine the life span of the cranes. LCC helps engineers to see how the costs increase during time and can pinpoint areas that need to be investigated further, for instance a technical analysis of the crane. This assumption can be seen in figure (13), where the CAPEX data is graph without depreciating the investments.

The hull & vessel construction costs are another cost driver on the Balder. High capital investments were made over the years to keep the hull in working condition and on classification standards. Furthermore, during the conversion of the vessel in to a DCV investments were made in the propulsion and DP system. This has made these cost another cost driver. Just as by the Hermod, coating of the vessel increases the R&M cost for the hull. Extra coating and maintenance of the hull and deck is programmed to take place in the future, and the cost forecast can give an impression of the total expenses needed during that particular time.

The Balder’s propulsion system capital expenses has also gone up since 2003 this is also related to the DCV conversion. However because the propulsion and DP system is used heavily during operation the wear and tear will lead to extra maintenance. The R&M cost analysis also suggest that. Future maintenance cost budget for this segment of the ship can be determined by interpreting the forecast together with the technical analysis and common engineering knowledge of the ship and its component.

Figure 13: Replacement investments Balder



Source: HMC internal data’s

5.3.3 Analysis Replacement Investments Thialf

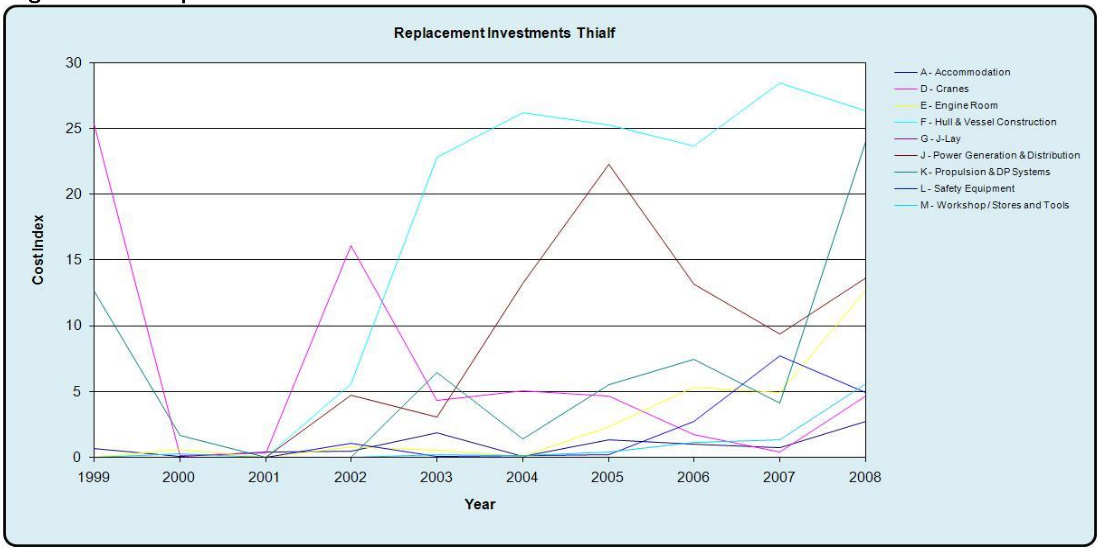
By purely analysing the replacement investments of the Thialf over the years without depreciating the capital investments the areas of the ship that more cash injection has been needed can be identified. Here the hull, the power generation, the propulsion and DP system are the major cost drivers. From these cost drivers the hull has been the major cash guzzler, suggesting major wear and tear of the hull. Taking into consideration that classification societies have high standard for hull condition, the high investments cost in these area points to deterioration. After the cost analysis a qualitative research was done to obtain more information about the state of the hull, and why the costs to maintain it are running so high.

From this research the cost analysis of this ship becomes comprehensible. Since 2002 there was a comprehensible coating program being perform on the hull and inner tanks of the Thialf. This coating project is expensed due to the size of the ship, and complexity of tanks coating. The program is meant to lower R&M costs in the future and this can be seen in the R&M cost analysis. The high capital investments in the coating are reducing the amount of regular maintenance that is needed, and sub sequential this lowers the daily maintenance costs. After the coating program is finish the EM department at HMC aspects that the cost for maintaining the hull will go down. This must be kept in mind to update the LCC and the revenue model. Here the technical state analysis being simultaneous done at HMC will give a better forecasting tool.

Another cost driver on this ship is the power generation and the propulsion & DP system. Both of these areas had high capital investments. The cost analysis for these two areas doesn't explain its technical state. Further technical analysis will shed light on these cost, however these cost drive do suggest that these cost will continue in the future.

The peculiar finding in the data analysis is the investments in the cranes on this vessel. In 2002 there was a high investment in the cranes, and since than the capital investments was limited to a much lower amount. This suggests two things, first of all, that the investment in 2002 has improved the technical state of the cranes and this has lowered the operational and future investments in this area. Secondly that new capital injection is needed and it's being delayed due to other factors. Further technical investigation is needed to find the through state of the cranes. However the cost data analysis does pin point this area of further investigation and during LCC this also have to be taken into account. A qualitative research for the cranes was made based on the findings. From this research the state of the cranes was found to be deteriorating and major investments are needed in the coming years but were delayed. This cannot be seen in the LCC just by analysing the data. The replacement investments for the Thialf cranes will increase in the future and updating the cost analysis and LCC will give a better forecast as the end life time of the vessel approaches. In figure (14) the analysis is graph to show the cost trend between 1999 and 2008.

Figure 14: Replacement investments Thialf



Source: HMC internal data's

5.4 LCC Analysis Pitfalls

During the LCC analysis the common errors associated with it should be avoided. It was very hard to keep tracks of all the pitfalls that one needs to consider, however this approach was necessary. According to the cost estimating guide made by the U.S. department of energy the common errors associated with LCC are:

- omission of data,
- lack of a systematic structure or analysis,
- misinterpretation of data,
- wrong or misused estimating techniques,
- a concentration of wrong or insignificant facts,
- failure to assess uncertainty,
- failure to check work,
- estimating the wrong items, and
- using incorrect or inconsistent escalation data

For instance, during the forecast stage and modelling the data from 1999 till 2002 was not included because of inconsistency. This makes the model more reliable. During data collection, misinterpretation of data made the process very slow, because the data collected had to be explained by the different departments at HMC. The cost data also contained insignificant facts that needed to be removed, for instance cost booked for purchase of materials to build a yard on shore to support these vessels. This information has nothing to do with the life time of the vessel and should not be included in the LCC.

Moreover, the data collected contained a lot of items, and the items that do not reflect the life time of the vessel had to be taken out. An Item such as a new crawler crane for the vessel can easily be taken off the ship, as it will only increase the LCC and will not reflect the true cost of maintaining a sailable ship. Avoiding these errors was important to have a very reliable analysis. However, there can always be common errors in the analysis. These should not be taken lightly, and double checking the work can only increase the reliability of the model.

Chapter 6 Life Cycle Costing Model

An economical model is a simplified representation of an economical phenomenon expressed often mathematically. These models can be used to predict and/or to explain economic theories that are difficult to comprehend only with words. The LCC model will make a graphical representation of all the costs associated with the maintenance and repairs of the vessel during its life time.

There are two general categories of models, one that is pure or abstract and the one that is applied. For the life cycle costing at HMC the applied model will be followed. *Applied models* are explicit, simplified representations of more general theories and are designed to apply to specific real-world problems or situations. (Boland, 2000) This description is important during modeling because it will determine how the model will work. HMC wants a model that they can use for the prediction of the total cost of operating their SSCVs, and to compare this to their profit target.

6.1 Model Formulation

As previously stated the model must be kept simple. By doing so, the model output will be more reliable, easier to understand and to use during decision making. Starting with a simple model and later adding to it as it progresses will minimize mistakes that can originate with complex models.

Furthermore, the modeling wheel will not be reinvented but will be adapted from established models and methodology. Using an existing model theory as a guide for the LCC model at HMC will make it reliable. The resulting model can be better tested due to this fact. The model building will follow the following main steps: 1) A written statement of the objective function or problem is to be made, 2) the decision variables are to be established and 3) the constraints stated.

6.2 The Written Statement of the Object Function

HMC has three SSCVs that have an assumed lifespan of seven, twelve, and twenty-two years. Before the SSCVs reach their life-end expectancy, investment decisions must be made. Either to start developing plans for a new ship, continue extending the life time of the vessels or to abandon this business. The model will determine the following:

- Three ships Hermod, Balder, and Thialf, with an assumed end of life 2016, 2021, 2031 respectively
- Maintenance cost will automatically increase the older the ship gets
- Operational cost will increase for an older ship (technical state of the vessel)
- Old ship will have more break downs, and this will result in opportunities lost to work, which translates directly to loss of profit.
- Level of EVA target is not easy to achieve with an older vessel, in other words the vessel is losing its earning capacity.
- The method use should be according to the equipment management accounting system.
- Economic state of the vessel must be established by the following.

