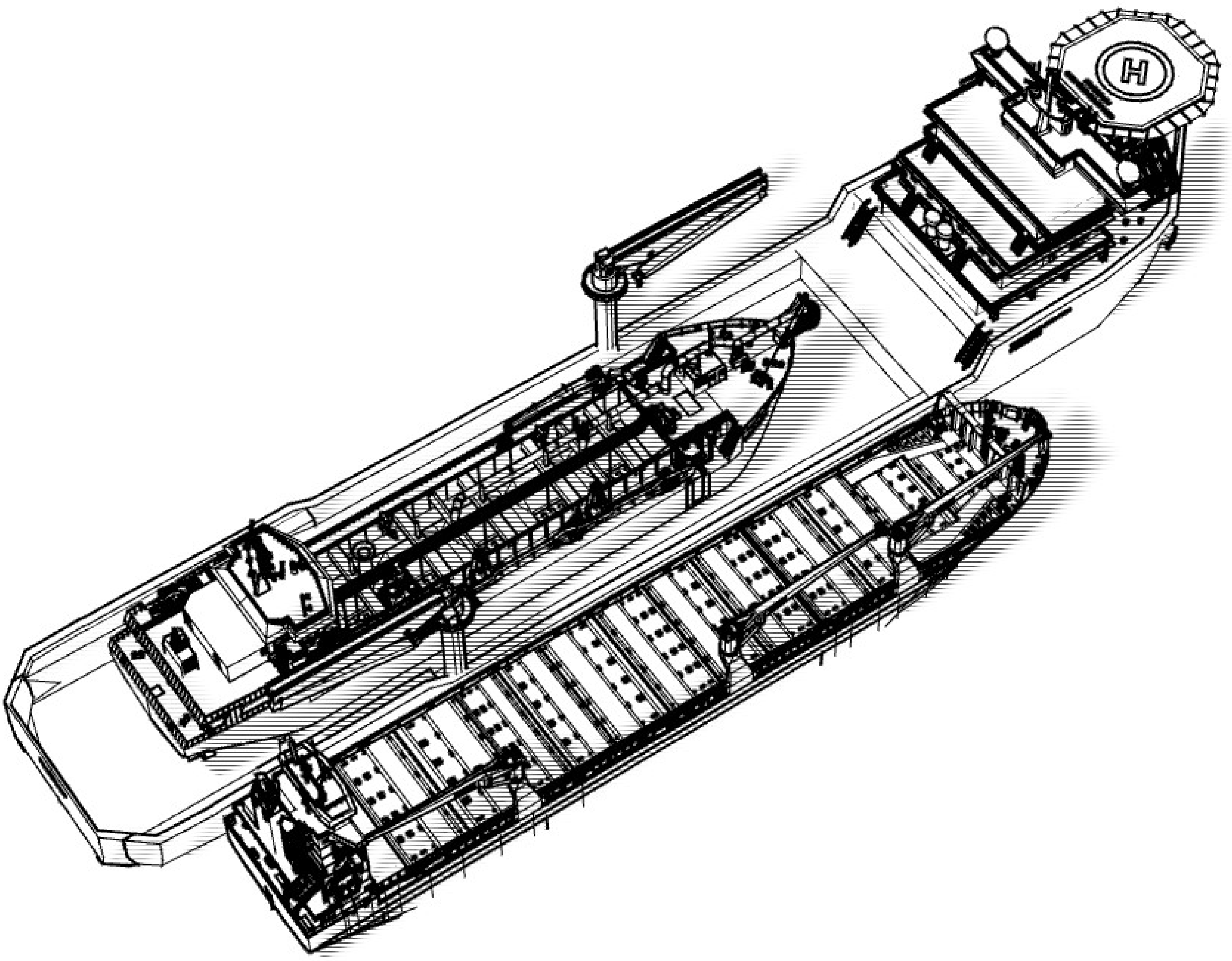
Evaluating the potential of a mobile shiprepair facility

A feasibility study in the conceptual phase

B.L. van der Plas

Delft, March 2019



TU Delft Delft University of Technology

DAMEN SHIPREPAIR & CONVERSION

Evaluating the potential of a Mobile Shiprepair Facility

A feasibility study in the conceptual stage

by

B. L. van der Plas

to obtain the degree of Master of Science
at the Delft University of Technology,
to be defended publicly on **Wednesday March 13, 2019 at 10:00 AM**.

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*This thesis is confidential and cannot be made public until **March 13, 2029.***

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DAMEN SHIPREPAIR & CONVERSION

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B. L. van der Plas
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Abstract

Setting up or dismantling a shiprepair yard requires vast amounts of time and resources. Current shiprepair yards are land-based facilities that can not be moved when demand for their services declines. A mobile shiprepair facility would be able to and Damen Shiprepair & Conversion (DS&C) expressed interest to investigate the potential of a mobile shiprepair unit. When executed correctly, such a facility may reduce total repair time and thereby increase vessel availability through a higher shiprepair efficiency and reduction of travel time to the repair yard. The resulting competitive advantage can lead to profit maximization of DS&C.

The goal of this thesis is to develop recommendations for DS&C regarding the feasibility of a mobile shiprepair facility. No facility of this kind exists to date, therefore the first step is to determine preliminary design features. The target market will be the mandatory intermediate and special surveys that a vessel is obliged to undergo every two and a half and five years respectively, requiring the vessels to undergo underwater investigations. A design feature following from that is the ability to haul vessels out of the water. The concept should moreover be sea-going, easy to (re)deploy and contain an all-round workshop and warehousing capabilities.

Subsequently, the costs and projected revenues of the concept are identified and combined in a financial model. The cost items which differentiate a mobile yard from a traditional land-based shiprepair yard are: direct labour cost, machinery & installations cost, housing cost and travel expenses. Revenue results from shiprepair services and includes the quantified competitive advantage. The feasibility of a mobile shiprepair facility is then further evaluated in two case studies: the Caribbean sea and the west-coast of the African continent. The target market in the Caribbean are Supramax/Handymax size vessels and the target market in west-Africa is the support vessels for the offshore oil and gas sector. Both case studies evaluate a semi-submersible non-propelled facility that operates in a sheltered location.

The Caribbean is the only area of the two case studies that shows potential. This can be explained by a higher efficiency and hence more projects that can be executed per year. Moreover, the same services can be sold for a higher price than on the west-coast of Africa. Several scenarios were identified in which the concept can be feasible on an annual base. However, the likeliness that these conditions persist during the projects lifetime is considered low and thus it is not recommended to deploy a mobile shiprepair facility in this area. Regarding the west-coast of Africa case study, even under the most favourable conditions - a very high occupational rate and an increase in target market conditions - it is not recommended to deploy a mobile shiprepair facility.

It has been concluded using a stochastic sensitivity analysis that the duration of the maintenance project largely determines feasibility. The sensitivity to the fuel price, day rates of future clients and the reduction in deviation days were studied as well. All three were found not to be of large influence for the determination of feasibility, although it had been suspected differently for the last two. It has been found that the added value of the concept can not be transformed enough into a competitive advantage.

If a change in conditions justifies the further development of this concept, this report provides several design criteria. Subsequently, recommendations are made on the design of a tool for the maximization of the reduction in deviation time of future clients to enhance the potential of the concept.

Abbreviations, Acronyms and Definitions

ABS .... American Bureau of Shipping
BDI .... Baltic Dry Index
BSI .... Baltic Supramax Index
BV .... Bureau Veritas
BP .... Bollard Pull
CAPEX ...... Capital Expenditure
CM .... Contribution Margin
DSAm .... Damen Shiprepair Amsterdam
DSCu .... Damen Shiprepair Curacao
DSR .... Damen Shiprepair Rotterdam
DS&C .... Damen Shiprepair & Conversion
DNV GL ..... Det Norske Veritas
DC .... Direct Cost
ECA .... Emission Control Area
EBIT .... Earnings Before Interest and Tax
FCS .... Fast Crew Supplier
FTE .... Full Time Employee
G&A .... General & Administration
GHG .... Greenhouse Gas
VHSS .... Hamburg Shipbrokers's Association
HSE .... Health, Safety and Environment
IC .... Indirect Cost
IRR .... Internal Rate of Return
IACS .... International Association of Classification Societies
ILO .... International Labour Organization
IMO .... International Maritime Organisation
ISO .... International Organisation of Standardization
LNG .... Liquified Natural Gas
LR .... Lloyd's Register
M&I .... Machinery & Installations
MGO .... Marine Gas Oil
MLC .... Maritime Labour Convention
MSRF .... Mobile Shiprepair Facility
NDBC .... National Data Buoy Center
NPV .... Net Present Value
OPEX .... Operational Expenditure
PoIC .... Percentage on Indirect Cost
PoS .... Percentage on Sales
R&M .... Research & Maintenance
RAO .... Response Amplitude Operator
TCE .... Time Charter Equivalent
WACC .... Weighted Average Cost of Capital
WCO .... Work Contracted Out
B .... Breadth of the to be towed vessel
R^2 .... Coefficient of Determination
K .... Condition factor
ρ_{xy} .... Correlation factor between x and y
D_1 .... Depth of exposed transverse section
r .... Discount Rate
Δ .... Displacement
v .... Sailing speed
σ_{xy} .... Variance between x and y

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1

Introduction

This introductory chapter provides an overview of the context wherein this thesis is built upon. Firstly, in Section 1.1 some information is given about the triggers and interest in a new flexible nature of the shiprepair industry and why Damen is considering its options within this industry. This will be done by performing a micro-to-macro-to-micro analysis, which provides the background for the problem description that will be discussed in Section 1.2. The chapter ends with Section 1.3 which discusses the research methodology and an outline of this thesis.

1.1. Evaluation of the company's strategy

Market changes and the reaction of a company to these changes are a vital part of management decisions. Keeping up with the trends in the market or even early anticipation to these trends can make or break the competitiveness of a company on the long term. This is true for every company competing in any market and it is not different for companies operating in the complex and therefore interesting shipping industry. This industry is composed of many different disciplines that together make a world of complex mechanisms with an extremely international nature, of which the shiprepair department is a vital part. This department will be basis of this research. Within the industry, Damen Shiprepair & Conversion (Hereinafter: DS&C) is the company for which (a part of) the corporate strategy is being investigated in this chapter. The investigation means to research the necessity of this research, and an analysis of possible future strategies and the necessary service changes will be executed.