- Repair and maintenance costs (OPEX)
- Replacement investments costs (CAPEX)
- Life extension projects costs (CAPEX)

- Value of money over time must be consider to predict the future costs

6.3 The Decision Variables

There are many costs that go in operating a ship, from the initial cost of investment for a new ship to the maintenance costs and manning hours. According to the marine engineering economics and cost analysis, to measure the desirability of one alternative relative to the others available, it is necessary to select a meaningful measure-of-merit, which must incorporate and sum all of the independent economic variables during the life if the ship. (Hunt & Butman, 1995) It is important during this stage of analysis to consider all the variables surrounding the ship, for instance initial cost of capital, operating cost that includes maintenance and replacement costs, revenues and also the possible recycling value. The total cost surrounding the crane ships operation at HMC will be consider. To successful determine the variables surrounding this sector the historical data were researched. The cost model will use data that specified the R&M costs (OPEX), replacement investments (CAPEX), and life extension projects costs (CAPEX).

Furthermore, the costs would be split into the various ship sections and it's further elaborated on in chapter 5. The costs categorize per ship section is to determine the sections of the ship that are the cost drivers to operate the SSCV. The main cost drivers would be established as the main variables to be modeled. To keep the model simple cost that are not increasing over the years are not considered.

Data was collected between the period of 1999 and 2008 and afterwards was analyzed. From the analysis the following cost drivers for the ship was determined.
Compared to other decision model in the marine sector this model would have a main difference. There are a lot of container ships for instance in the world, and these can easily be compared to one another. However, there are only seven SSCV in the world, it would be hard to compare the model to other SSCV, however a better solution would be to compared it to a model composition of other ships and marine structures.

6.4 The Constraints

The model is the visualization of the object function. The object function in this research as previously stated is the economic viability of the ship in a future point in time. For the solution to be logical the model should work between a set of constraints or degree of freedom. The degree of freedom can be a restriction on materials available that can be used in producing a ship, the environment in which it operates, the economical situation, political restriction and or the ship itself. In this research the easier constrains to be defined are the business rules of HMC. The first constrain that exist from the HMC business rule is that the ship operation cannot exceed 332 days. At the current moment HMC conserve 9% of the total year for maintenance, this means that 332 days per year the ship is available to provide its service. The constraint takes this business rule into affect. Also the ships should not exceed its available working days because of the negativity surrounding the lack of maintenance. Another constrain for this model is the technical state of the vessels. The technical state is important to establish the relationship between this and the cost of the maintenance and replacements.

6.5 Cost Model Selection

After verbally stated the object function a model must be selected to perform the cost estimation. According to the NASA handbook for cost estimation and modelling one or a combination of these methodology can be used (CEH, 2008).

Methodology 1:	Parametric

Methodology 2:	Analogy

Methodology 3:	Engineering Build Up

A parametric methodology uses historical data and mathematical expression. Furthermore, during this method the depended, independent and cost drivers' variables will be selected and can be analysis using regression analysis.

The analogy methodology is a comparison analysis. This method use a system or clusters of system to estimate the cost. The findings can later be extrapolated to fit the system being analyzed. The engineering build up method on the other hand can also be called a “bottom-up” method (CEH, 2008). This means that the lowest detail of the engineering will be analyzed from material and labor cost to define the total cost of the system. In the later stages these can be used to estimate how much labor and material is needed for maintenance and repair during the whole life cycle.

The LCC in this research covers only operational costs and will later be used in a more comprehensive model at HMC that also covers the technical state of the vessel being analyzed. Because of this a simple model is needed to estimate the LCC and a parametric approach will best suit this situation. Historical data is available at HMC make this methodology easier to perform than the other two methods. Furthermore, only a few pieces of data are known, which are R&M costs, year and days worked.

6.6 Parametric Methodology

This approached is based on historical data, and because of the data available this method would be the easiest to implement. Furthermore, the mathematical expressions obtained through regression analysis are easy to find because of software capabilities such as MS Excel. The regression analysis will expressed a line $Y = a + bx$ of the historical data. This line is a relationship between two parameters, such as time and cost. By obtaining a regression line it's easy to predict the cost of maintenance on a specific time in the future. This can be trustily taken into consideration by the implicit assumption of parametric cost estimating that the same forces that affected cost in the past will affect cost in the future (CEH, 2008).

After obtaining this regression line the value of money and depreciation of the cost will be added to find a more natural relationship such as Y = a x ^ b. This will be done by the finance department. However the regression line will give engineers in the equipment department a better tool to see the relationship between R&M expenses and profits.

Moreover, this methodology gives the estimator to be flexible in creating its own estimating relationship. In this freedom problems can be encounter in this method of LCC. The problem with the parametric methodology is that the estimator must make it clear how the parameters relationship works, which data was used and how was it constructed. If valuable information is missed the model would not be of good used for future estimation when done by another estimator. The conclusions and findings of this LCC can also be vague if not enough information about the whole procedure is properly documented. Furthermore, the dependent variable must be point out consequentially the independent variable will be defined. In this case the cost will always be a dependent variable and the cost drivers will influence the cost, these can be labeled as independent variables. The cost drivers are important because they show the relationship with cost during time and how they are affected. For instance, the cranes are cost drivers of total cost for most of the SSCV's, and the high rate of usage is the cost drivers behind the cost of maintenance of this piece of equipment. By indentifying these variables during the estimation more information will be available for future investment decisions, such as upgrading of cranes or better maintenance programs.

After using parametric methodology to find the relationship between the cost and the age of the vessel, the equation can be used in conjunction with earlier LCC models to forecast the future costs. To produce the LCC model earlier models such as Remer (1977) and Dhillon (1989) will be used and further elaborate on. To calculate the LCC, the cost of operation during a specific time period must be summed and added to the initial cost of capital and can be obtain by the following formula (Remer, 1977):

$$LCC = P + \sum_{i=1}^{n} U_j \quad (1)$$

Where ***P*** is the initial capital of investment, ***U*** is the operational cost and ***n*** the life of the system. To elaborate a more appropriate model to the needs of HMC the initial cost of capital will not be included. This due to the desired of the company to isolate the operational cost and later used a pure cost forecast in their own revenue model. Furthermore, not much cost data is available from the delivery date of the ship in 1978 up to 1999. By eliminating the initial cost of capital the formula becomes simply:

$$LCC = \sum_{i=1}^{n} U_j \quad (2)$$

The operational cost ***U*** consists in this research of repair and maintenance cost of the ships denoted in operational expenses (OPEX) and replacements investment cost of the ship denoted as capital expenses (CAPEX). The CAPEX must be collected and then depreciated over the specific time in order to find the true operation cost of the ship regarding maintenance and repairs. With the data collected the formula can be used with help of computer software's such as excel® to calculated the LCC. The outcome of the LCC can then be used in the modeling forecast of the future value of operating these ships.

A major disadvantage that LCC can have is that the model describing operating costs over a life time period uses available data bases, and these can be inadequate (Remer, 1977). The LCC analysis at HMC did encounter these problems due to change in book keeping over the years. A backlog of all cost had to be done to make all data uniformly to the current book keeping status. Operating costs often increase or decrease in a uniform manner with time (William, Elin & Patrick, 2009). Taking this trend into consideration the cost analysis can easily be performed over a selected period of time.

According to early studies done on LCC you can calculate the LCC using discounted future value of money or ignoring this (Remer, 1977). It all depends on the researcher on what he is trying to uncover. At HMC the model equation for the future costs are the most important, the future value of money is linear and can easily be added in the total LCE project. However, the model will include the discounted future value of money with an interest rate set to zero.

The discounted future value of money can be calculated with the following formula. With ***P*** being the present value of money and ***F*** being the future value of money for a specific interest rate i over the number of years between the present and future denoted by ***n***.

$$P = F\,(1 + i)^{-n} \qquad (3)$$

Future operating costs for a project are often more difficult to estimate than the initial project investment cost (Remer, 1977). The formula (2) was then enter in MS excel and used to perform the LCC for the costs call centers of the vessels over the period 1999 to 2008. The excel sheet than calculates the LCC and the obtain graph shows the trend over the year.

By obtaining the regression line relationship between cost and time a forecast model can be made. This forecast is easier to implement due to the nature of the methodology already explained. The important part of the forecasting model is to make logical assumptions based on facts. Facts such as when is a vessel due for maintenance for the shipyard. These assumptions will prevent the LCC to be unrealistic low. In a competitive situation if a company's estimate of its costs is unrealistically low (underestimate) then it may obtain an order but risks making a financial loss (McNichols 1979). Also the forecast should not make it to high either because of self-fulfilling prophesy when making an R&M budget. This means that the more money you planned to invest the more of it you will invest even though it's not needed. That's why the forecast cannot be used as the only source of future prediction. The technical state of the vessel is also needed, so is the future earnings and market forecasts and risks.