One way of evaluating the future of a company, in this case Damen Shipyards and its shiprepair division, is by firstly zooming out and looking at the macro factors that are shaping the world and therefore the industry where the company is operating in. The corporate strategy of a company depends on the trends happening in its industry and the world. Future trends and the reaction to them shape the course of a company in the future. This line of thinking has been summarized in Figure 1.1 by the green arrows. Having the goal of ending with DS&C in the future (2025 in the figure), many conversations have been taken place with experts in their own field of work, both within and outside of Damen, see Table 1.1. For a complete analysis, both the newbuilding and shiprepair industry have been taken into account, whereas the shiprepair department will receive the focus at the end of the analysis.

Table 1.1: Expert consultation for the background research

Name	Function	Company
Solco Reijnders	Program Manager Innovations	Damen Shipyards
Kees Jan Groen	Commercial Director Shiprepair	Damen Shiprepair & Conversion
Ferdinand van Heerd	Lead Engineer Naval Architecture	Huisman B.V.
Jeroen Heesters	Group Commercial Director	Damen Shiprepair & Conversion
Jurriaan Daams	Project Manager	Damen Shiprepair & Conversion
Claas Vis	Superintendent	MF Shipping Group
Jan Derk Kampinga	Manager Technical Department	Shipping Group Groningen
Piter Oosterhof	Manager Fleetmanagement	Wagenborg

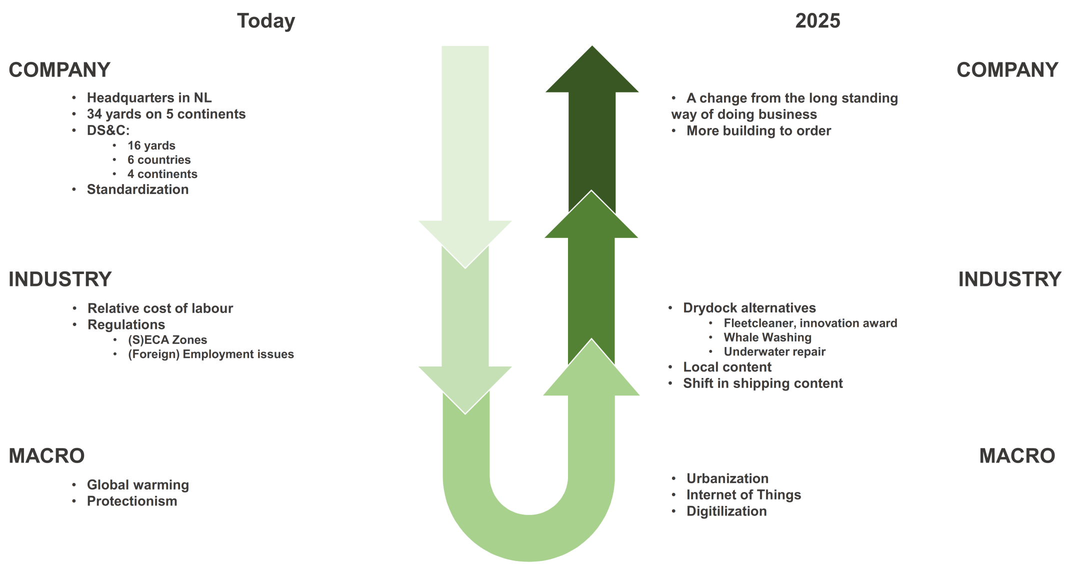


Figure 1.1: U Exercise
Source: Graph made by author, with input from expert consultation

The first part of the evaluation is a summary of the current situation with regards to the company itself. Numbers about revenues or employees hold a significant amount of information about the company, but the nature of the company is the most important factor that is being described in this part. What sets Damen apart from other ship builders and how does this translate into the corporate strategy that is being applied?

Today: Company

At the point in time of the writing of this report, Damen Shipyards Group employs around 10.000 people at 34 yards on 6 different continents. The headquarters of the company is situated in Gorinchem, the Netherlands, which is also functional as a production yard. Damen is mostly and originally a shipbuilder that is currently operating in 14 different markets; Harbour & Terminal, Offshore Oil & Gas, Offshore Wind, Pontoons & Barges, Dredging, Public Transport, Sea & River Cruising, Defence & Security, Fishing, Aquaculture, Yachting, Inland Shipping, Seagoing Transport and Environmental Safety & Control. Where the company started in 1967 with the manufacturing of tug boats, it now offers a great portfolio of ships. Table 1.2 shows the ships that have been delivered in 2017 categorized by the market they operate in. A big percentage (39%) of the delivered vessels are workboats & tugs, the market in which the company started to sell their first vessels in 1967. What can be seen is that the company has diversified itself over the years. This has been done by on one side setting up new divisions inside the company itself and on the other side taking over companies that manufactured vessels serving in markets where Damen was interested in. An example of the latter is the acquisition of Amels, a Dutch yacht builder that is part of the Damen group since 1991. Both setting up new divisions within the company and delivering quality builds are fruits of the large research & development (hereinafter; R&D) department, said to be the backbone of the company.