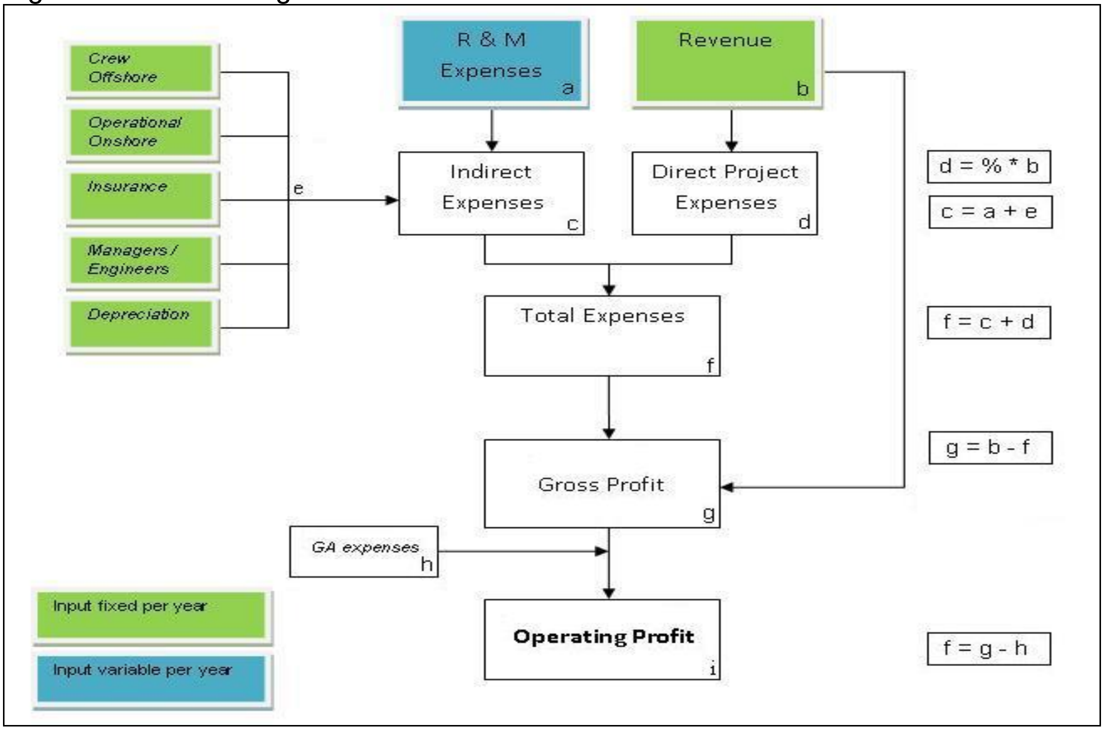
The forecasting must further be updated every year, and this will keep adjusting itself to the current conditions. The methodology of the model must be understood in order to update the model every year. By updating the model HMC can now exactly how their vessels are performing qua R&M expenses.

6.7 Operating Profit Model

After making a cost model that can forecast the future maintenance and repairs expenses for the vessels an operating profit model must be made. The operating profit model is a step closer in achieving the total HMC project. The total project outcome should be the EVA of the individual vessel in the future when the maintenance costs keep increasing. With this model HMC can forecast when a specific vessel will not meet their specific EVA target. In order to have a dynamic model it has to take the expenses and the technical state of the vessel into account. To achieve this, a simple model has been made to determent the operating profits of a vessel when the costs increase. From this simple model the other constraints and variables can be added on, this makes the formulation of the model much easier to achieve (Pidd, 1999).

The model will be based on the profit and loss account procedures of the finance department at HMC and in figure (15) the model diagram for the operating profit can be seen.

Figure 15: Model Diagram



Source: model diagram made by author based on HMC P&L

With the help of the finance department the P&L sheet was broken down in pieces to form the model. During this exercise the inputs and fixed constrains of the model can be classified. The main input is the expenses for maintenance and repair of the ships. The input comes from the forecast model, and changes over time. The second main input for this model is then revenue generated per vessel. This input will be fixed per year for now, but later will be variable according to the days the vessel worked. It will become a variable input.

Other inputs in the model that will be fixed over the years for now are the other cost associated with running this business. These inputs are as follow, the crew management, operational management, insurance, human resources, and depreciation expenses. These five cost components are divided into a fix and a variable cost. The variable cost are dependable to the amount of days worked. However in order to start simple the variable cost will also be fixed. Furthermore, these inputs are fixed during the whole life time of the vessel. In the later model these cost will be variable for the first five year of the life time of the vessel and than will stay fixed due that it is very hard to predict crew cost for instance for the next twenty years.

After identifying the inputs that we want the model to calculate the concept of the model was made to show how the calculation will work in excel. This interpretation of the model will be useful in later stages when more inputs and constrains needs to be added in. The flow chart will show the user where new inputs are needed in order to achieve the final results, such as the EVA target of the vessels.

The blue boxes are the input that varies each year, for instance the forecasted expenses for maintenance and repairs. These costs are booked at HMC as equipment management (EM) and that's the name of the first input. The green boxes are the inputs that are fixed over the years, and can be linked to the expenses directly from the accounting books of HMC. The model intention is to show how the increasing maintenance expenses affect the operating profits.

The formula (2) indicates the calculation programmed into excel sheet to find the operating profit OP where R is the revenue, EM_{exp} the expenses for the equipment management, DR_{exp} the direct resource expenses, DP_{exp} the direct project expenses. The GA is the general and administrative expense and varies over the years due to increase or decrease in personnel. This is forecasted by the finance department and has a gentle increase over the years and doesn't have a heavy impact on the operating profits.

$$OP = [\,R - (\,EMexp + \sum_{i=1}^{y} DRexp + DPexp\,)\,] - GA \qquad (4)$$

All the expenses also the EM expenses are added in the indirect expenses. A percentage of the revenue will become the direct project expenses. The indirect and direct project expenses will be added in to become the direct expenses. These expenses will than be subtracted from the revenues to get the gross profit. The general and administrative expenses will be subtracted from the gross profits afterwards to get the operating profits of the company.

The model will calculate the operating cost for the particular year with its particular EM expenses and will model the profits opposed to the EM expenses. From this model HMC can see when the vessel can no longer generated positive operating profits when their is continues increase into maintenance cost of a vessel.

The model diagram was very useful when making the excel sheet to calculated the operating profits per year. With the help of excel sheet software the model was made and set to graph the result ride away. This is very useful for the operator when there are extra costs that need to be added during the EM budget estimation. Peak years will automatically show in the graph.

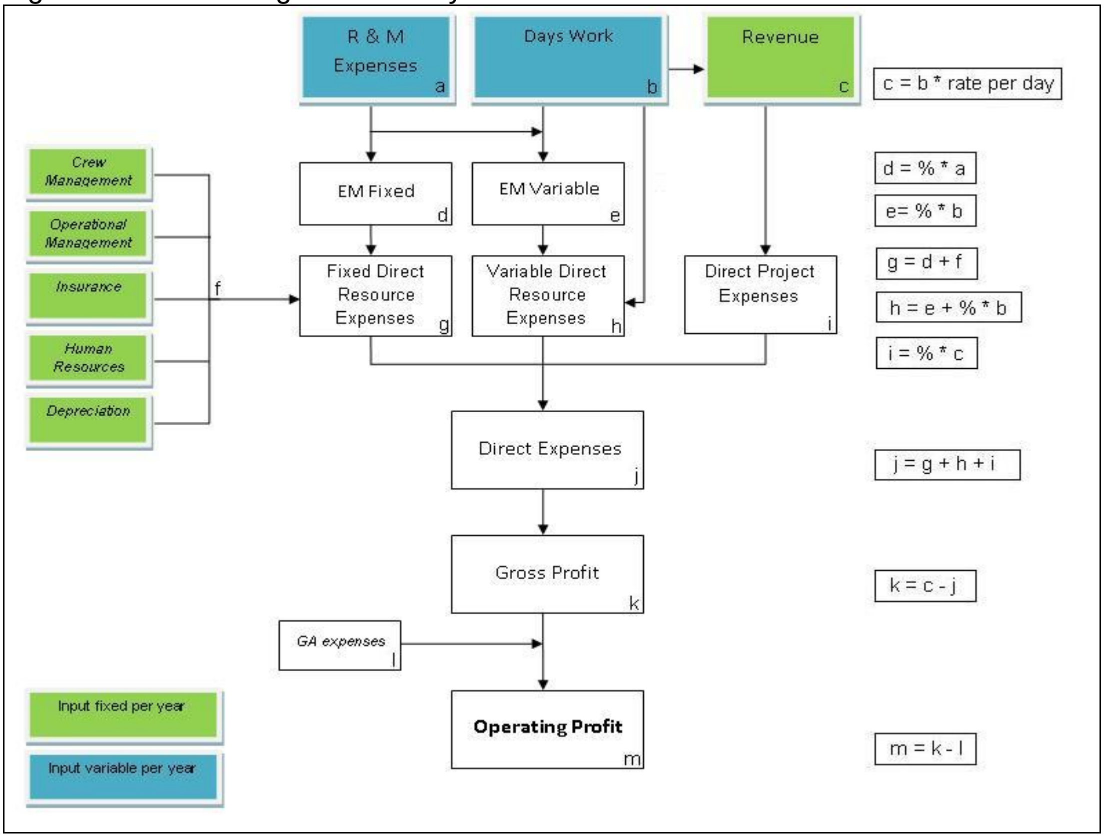
6.8 Operating Profit Model Expansion

As previously stated the first model is build very simple in order not to get lost in all the data and information available. The simple model can than be expanded on by adding more parameters and constraints. The operating profit model in the chapter above is fixed to the amount of days worked in 2009 and to the indirect and direct cost associated with it. However, amount of days work can varies over time. The amount of days worked is influenced by the offshore market and the technical state of the vessel. The last one is not an acceptable reason for HMC and can be viewed as lost in revenue.

This model should be dynamic to this constrain. It must allow the increase or decrease of the amount of days worked, affecting the variable expenses component of the crew management, operational management, insurance, human resources, and depreciation expenses. The forecast of days work in the future is a risk analysis that will be made by the intelligent department at HMC. The obtain data can than be plugged in the expanded model and the future cost of operating on vessel in particular can be obtain. With this HMC can than measure the EVA performance of their vessels separately. This tool is important when investment decisions must be made, such as should HMC continue to pour money in maintenance if the vessel is deteriorating, or is it economical more practical to buy a new vessel and if so does the market forecast show enough days that the vessel can work in order to have a positive cash flow. To facilitate such model expansion the original model should not is sensitive to change or add-ins. In figure (16) the model diagram for the expansion model can be seen.

The days work in this model is will be the same as the EM expenses input, this changes over time. The amount of days work will determine the revenue made by the vessel and the variable equipment management expenses and the variable direct resource expenses. Just as the previous model these expenses will be added with the fixed direct resource expenses with the direct project expenses to reveal the direct expenses for the SSCV being modelled. After this step the model remains the same as before. This model will be sensitive to the amount of days work, as soon as the days work goes down the revenue will go down and will become visible in the model.

Figure 16: Model Diagram with Days Worked



Source: model diagram made by author based on HMC P&L

The model diagram will be very useful when the excel sheet is to be modified. It gives the programmer the ability to see how the cost interacts with each other and where he must do the modification. The amount of days work is a risk analysis done by HMC by studying the market carefully and than this can be later be inputted in the model. Furthermore, from the risk analysis outcome the financial department will determine the variable expenses over the six cost centres. The calculation formula for this allocation of costs must be than added into the model to make it calculated the variable direct resource expenses. Due to time constrains and the magnitude of the whole project at HMC this step will be omitted from this thesis.

Chapter 7 Findings

7.1 Major Thesis Findings

Before the start of this project there was only an idea of what the outcome will be. Everybody at HMC had a different expectation and a different interpretation of the projects outcome. All the different expectation and interpretation already makes the project a success because it promotes engagement of all the departments in this organization. Furthermore, the results from this researched will be scrutinized by all the departments and this will result in a very reliable model when the whole project is finished.

This research has highlighted a lot of problems one can encounter when making a life cycle costing model and life cycle engineering model. There are a lot of theories available from industries that perform LCC model and LCE model. However, none of these industries had these types of assets which are very specialized for a specific job. Most theories cover the beginning stages of a product such as research and developed and eventual production and than further continue to monitor the cost during the life time of the product and later its disposal. This project however deals with assets that are more than thirty years old. With no data available as initial cost of investment this research takes a peak in a specific time window and tries to establish when this product can no longer generate a positive EVD target.

Because of this operating window of the models many theories and concepts had to be cut and paste to form a working concept for HMC. This was the first obstacle that had to be overcome. Which theory can help produce the desired outcome and how can it be rewritten took more time than anticipated, mainly because existing theories had to be broken down in smaller working pieces. For instance LCC model by Remer (1997) and by Dhillon (1989) included the initial investments, in this case it should have been the cost of constructing the ship, but the initial investment data is no longer available and can be consider that it has already been recouped. These models also takes into account the future value of money, however in order to establish a trend between the cost and the physical state of the vessel this value of money was not added in the beginning stage. The value of money will however be included in the final model, and this will be done by the finance department, mainly because they already have their own depreciation matrix. By adding the future value of money, the lines being modelled to show increase in cost will curve steeper as the end of life time of the vessel is approaching.

By adapting the existing models the LCC of the R&M costs can be calculated from 1999 till 2008. During the gathering of the R&M's data available for this operation major discontinuity was found in the accounting system at HMC. The accounting rules have changed over the years and this discontinuity was considered during the LCC calculation. Data from 1999 to 2002 was booked in the accounting system as four segments of the ship and in 2003 it was widen to what it is today. Furthermore in 2002 the switch to euro also had an impact on the previous data. For forecasting purpose the data between 1999 and 2002 was left out.

The R&M costs are booked as OPEX for daily repair and maintenance, and CAPEX for repairs and maintenance that needs a big investing capital. From these two the OPEX shows how the costs per year increase when performing regular maintenance, and can be linked to a steady deterioration of the vessel. The CAPEX on the other hand shows trends in R&M, its shows when a part of the ship needs repair or that has experience major failures or that its about to experience major failures if these investments are not done. To view this trend the depreciation of the CAPEX was left out during the analysis. The CAPEX depreciated data was used later to forecast the yearly total cash out for R&M of the vessels.

After forecasting the costs data for R&M in the future the modelling part of the research was preformed. During the forecasting stage of this researched a simple regression analysis was used. Even though the regression analysis is simple and the relation ship of cost versus year can be established, it is not super reliable for future predictions more than 20 years old. This is mainly due that the value of money is not yet included in the analysis, and furthermore the taxation that puts value to money changes. None the less the regression model for costs is a good indication of how the cost increases over time.

The modelling process was performed almost at the end of the research, because a better understating of the finance by HMC needed to be researched. The financial system was studied and from there a model that suits HMC was made. A major finding when studying the financial system was found to be that the R&M costs are dependent on the revenue generated. This makes sense because any company making their maintenance budget will not allocate finance higher than the forecasted revenues. Furthermore, revenues are generated by the amount of days worked. The final model most include the days worked in order to find the revenue and the amount of finance that will be allocated to all the costs centres such as R&M. The model will become more dynamic to all the parameters confronted with this type of business.

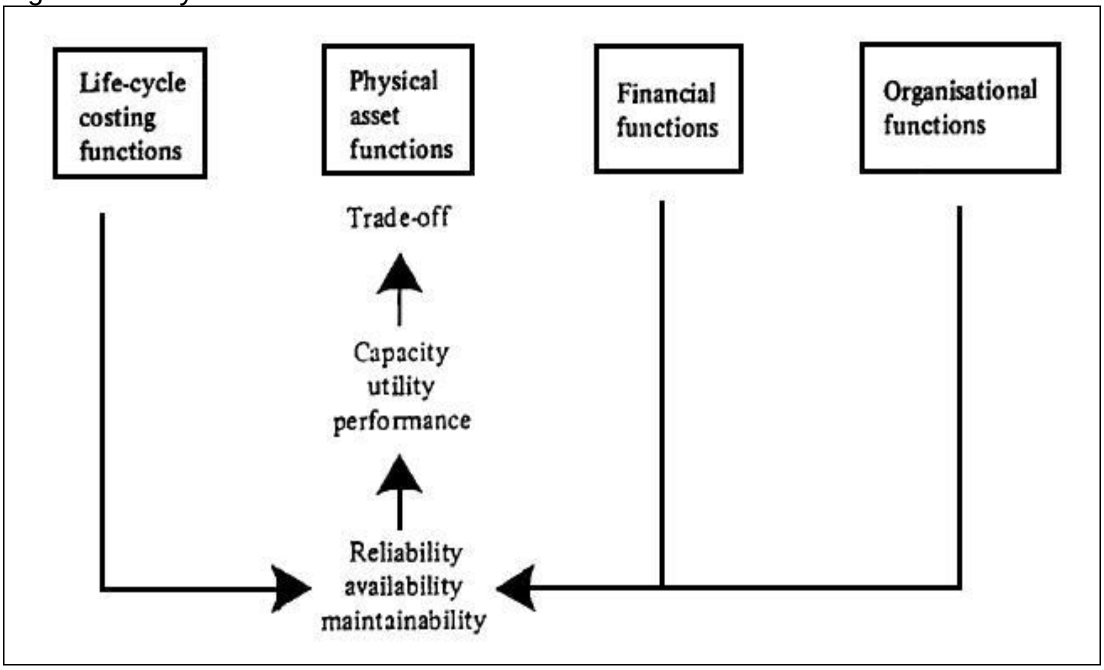
This researched has give HMC support for their project and their perspective is still needed in this case. The departments linked to this projected, such as the finance department and the equipment management department must put their input into this research to finalized the model. For instance the equipment management department have value input from a technical stand point and the financial department will view the concept model to see if it will performed what HMC management teams wants.