Table 1.2: Numbers on 2017 ship deliveries

Market(s)	Number of deliveries	Percentage
Workboats & tugs	64	39%
High speed crafts & ferries	40	24%
Dredging & specials	23	14%
Defence & security	16	10%
Pontoons & barges	12	7%
Offshore vessels	5	3%
Yachts	5	3%
Total	165	100%
Repair & Maintenance	1300 (Projects)	-

Damen ships are known around the world for their high level of quality, something that is being assured and proven by the fact that the company builds vessels on stock. This unique way of serving market demand is what sets the company apart from the rest of the shipbuilders in the industry. Building and selling vessels from stock brings with it a number of advantages. The standardization that is the foundation of building vessels from stock means that the quality of the product can be guaranteed and proven technologies are used to furthermore assure a high resale value for the client. More important, the delivery time can be dramatically shorter than when building a vessel to order. Having done the bigger part of the engineering already and having the hull of the ship manufactured and 'on the shelve', Damen is able to supply a vessel to their clients much faster than its competitors can. Besides being a valuable asset itself, a shorter lead time makes it possible for Damen to sell their vessels at a competitive price, especially given the high degree of quality that the vessels have. The standardization combined with the extensive knowledge within the R&D department allows Damen to be able to build a ship for almost every customer, even if the requests are special and never done before by Damen or any other shipbuilder, by slightly changing one of the many proven designs. The Damen vessels are being build at different yards spread all over the globe, as can be seen in Figure 1.2. The annual turnover of the company is generated on all the continents of the world (excluding Antarctica) where Europe and the combination of Asia and Oceania generate the bulk. Table 1.3 shows the turnover for both the average between 2013-2017 and 2017, showing two different elements for closer inspection. First of all, new building is not the only service within the Damen group, the table shows four more divisions; Building on site, Repair & Maintenance, Services and Components. More interesting even is the change in the division of the annual turnover between the average of 2013-2017 and 2017 itself. The most significant change can be seen in the new building and building on site division percentages. The latter is part of the new building division with the difference that the vessels are not build on a Damen yard. Still being Damen vessels, they are build at a clients location using (or only parts of) a Damen design, material packages and building assistance. This growing industry is mainly caused by the growing trend of protectionism and the need for local content. Both will be explained later in Section 1.1 & 1.1.

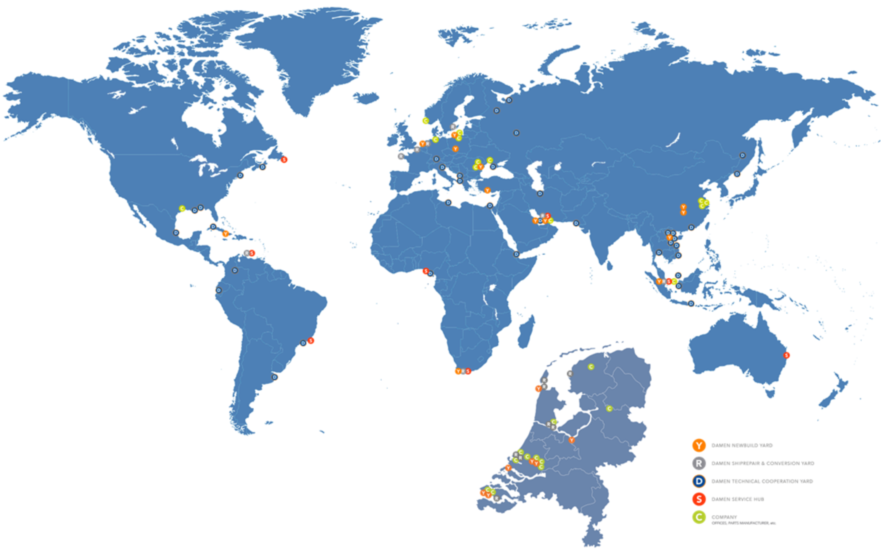


Figure 1.2: Global presence of Damen

A quarter of the annual turnover of 2017 is generated by the Repair & Maintenance (hereinafter R&M) department by achieving 1300 R&M jobs in 2017 only. Looking at Figure 1.2, the R&M department consists of 16 yards with a total of 50 (covered) drydocks, slipways, repair halls or synchro lifts. Two of the largest drydocks in Europe are situated at Damen Shiprepair Brest and Damen Verolme in Rotterdam. Together with the presence on four continents, the R&M yards are strategically located to facilitate a large selection of vessels at many of the key points in the maritime traffic routes. The R&M jobs include repair jobs, maintenance jobs and conversions ranging from simple special surveys to collision damage repair and even the conversion of a Floating Production, Storage and Offloading unit. It is this division where this report will be focused upon and further reasoning behind this will be made later in this chapter.