Finally, a major finding from this research is that the company has never used LCC and or LCE before for their assets. Due to this it took longer than anticipated how to perform the LCC. Data were available but which one to use, how to use them and how to collect them was a tedious job. A LCC analysis was never done for sea going vessels mainly due to the nature of this industry. In the shipping industry there are four markets in control, which are the freight market, the sales & purchased market, the new building market and the demolition market (Stopford, 1997). These markets interact with each other to make the cash flow in shipping. Because of this cash flow a ship owner doesn’t have to perform a LCC to start control cost when its ship float is getting older. If the freight market is down and is fleet is old he might consider selling it in the second hand market or even selling it as scrap metal in the demolition market. However a specialized vessel reacts different to the market. For instance if HMC sells one of its crane ships because he consider it cost inefficient, its competitor might buy the vessel and still make money with it.

All and all, he organization of HMC has helped in performing this research and it will be the backbone of the future implementation of LCC and LCE. In order to perform LCC in the future HMC must remember the key factors involve with this. The model Woodward (1997) mention these key factors and it's after performing the LCC that these factors made more sense. In figure (17) the key factors can be seen and how they react with each other to establish the utilisation rate of the vessel, and the trade offs related to this.

Here the LCC functions contain the specification of the vessel, the expenses used to operated the vessel, and the days worked reflecting the revenue per vessel. The financial functions is the initial investing capital (this is applicable if HMC is buying a new vessel) and also the revenue. The organizational functions are the maintenance of the vessel, what is the technical state of the vessel will be classified here. Furthermore, in the organisational functions when HMC is constructing a new vessel the design development will be here implemented and when disposing of the ship this will also be a part of this function.

Figure 17: Key factors in LCC

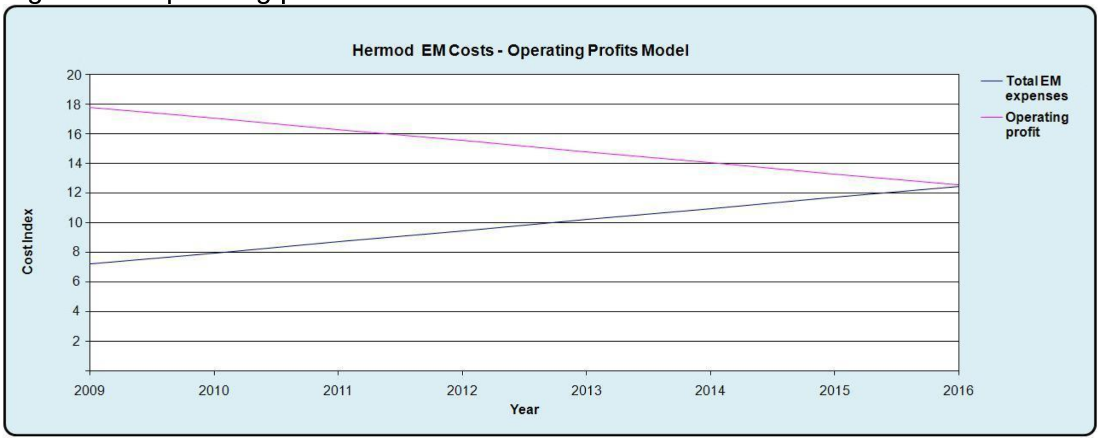


Source: Woodward 1997

7.2 Operating profit model outcome

This researched has delivered three graphical models of the R&M cost plotted over a specific period of time. The income was later calculated as explained in sub-chapter 6.7 to find the operating profits for every year. In figure (18) de model for the Hermod can be seen.

Figure 18: Operating profit model Hermod*

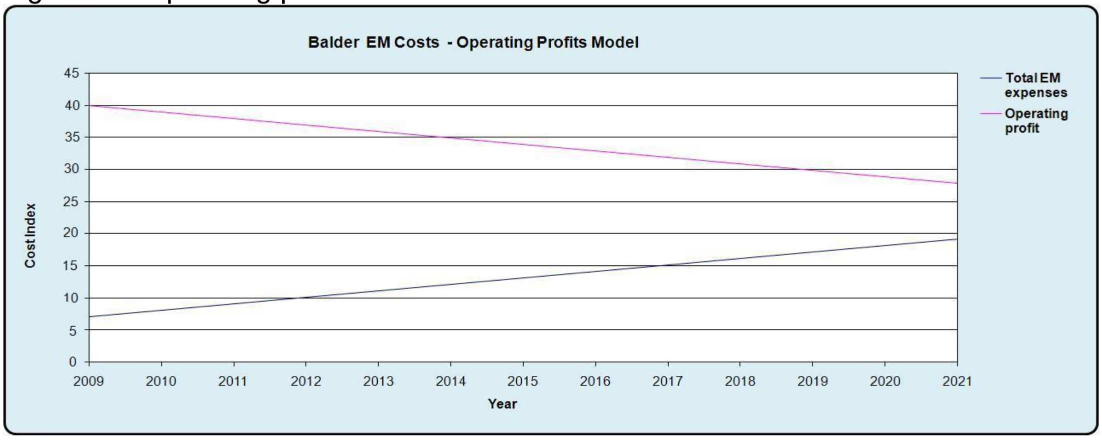


Source: model build by author based on HMC P&L

From this model the first four years are very accurate, and it shows how the operating profits decrease when the R&M cost increase. The value of money is not present in this model this means that after the first four years the shape of the cost line will exponentially increase. However, the model is an interaction of the R&M cost and serves as guidance for the engineers at HMC. For instance, if the day rate stays the same in 2016 and the cost increase steadily the vessel Hermod will not be economical productive.

In figure (19) the graph of the operating profit model for the vessel Balder can be seen. Just as the previous model the first four years are relatively accurate. In the first four years the operating profits are still high and the graph suggests that it will stay profitable till its stipulated COO even though there is no value of money included in this model.

Figure 19: Operating profit model Balder*



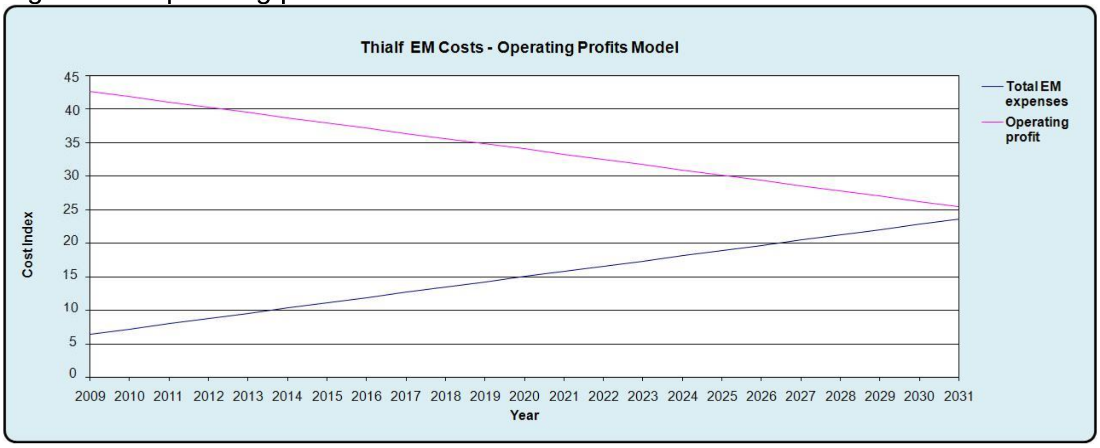
Source: model build by author based on HMC P&L

The vessel Thialf is the vessel that HMC wants to keep in operation the longest and figure (20) shows the operating profit model of this vessel. The stipulated year of COO for this vessel is 2031 and with a simple model like this we can already predict

* on request excel data can be viewed with author due to confidentiality

that this will be hard to achieve. From 2010 till 2013 this model shows a healthy profit to be made if the day rate and amount of days work stays the same. Between these two periods this model can be deemed very accurate. Beyond 2013 the value of money will give the cost line a concave shape.

Figure 20: Operating profit model Thialf*

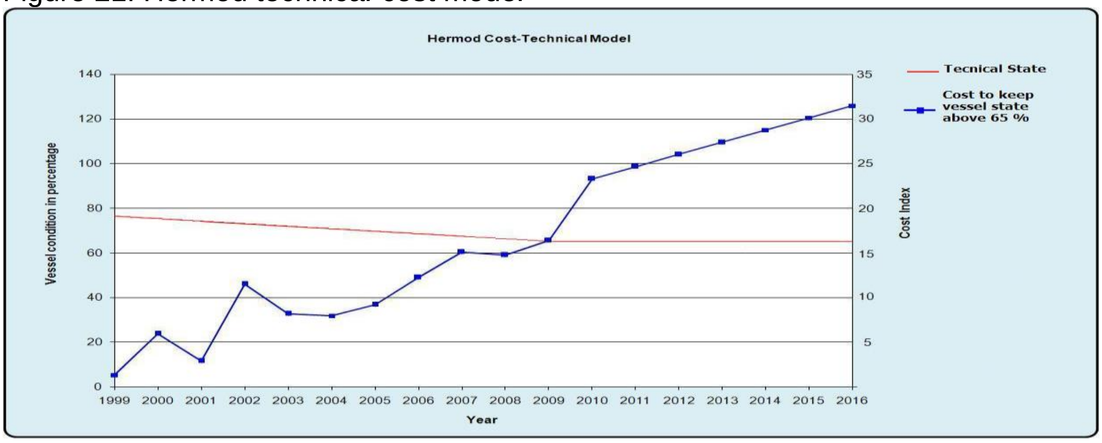


Source: model build by author based on HMC P&L

7.3 Hermod technical model outcome

The technical input in figure (5) was plotted graphically with the R&M expenses over the period 1999 to 2008 in order to find the amount of cost required to maintain the vessel Hermod. After wards this margin was added in the forecast of the cost to obtained the yearly R&M expenses in the future, this can be seen in figure (21). The graph below shows how the cost to maintain the vessel above the required 65% condition increases over time. Till the end of 2008 the Hermod was in good condition however it is predicted by HMC that the condition of this vessel will steadily decrease in the coming years and extra capital will be needed to keep the condition of the vessel above the 65% target. Hence the rapid increase in 2010.

Figure 21: Hermod technical-cost model



Source: model build by author based on HMC technical model

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* on request excel data can be viewed with author due to confidentiality

This model can be applied for the other vessels at HMC. However, the technical inputs for the Balder and the Thialf are being updated because of the dry docking of these vessels. This dry docking period will give HMC engineers the opportunity to better appraise the technical state of the vessel.

The graphical output of the Hermod model can be further used as a decision tool. Engineers at HMC can give their recommendation for which areas needs more investments than others. Also their advice can be used to implement business straggles, for instance should they keep the vessel as it is, should they sell it, or should HMC invest in a brand new vessels.

Chapter 8 Conclusion

8.1 Major Thesis Conclusion

1) Even though there is a lot of information available on Life Cycle Costing and Life Cycle Engineering the literature review didn't reveal any material on how to perform LCC or LCE for these types of vessels. It is new to the industry to use LCC to analyze operational cost of a vessel, mainly the repair and maintenance costs. The knowledge available had to be adjusted in order to fit the offshore industry requirements.

2) The offshore industry is a derivative of the demand for oil and gas, and has a cyclical character. The success of a company is based on the ability to deliver its services. In this case, transporting and installing gas/oil platforms and units. During the low periods the ship will lay idle for a long period of time, and the cost data OPEX reflects this period.

3) The days work expresses the high and also the low maintenance cost. The maintenance cost has a correlation with the total days work. During high working periods the cost of maintenance for the ship was very high. However, the technical state of the vessel cannot be predicted from the cost data analysis alone. In the last years the vessels had a high utilisation rate reflecting the market but not the technical state of the vessel. During vessel operations and in route routine maintenance and upgrades can be performed.

4) The LCC did give good indications on how the cost of maintaining these ships has increased over the years. The LCC graph shows a constant increase in cost in almost all of the ship subsection. By adding the OPEX and CAPEX in one graph this increase is even better illustrated. The trend here is that the R&M cost will continue to increase at a constant working period.

5) Common engineering knowledge suggests that when a replacement investment is made on the vessel the maintenance costs will go down. However, during the data analysis a steady increase of the R&M costs were observed. Even though replacement investments have been made over a ten year period the R&M costs did not diminish. This suggests that these vessels are getting older from a cost efficient stand point.

6) The LCC also highlights the cost drivers, allowing the operator to focus the technical analysis to these areas. These cost drivers such as the cranes and hull of the ship can be viewed as areas that are deteriorating. However, these vessel areas are also the ones most used during operations.

7) Besides highlighting the cost drivers the LCC can be used to forecast the future expenses needed to maintain the vessel in working condition. It is hard to predict the R&M costs exactly in the future, but an LCC forecast is a good indicator of the cost in the future. As expected, the forecasted costs also highlighted the future cost drivers. Keeping these cost drivers in mind when investing in life extension for the vessel will control cost and avoid ad-hoc investments.

8) The operating profit model was kept simple in order to see if it would work according to HMC business rules. In the future this model can easily be expanded to incorporate other parameters and variables. The model reaffirmed that the remaining economical life of the vessels is very sensitive to the generated revenue.

9) Increase in R&M expenses also has an influence on the model. The higher the R&M costs, the lesser the operating revenue will become, resulting in a decrease in the economical life time of the vessel. A model was made for the three vessels and the main difference between them is the year of cessation of operation.

10) From the preliminary results the vessel Hermod is the only vessel that will have a poor economic performance before reach its COO. However, further value of money must be included in the operating profit model and also the EVA target is still not present. This means that the economic performance of the other two vessels will also be poor before reaching their COO.

8.2 Recommendations

1) LCC and LCE can be very beneficial for HMC, but their accounting practices should include this type of cost analysis. A life cycle data bank can be made to keep track of all the costs during the life time of the vessel. The life cycle data bank will make it easier for a company to assess how their vessels are performing financially and what the level of technical state is.

2) The data bank structure must be linked to other financial and administrative tools at HMC. The data bank explained in subchapter 3.7 gets data inputs from the financial performance of the assets, maintenance records, operations utilization, operations management data, and comparative performance data at HMC. These major components will be added together to form an LCC data bank.

3) All the LCC components, such as operations utilization records and R&M costs data, discussed in this research should be introduced to all the disciplines at HMC. By doing so the whole life time of the vessel can be viewed at any time, and business decisions can be supported through this.

4) To structure the interdisciplinary approach to support the data bank, the data bank model explained in sub-chapter 3.7 is an outstanding start for HMC.

5) It is recommended to further develop a technical state model that in combination with the LCC model may improve the model’s ability to predict the cost of the vessel. The technical state will become a parameter in the profit model, and it is of great importance to determine an adequate value for the technical state. The evaluation of the technical state might be the most difficult step. However, it can be done by determining the devaluation of the vessel over the years by comparing all the components of the vessel to new components and analyzing the deterioration of the vessel with the help of on board engineers and technical surveyors.

6) Furthermore, the final model must include the amount of days worked in a year per vessel. This variable is a bit complicated, mainly because it is influenced by the technical state of the vessel. The poorer the condition of the vessel, the more time

HMC must spend repairing and maintaining it, thus lowering the productivity of the vessel. The vessels are already more than thirty years old, which means that a high utilisation rate for the SSCV's will increase the R&M costs. The addition of the days worked will make the final model very dynamic and very specific to HMC needs.

7) This researched can help to determine other business aspects for HMC. For instance the relationship between oil prices and date rate can be studied, and from the findings the affect of the oil price can be linked to the R&M costs of the ship. A link was found between the R&M costs and the days worked, and the day's work has a relationship to the cyclical oil prices. With this study HMC will have one more tool available when making work related decisions in the future.

8.3 Further Academic Research Topics

This research was very challenging because of the offshore industry, an industry that is a derivative of the demand for oil. The offshore market is dynamic and very demanding. To succeed in this industry a company should have the planning and know-how in addition to assets that perform a specific service. An LCC analysis can help make an offshore company more efficient in its planning and skilled to provide service anytime the market calls for it. From this challenge many academic topics presented themselves for further research which is listed below.