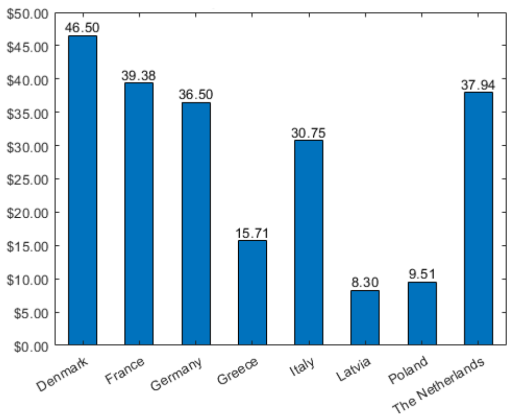
Table 1.3: Numbers on turnover distribution

Division	Average 2013-2017	2017
New building	58%	48%
Repair	20%	24%
Building on site	12%	20%
Services	4%	4%
components	4%	2%
Other	2%	2%

Today: Industry

The strategy described above is a reaction to the trends related to the industry where the company is operating in. To understand the current corporate strategy it is crucial to emphasize what is currently happening within the industry. Which factors play an important role for clients when it is time for them to choose between your company or a competitor and what are the rules and regulations which have to be complied to by every company within this industry? The shipping industry is a manufacturing one by nature, including the R&M department. Two factors that greatly influence the competitiveness of a yard for newbuilding or repair projects within such an industry are the (relative) cost of labour and the (regional) regulations. Most of the trends within the shipping industry are a result of changes with regards to these factors and that makes them interesting to analyse in more detail.

Cost of Labour As said above, the main costs of a newbuilding project or repair project are the cost of labour and the cost of the materials needed. Both costs have different factors on which they are based, but the common factor is location. The location of a shipyard is of key importance to the cost of labour and the cost of materials. Although, the location plays a more significant role for the labour cost when related to the Damen yards. Material cost related to the location depend mostly on the transportation and supply chain costs for bringing (special) material to the shipyard. This can differ dramatically when comparing the location of a yard in a remote area without proper transport facilities and qualified (sub) contractors nearby to a yard located in a dense shipping area within a major port. More on this kind of complications will be described later in the report. The (relative) labour cost is dependent on the location of a shipyard in a slightly different perspective and relates more to the wages earned by employees in different countries. Looking at both Figure 1.2 and Figure 1.3 it is possible to conclude that most of the newbuilding yards operated by Damen are located in so called 'low-wage countries'. The largest newbuilding facility at the time of writing is located in Galati, Romania, which is considered a low-wage country, and Damen is at the moment of writing considering to take over another shipbuilding facility located in the same country. The most important reason for the choice of this country is, apart from a location close to a relatively connected part of the worlds oceans, the cost of labour. Figure 1.3a shows the average hourly labour cost in European countries that have been selected on their drydock capacity related to the shiprepair industry. The information has been taken from statistics composed by the International Labour Organization (Hereinafter: ILO) [ILO, 2018], a division of the United Nations. The total number is made up of the wages & salaries and the non-wage cost, where the non-wage costs are composed of the employers' social contributions plus taxes minus subsidies. The original data is presented in Dollars but it has been converted to Euro to enable a better comparison. Low-wage countries like Poland and Latvia have an average labour cost that is more than four times lower that the cost of labour in for example the Netherlands.
If the annual data on labour cost from 2017 is compared in Table 1.3b, defined as the total labour costs divided by the corresponding number of hours worked by the yearly average number of employees expressed in full-time units by the European commission [EUROSTAT, 2018], it is possible to conclude that the numbers for Romania are even lower than the numbers for Poland and Latvia and just a little bit less than six times compared to the Netherlands and five times compared to the average of al 28 EU countries. Wages in West Europa are relatively high, which has its consequences for companies operating manufacturing sites in those areas. A trend that is being seen, more at the shiprepair yards than the newbuilding facilities, is that it is being preferred to have the work done by third party employees that employ workers from countries with lower average wages than the country in which the yard is in. This trend is not only a consequence of the high difference in average wages, another characteristic of the shipbuilding and shiprepair industry is causing yards to shift from using their own workers to having third parties bring in labourers. Planning work in a shipyard together with the planning of the amount and type of workers needed to get the job done is one of the biggest chal-



(a) Average hourly labour cost ILO 2016

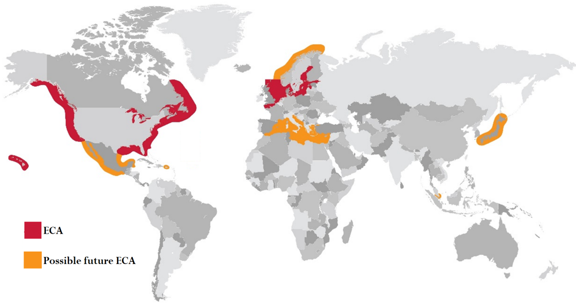
Country	Hourly Labour Cost (€)
Poland	9.4
Latvia	8.1
Romania	6.3
The Netherlands	34.8
EU (28 countries)	26.8