- Expenses / condition relationship model for technology systems
- Life Cycle Engineering for ship optimization
- Repair and maintenance program for lowering operational costs of ships
- Life Cycle Engineering of ships to provide warranties
- Life Cycle Costing manual for the marine industry
- Repair and maintenance model using Monte Carlo analysis or decision matrices
- Life Cycle Engineering of ships to reduce dry-docking time
- Life Cycle Costing to update rules and regulations for classification societies
- Life Cycle Engineering and Life Cycle Costing to improve the ship design to lessen the negative impact on the environment
- Life Cycle Costing for offshore structures

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Appendix 1

Thialf

Data Sheet

Thialf, our largest deepwater construction vessel (DCV), and is capable of a tandem lift of 14,200 t (15,600 short tons). The dual cranes provide for depth reach lowering capability as well as heavy lift capacity to set topsides. This multi-functional dynamic positioned DCV is tailored for the installation of foundations, moorings, SPARs, TLPs and integrated topsides, as well as pipelines and flowlines.

Dimensions

Length overall	201.6 m	661 ft
Length of vessel	165.3 m	542 ft
Width	88.4 m	290 ft
Depth to workdeck	49.5 m	162 ft
Draught	11.8-31.6 m	43-104 ft
GRT	136,709 t	-
NRT	41,012 t	-

Accommodation / Helicopter Deck

The living quarters are equipped to accommodate 736 men. All quarters have heating and air conditioning facilities. The helicopter deck is suitable for a Boeing Chinook 234.

Life-Saving / Fire-fighting

Life-saving and fire-fighting equipment according to the latest governmental requirements.

Mooring System

12 Delta Flipper anchors of 22.5 t each, on 3 1/8" wire ropes of 2,400 meters (8,000 ft) long. Minimum breaking strength 480 t. Kongsberg Albatross ADP 503 and ADP 311 automatic and dynamic positioning and mooring assistance.

Diving System

Containerized saturation diving system with diving bell can be made available.

Portside Crane

Main hoist revolving	7,826 st	up to 31.2 m (102 ft)
Auxiliary hoist	1,000 st	36.0 - 79.2 m (120 - 260 ft)
Whip hoist	220 st	41.0 - 129.5 m (134 - 425 ft)

Starboard Crane

Main hoist revolving	7,826 st	up to 31.2 m (102 ft)
Auxiliary hoist	1,000 st	36.0 - 79.2 m (120 - 260 ft)
Whip hoist	220 st	41.0 - 129.5 m (134 - 425 ft)

Main Hoist Lifting Height

95 m (312 ft) above work deck for each crane. Lowering depth of auxiliary hoists 460 m (1,500 ft)

below work deck at minimum radius.

Main Hoist Plumbing Depth
Lowering depth of main hoist at minimum radius with 3,500 t is 307 meters below heel point and with 2,990 t, 351 meters below heel point. Heel point is 24.4 meters (80 ft) above work deck.

Tandem Lift
Main hoist 14,200 t (15,600 sht) at 31.2 meters (102 ft) radius (subject to stability calculations).

Ballast System
Ballast pump capacity 20,800 cubic meters/hour.

Dynamic Positioning System
The Thialf is equipped with a Class III Dynamic Positioning system with the following characteristics:

Thrusters
6 x 5,500 kW - 360 degrees azimuth, total thrust 400 t

Modes of Operation
• Manual
• Joy-stick
• Auto-pilot
• Full DP mode
• Position mooring

Special DP functions
• Track follow
• Heavy lift
• Follow floating object
• External force compensation

Position reference systems
• 2 x satellite DGPS
• 1 x mechanical taut wire (300 m)
• 1 x Artemis
• 2 x acoustic SSBL/LBL
• 1 x Fan-beam laser

Transit speed with 1 tug
Max. 7.0 knot at 12.5 m draft

Balder

Data Sheet

The Balder was built in Japan in 1978 by Mitsui Engineering & Shipbuilding Company Ltd., and is the sister vessel of the Hermod. The ship is 505 feet long and 282 feet wide. Its draft is currently 36 feet, but during our work we take in ballast water to increase the draft to 82 feet. This principle is known as semi-submersible.

The Deepwater Construction Vessel (DCV) Balder is capable of a tandem lift of 6,300 t (6,945 short tons). The cranes provide for depth reach lowering capability as well as heavy lift capacity to set topsides. This multi-functional dynamic positioned DCV is tailored for the installation of foundations, moorings, SPARs, TLPs and integrated topsides, as well as pipelines and flowlines.

DCV Balder provides a toolbox for Deepwater field development up to 3,000 m waterdepth. The toolbox consists of:

- DP class III
- Large workdeck area
- Dual crane capability
- J-lay system
- Mooring line deployment winch
- Deepwater lowering capability
- Deepwater pile installation capability

DCV Balder was converted and commissioned in 2001/2002 and has successfully executed various projects since.

Dimensions

Length overall	154 m	505 ft
Length of vessel	137 m	450 ft
Width	86 m	282 ft
Width of Deck incl. TSM & Fairleaders	105.5 m	346 ft
Depth to work deck	42 m	138 ft
Draft	11.5 - 28.2 m	38 - 92 ft
Draft (Incl. Thrusters)	4.5m Under Hull	-
GRT	48,511 t	-
NRT	33,938 t	-

Accommodation / Helicopter Deck
The living quarters are equipped to accommodate 367 men. Additional quarters, installed in January 2007, provide accommodation for 392 men. All quarters have heating and air conditioning facilities. The helicopter deck is suitable for a Sikorsky 61-N.

Life-saving / Fire-fighting
Life-saving and fire-fighting equipment according to the latest governmental requirements.

Propulsion / Power
Propulsion by two electrically driven, controllable pitch propellers of 4,400 kW each in short nozzle. Seven thrusters of 3,500 kW Fixed Azimuth Thrusters Type LIPS FS3500-571/NU. Power supply by six diesel driven main generators of 2,765 kW each. The 6 DP Thrusters are supplied by six diesel driven generators of 4,000 kW

(5,000kVA)

Mooring System
12 Delta Flipper anchors of 22.5 tons each, on wire ropes of 4,500 meters (15,000 ft) long. Minimum breaking strength 386 t.

Diving System
Containerized saturation diving system with diving bell can be made available.

Portside Crane

Main hoist guyed	3,000 st	26 – 33.5 m	86 - 110 ft
Main hoist revolving	2,200 st	26 - 27.5 m	86 - 90 ft
Auxiliary hoist	1100 st	28.6 - 123 m	93.8 – 403.5 ft
Whip hoist	75 st	30.8 - 127 m	101 - 416 ft

Starboard Crane

Main hoist guyed	4,000 st	24 – 37.5 m	80 - 123 ft
Main hoist revolving	3,300 st	24 – 33.5 m	80 - 110 ft
1st Auxiliary hoist	1,000 st	27.2 - 84 m	89 - 276 ft
2nd Auxiliary hoist	660 st	30.8 - 95 m	101 - 312 ft
Whip hoist	250 st	36.7 - 113 m	120 - 371 ft

Main Hoist Lifting Height
Maximum lifting height of 3000 crane main hoist: 116 m
Maximum lifting height of 4000 crane main hoist: 98 m

SB Aux Hoist Plumbing Depth
Lowering capacity of 4,000 crane auxiliary hoist: 400 st at 3000 m below water level at minimum radius. Subsea lowering capabilities are project specific engineered for the use of SB crane / A&R (Abandonment & Recovery) Winch and MLD (Mooring Line Deployment) Winch.

Tandem Lift
Main hoist 6945 Sht at 33.5 meters (100 ft) radius.

Ballast System
Static and dynamic ballast system both fully computer controlled. Ballast pump capacity 8,000 cubic meter/hour. Dynamic ballast water handling 500 t/sec.

Pipelay Equipment
A Multi-Joint Pipe Handling system is fitted on the Balder PS deck designed for the handling of the following type of pipes; Single wall diam. 4.5”–32”, Single wall pipe with buoyancy max diam 50”. Pipe-in-Pipe diam 6”–24”, outer pipe diameters 10" - 30", External insulated pipe, Heat traced pipe.

J-lay tower and A&R system specifications are given separately.

Mooring Line deployment Winch
MLD-winch system specifications are given seperately

Dynamic Positioning System
The Balder is equipped with a Class III Dynamic Positioning system with the following characteristics:

Thrusters	Position reference systems

7 x 3,500 kW - 360 degrees azimuth, total thrust 385 t;
2 x 4,400 kW Propulsion Units may also be used for DP Purposes Modes of Operation

- Manual
- Joy-stick
- Auto-pilot
- Full DP mode

Special DP functions

- Auto Track Mode / Pipe lay Mode
- Heavy lift Mode
- Follow Target / Floating object Mode
- External force compensation

- Redundant satellite DGPS system
- 1 x Artemis Mk IV
- 2 x acoustic SSBL/LBL (HiPap)
- 2 x Fan-beam laser-systems
- 1x LTW Taut wire System 500 m max depth

Deckload / Transit Speed

- Deck load capacity 20 tons/square meter
- Total deck load capacity 8,000 tons
- Transit Speed Pending on Loading condition Max. 6.5 Kn

Hermod

Data Sheet

The Hermod was built in Japan in 1978 by Mitsui Engineering & Shipbuilding Company Ltd. The ship is 505 feet long and 282 feet wide. Its draft is currently 36 feet, but during our work we take in ballast water to increase the draft to 82 feet. This principle is known as semi-submersible. The Hermod is capable of a tandem lift of 8,100 t (9,000 short tons).