(b) Average hourly labour cost Eurostat 2017

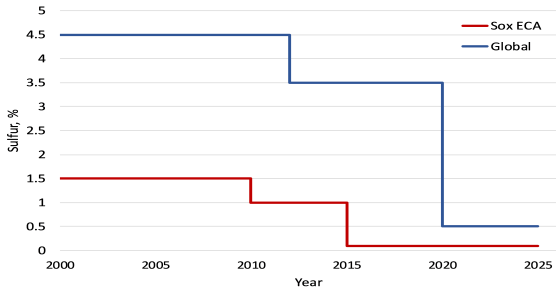
Figure 1.3: Numbers on cost of labour in different EU countries
Source: Conversion rate €/$ = 1/1.1631 (19^{th} June 2018)

lenges. This challenge is significantly lower in the newbuilding business compared to the shiprepair industry, especially when the vessels are being build on stock, as is the business model that is operated by Damen. Looking at more detail within the R&M industry, the planning increases in difficulty. Having ships coming in for their regular surveys can be planned ahead quite effectively and the planning of the workforce needed as well. Emergency repairs are harder to plan, having a capable workforce available at all time for such events to happen is not efficient in many ways. This problem causes shipyards to rely on third party employees instead of their own workforce, with the side note that those workers mostly come from low-wage countries.

Regulations The leading factor that is currently determining the course of the total shipping industry is the tight regulations. regarding ship's emissions. The regulations will not be described into large detail due to the nature of this report, the consensus of this section will be the consequences of the mentioned regulations for both the newbuilding and shiprepair industry. The International Maritime Organization (Hereinafter: IMO) is currently implementing strict rules that have the intention to reduce the (bad) impact that the maritime industry has on the environment and peoples' health. It has set goals for the future regarding the reduction of polluting gasses. A number of regulations are made that are to be followed by shipowners and ship-operators to reach these goals. The IMO decided in October 2016 to reduce the maximum sulphur (So_x) content ratio to air in the exhaust gas from 3.5% to 0.5% globally as from 2020. The limit that has been already in place for the Emission Control Areas (Hereinafter: ECA), seen in Figure 1.4a of 0.1% stays unchanged. Both limits are displayed in Figure 1.4b. Together with the target set by the European Commission in their 2050 roadmap [EU2, 2011] to reduce the Greenhouse Gas (Hereinafter: GHG) emissions to a 80% reduction, where 100% stands for the total emission globally measured in 1990, this is causing shipowners and ship-operators a number of problems. Investments into emission reduction systems need to be made to have ships comply with current and future regulations. This is something that is extremely hard in the current state of the industry, as will be explained later in this chapter. The problems faced, however, create opportunities for both new-building yards and companies and shiprepair yards.
One way of reducing dangerous emissions in the shipping industry is to switch to alternative fuels for the propulsion and energy generation of a vessel. This is true for both the reduction of CO_2 and SO_x, Different alternative fuels have different methods for the reduction of dangerous particles. Both when building a brand new ship or when deciding what to do with an existing vessel, determining how to react to the latest and future regulations is currently one of the biggest decisions a shipowner has to make. There is a high level of uncertainty about among others the fuel prices and availability of all kinds of combustibles after the implementation date of the new sulphur regulations (1^{st} January 2020), which has the consequence that nobody is certain about the perfect way to react to the new regulations. Numerous studies have been executed to investigate which course of action is the right one for different ship sizes and zones of operations. Abadie et all [Abadie et al., 2017] use among others the lifetime of a vessel, technological possibilities, uncertainty in future fuel prices and percentage of sailing time in ECA zones to determine the best option based on the Net Present Value (Hereinafter: NPV). Lindstad et all [Lindstad et al., 2017] propose a similar method that



(a) Current and future ECA zones



(b) Maximum allowed sulphur content

Figure 1.4: Information on the new SO_x regualations
Source: https://www.dieselnet.com/standards/inter/imo.php, visited on 19^{th} June 2018

concludes on different options for various vessel types and sizes for complying to the newest rules. Not only independent researchers have been doing studies on this matter, companies themselves should investigate the best option for any of their existing or new vessels. Damen is not a shipowner. But, because it is building vessels on stock and the competitiveness of their vessels will depend greatly on their ability to comply to the emission reduction regulations, it is conducting similar research. Fact stays, nobody is completely certain what will happen when the global maximum sulphur content to air in the exhaust of a vessel will be set to 0.5%. Only then will it be known if the best decision is made.

The other option for complying to the latest regulations with regards to the sulphur content in a vessels' exhaust is the implementation of a scrubber into the system. When the decision has been made to go forward with this tactic, a shipowner has to rely on shiprepair and conversion yards to do the work. The conversion of a vessel to prime it for the use of a different fuel for reducing emissions, mostly tank and pipework renewal, needs to be done by a shipyard. Where the new regulations and incentives to reduce dangerous emission cause headaches for shipowners and operators, it generates opportunities and work for shiprepair and conversion yards. Preparing a shipyard for conversions like these is a trend that is seen more and more.

Today: Macro

Trends happening at a company are a result of trends happening in that specific industry. These as well don't come out of the blue and are a reaction to what is happening in the world, now and in the future. Firstly the current movements are being investigated, after which the future global market trends will be discussed to scale down afterwards. The rise of the average global temperature together with the rise in protectionism are two factors that influence global decisions and trade greatly.

Global warming The regulations mentioned above are a direct result of and reaction to global warming. Criticized by some and acknowledged by many, the warming up of the earth is an event that is having an effect on many decision made by world leaders today. Climate change, the reasons for it to happen and the reactions to it happening are not only in the minds of the people making decisions. It is also affecting the lives of every person on the planet. People are getting more and more concerned about the health of the planet that they are living on. They are implicating more and more pressure on companies and industries that are having a big impact on their well-being. The measures mentioned above are just one reaction in one industry. The entire world trade and industries have their impact on the world's climate and how to minimize it is high on their priorities list. A growing world's population is described by many as the top cause for a rising change in the global climate. More people means more emissions of greenhouse gasses and a higher stress on the world's flora and fauna to feed the increasing number of world citizens.

Protectionism The next macro trend currently shaping the world, and in an important way the shipping industry, is the rise in protectionism. Mostly seen in international trade, it was already recognized in 2015 by the Global Trade Alert of [Evenett and Fritz, 2018] and mentioned again by the Global Trade Watch of the Dutch bank ABN-AMRO [van Dijkshuizen, 2018]. The latter showed that the Baltic Dry Index (Hereinafter: BDI) has fallen in the recent weeks before the publication date of the 2^{nd} of March 2018, a trend that congregated with publications on (trade) protectionism of some of the major importers and exporters of the world. The Baltic

Dry Index is a measure of the price of shipping major raw materials such as metals, grains, and fossil fuels by sea created by the London Baltic Exchange based on daily assessments from a panel of shipbrokers. It depicts the world trade without any political or other influences [Stopford, 2009]. Figure 1.5 shows the BDI with a time series of the last 3 year. A fall in the BDI means a hard time for shipping. It shows that the protectionism, implemented by the largest economies, means nothing but trouble for the shipping industry.

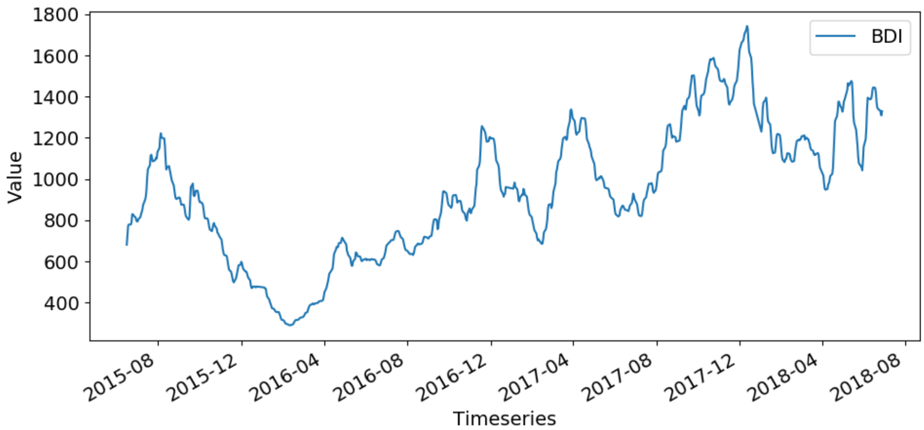


Figure 1.5: Baltic Dry Index
Source: Plot is made by author, data is taken from the Bloomberg database

Future: Macro

Two factors will be mentioned that will most likely happen in the (near) future and that might have an effect on the future shipping industry and therefore Damen in the future as well. Starting at the macro factors and zooming in gives a decent image of the future trends in the industry and where they originated. Although speculative, the future, or what most people think the future will be, is where corporate decisions are made on.

Demographic movement The first trend is of a demographic nature. It is expected and mentioned by many that the future population will not only grow, like briefly discussed above. The average age of the societies will rise and an increase in the urbanization is likely to happen. These growing cities are mostly situated at the coast because of the connectivity options. Both events are a direct result of the increasing prosperity of developing countries, where people start to live longer and tend to move to urban areas where there is the prospect of a better living standard [Dobss et al., 2012]. One example is the rise of China. Not only are many Chinese cities growing in size and numbers, farmers are being seen to move to urban areas. This trend is true for many developing countries, of which numerous are connected with a border to the sea. With this trend comes the fact that the consumer class increases, meaning that more people have incomes that are high enough to become significant consumers of goods and services. This has influences on the need for trade to and from the emerging urban areas, as well as the capacity of the (nearby) ports, harbour and shipping areas and the services they offer.