Dimensions

Length overall	154 m	505 ft
Length of vessel	137 m	450 ft
Width	86 m	282 ft
Depth to workdeck	42 m	138 ft
Draft	11.5 - 28.2 m	38 - 92 ft
GRT	73,877 t	-
NRT	22,166 t	-

Accommodation / Helicopter Deck
The living quarters are equipped to accommodate 336 men. All quarters have heating and air conditioning facilities. The helicopter deck is suitable for a Sikorsky 61-N.

Life-saving / Fire-fighting
Life-saving and fire-fighting equipment according to the latest governmental requirements.

Propulsion / Power
Propulsion by two electrically driven, controllable pitch propellers of 4,400 kW each aft and two electrically driven, retractable, controllable pitch thruster of 1,470 kW each forward. Power supply by seven diesel driven main generators of 2,765 kW each.

Mooring System
12 Delta Flipper anchors of 22.5 tons each, on wire ropes of 4,500 meters (15,000 ft) long. Minimum breaking strength 386 t.

Diving System
Containerized saturation diving system with diving bell can be made available.

Portside Crane

Main hoist guyed	4,000 st	26 - 39 m	86 - 128 ft
Main hoist revolving	3,000 st	26 - 30.5 m	86 - 100 ft
Auxiliary hoist	660 st	29.6 - 81 m	97 - 266 ft
Whip hoist	80 st	33.9 - 110 m	111 - 361 ft

Main hoist lifting height 92 m (302 ft) above work deck. Lowering depth of auxiliary hoist up to 3,000 m (10,000 ft) below work deck at minimum radius.

Starboard Crane

Main hoist guyed	5,000 st	24 - 40 m	80 - 131 ft
Main hoist revolving	5,000 st	24 - 32 m	80 - 105 ft

1st Auxiliary hoist	1,000 st	27.2 - 80 m	89 - 262 ft
2nd Auxiliary hoist	660 st	30.8 - 101 m	101 - 331 ft
Whip hoist	300 st	34.4 - 113.2 m	113 - 371 ft

Main hoist lifting height 81 m (266 ft) above work deck lowering depth of auxiliary hoist up to 3,000 m (10,000 ft) below work deck at minimum radius.

Tandem Lift
Main hoist 8,100 tons at 39 meters (128 ft) radius.

Ballast System
Static and dynamic ballast system both fully computer controlled. Ballast pump capacity 8,000 cubic meter/hour. Dynamic ballast water handling 500 t/sec.

Deck Load / Transit Speed

- Deck load capacity 20 tons/square meter;
- Total deck load capacity 8,000 tons;
- Transit speed with 8,000 tons deck load 6 knots at 11.5 meters (38 ft) draft.

Appendix 2

Technical state Hermod per ship section

EM SSCV's - Cost Centers Specification

Legenda			Explanation of percentages	
excellent	green	100-80%	100% = new build state	**HERMOD**
acceptable	yellow	80-60%		
not-acceptable	orange	60-40%		
re-jectable	red	< 40%	0% = not of any value anymore to generate an income	

Average score overall	65.15	%

A - Accommodation	Safety	Availability	Workability	Reliability	Average %
Elevators	70%	60%	50%	65%	61.25
Cabins	70%	80%	40%	60%	62.5
Laundry	80%	90%	80%	80%	82.5
Galley	65%	65%	65%	65%	65
Offices	75%	75%	75%	75%	75
Corridors	75%	100%	75%	75%	81.25
~~Gym~~					0
~~Cinema~~					0
Messroom	70%	70%	70%	70%	70
Change Rooms	60%	50%	60%	60%	57.5
Provision Stores	75%	80%	80%	80%	78.75
					70.416667

B - Anchor & Moring System	Safety	Availability	Workability	Reliability	Average %
Anchor Winches	70	60	70	50	62.5
~~Anchore Wire~~					0
Fairleads	70	60	40	50	55
Skagit	60	25	40	60	46.25
Winches	60	60	60	50	57.5
Capstans	60	75	75	70	70
Pendant Winches	70	70	70	70	70
Bridle Retreiver Winches	65	75	70	75	71.25
Towing Gear	70	80	70	75	73.75
Monitoring System	60	60	60	60	60
					62.916667

C - Ballast System	Safety	Availability	Workability	Reliability	Average %
Ballast Tanks	60	70	50	50	57.5
Dynamic Ballast Tanks	60	70	50	50	57.5
Piping & Valves	60	60	50	50	55
Pumps	60	60	60	60	60
Monitoring System	70	70	70	60	67.5
					59.5

D - Cranes	Safety	Availability	Workability	Reliability	Average %
Main Hoist	80	80	80	80	80
Aux. Hoistt	80	80	80	80	80
Whip Hoist	80	80	80	80	80
Boom Hoist	70	70	70	70	70
Slewing System	50	80	50	40	55
Tuggers	50	70	70	50	60
Air system	70	80	70	80	75
Hydraulic System	75	75	75	75	75
Electrical System	70	70	70	60	67.5
~~General~~					0
~~Crane Wires~~					0
~~Crawler Crane~~					0
~~Maeda Minirups Crane~~					0
					71.38888889

E - Engine Rooms	Safety	Availability	Workability	Reliability	Average %
Fuel System	65	70	70	70	68.75
Lub Oil System	80	80	80	80	80
Seawater System	70	80	75	70	73.75
Fresh Water System	80	80	80	80	80
Compressed Air System	70	90	90	90	85
Bilge System	70	75	60	70	68.75
Sanitary System	70	60	40	50	55
Steam Systen	30	30	30	30	30
~~HVAC System~~					0
Steering Gear	60	60	40	50	52.5
Provisions Cooling/ Freezing Syst.	70	80	80	80	77.5
Sewage System	60	60	60	60	60
Starting Air System	70	90	80	70	77.5
Control & Monitoring Sytems	60	60	60	60	60
					66.82692308

F- Hull & Vessel Construction	Safety	Availability	Workability	Reliability	Average %
Hull	75	75	75	75	75
Deck	50	60	50	40	50
Helideck	70	70	70	70	70
Masts	65	65	60	60	62.5
Holds	50	50	50	50	50
Fuel Oil Tanks	65	80	65	65	68.75
Potable Water Tanks	70	80	70	75	73.75
Lub	70	70	70	70	70
Oil Tanks	70	75	70	75	72.5
Bilge Water Tanks	60	50	60	60	57.5
Sludge Tanks	60	50	60	60	57.5
Sewage Tanks	70	80	60	40	62.5
Cofferdams / Void Spaces	60	60	50	50	55
Watertight Doors	60	60	60	70	62.5
Walkways / Stairways	70	70	60	70	67.5
~~Column Elevators~~					0
~~Impressed Current~~					0
					63.66666667

J - Power Generation / Distribution	Safety	Availability	Workability	Reliability	Average %
Main Diesel Engines	40	70	60	20	47.5
Main Generators	40	70	60	40	52.5
Main / Aux Distribution Board	40	70	60	50	55
Transformers	40	60	60	40	50
Cabling	40	40	40	40	40
Emergency Power System	60	60	60	70	62.5
UPS	70	70	70	70	70
Alarm System	70	70	60	70	67.5
					55.625

K - Propulsion & DP System	Safety	Availability	Workability	Reliability	Average %
Main Propellors and Drivers	70	70	70	70	70
Thrusters and Drivers	40	60	40	40	45
Rudder Nozzles	60	70	60	50	60
DP System					0
Reference Systems	65	65	65	65	65
					60

L - Safety Equipment	Safety	Availability	Workability	Reliability	Average %
Life Boats	70	80	70	70	72.5
Fast Rescue Boat	70	60	60	70	65
Life Rafts	60	75	60	60	63.75
Personal Lifesaving Equipment	80	80	70	80	77.5
Fire Fighting Equipment	80	80	80	80	80
CO2/ Halon System	60	70	70	60	65
Gas Detection Equipment	70	80	80	60	72.5
~~Stretcher Elevator~~					0
					70.89285714

M - Workshop, Stores and Tools	Safety	Availability	Workability	Reliability	Average %
Ship Related Consumables	70	75	75	75	73.75
Fixed Welding Equipment	60	80	75	65	70
Workshop Equipment	65	65	65	60	63.75
~~Personal Gear~~					0
Electric Consumables	70	75	75	75	73.75
~~Transport and Handling~~					0
~~General Chemicals~~					0
~~Forklift~~					0
					70.3125