Internet of Things Innovative technologies can not be left unspoken when assessing future trends, especially not when analysing at a company where the R&D department is its backbone. Apart from alternative ways to fuel equipment for the transportation of goods and people in the future, the focus will be on digital technologies. These type of innovations are already present in many industries and they will start to gain a large foothold in the old-fashioned shipping industry and the services that are connected to it. Not only will the internet of things, connecting objects and services to the internet for smarter usage, have an impact, artificial and virtual reality can change the way the shipping industry will work. The consequences for the shipbuilding market might be more obvious than those for the shiprepair industry, but the latter do exists. One example is the reasoning behind unmanned vessels. When it is being tried to reduce dangerous collisions between vessels or vessels and other objects, the market for shiprepair yards is being jeopardized. Building vessels from lighter materials, another trend seen in shipbuilding industry, can have the consequence that the damage is more significant when a collision eventually happens, a fact that is positive for the shiprepair market. One certain thing is that digital technologies will start to play an important role globally and the shipping industry and its companies needs to find a way to follow this trend and use it to their advantage. More on this follow in the two coming paragraphs.

Future: Industry

A company's strategy is dependant on the movements in its market. This applies both for the current strategy and the future strategy, of which the latter is the goal of this analysis. Continuing on the macro events that are bound to happen as mentioned above, two trends of the shipping industry expected to occur will be mentioned in this paragraph. Current innovations in the market, focussing on the shiprepair market, will be mentioned first. Ffter this one of the biggest trends in the shipbuilding market is discussed. A small example consisting of a possible consequence of the surge to renewables finishes the paragraph.

Innovations in the shiprepair business To illustrate the industries movements, specific for the shiprepair industry, a number of innovations, currently being implemented, are mentioned together with the overall trend that demonstrates all innovations.

- *Hydrex*: A company that is specialized in underwater repairs. Repair & maintenance jobs that are being performed underwater are more complex than jobs that are executed above the waterline. The jobs that are being performed by Hydrex include hull repairs, tube seal removal and thruster repair and replacement. Previously not possible, due to improved technologies it is now possible to perform such jobs underwater, around the globe.
- *Whale Whashing*: This company has devised a machine to wash the hulls of vessels while they are in port and busy with jobs related to the hauling of their freight. With the purpose of reducing the drag of the fouling on the hull, it aims to reduce the use of fossil fuels by increasing the fuel efficiency. They market it as a carwash for ships, but not just with an aesthetic purpose.
- *Fleetcleaner*: Winner of the Dutch Maritime Innovation Award 2018, this company has build a machine and service with the same purpose as the carwash system of WhaleWhashing. Decreasing the emissions of dangerous and greenhouse gasses and increasing the fuel efficiency by reducing the drag caused by fouling on a ships hull. The work is done by a(n) (autonomous) robot that walks over the hull and cleans it in the meantime. It can operate during the (off)loading of a cargo vessel, not causing any delay in the voyage planning of a vessel.

What all innovations have in common is the fact that the service they provide does not depend on a drydock facility, where this would have been needed in het past. Cleaning the underwater area of a vessel could only be done while the vessel is out of the water, let alone repairing underwater equipment. Not needing a drydock facility would mean, apart from the missing of the cost for hiring a drydock facility a decrease in the time a vessel is off hire, increasing the time it can earn money hauling freight. Although positive for the company operating the vessel, it would mean a decrease in the competitiveness of companies operating drydock facilities.

Local Content Seen already in the increase in the percentage in turnover from building on site shown in Table 1.3 and fuelled among others by the protectionism mentioned in Section 1.1, local content is gaining in importance. Using local workers, facilities and services is more and more a factor in negotiations and a demand from clients. An example of this trend is the fact that Damen is currently involved in the tender phase of a project with the Brazilian Naval forces. Damen is teaming up with Saab to supply four corvettes, which will be build at an Brazilian yard. This would involve a Damen design together with a training and technology transfer programme. The Damen Technical Cooperation, a department of Damen specialized in building on site, is taking full advantage of the urge for local content. Although this is now purely focused on newbuilding, it is believed that the trend towards local content will be implemented in the shiprepair industry as well.

Shift in shipping content Sharmina et all [Sharmina et al., 2017] have investigated the implications of the global energy scenarios on future shipped trade. A consequence of low-carbon regulations is a decline in shipping related to the energy sector, which is a large part of the total shipping cargo. Their research combines the conclusions from previous paragraphs and looks forward to the changes in the shipping industry as a consequence of the shift from fossil fuels to renewables to battle global warming. Their conclusions will be used as an example of future scenarios where the shipping industry, including the shipbuilding and shiprepair industries, will have to prepare for. The article concludes that the trade that is being shipped over sea will change drastically. Since currently 44% by tonnes and 16% by value of international seaborne trade is related to fossil fuels, decarbonisation of the world will lead to a radical decrease in the shipment of commodities related to fossil fuels. Although the supply of natural gas (liquefied or gaseous condition), bio-energy and potentially liquefied carbon dioxide can take up some of the loss in trade, vessel distributions globally and for example the demand for bulk carriers and tankers will shift. Consequences for shipbuilders are perhaps more obvious than for shiprepair facilities. The latter however should consider focusing on changes in their services, facilities and locations to serve future market demand.

Future: Company

To conclude the evaluation, all above mentioned trends and movements come together to be applied to a possible future corporate strategy for the company itself and how they can be implemented into the R&M department of the company. Recent innovations in the shiprepair industry show that the industry is changing into a direction that leaves the standard old-fashioned way of practice. Where both the surge to the reduction of global warming and rise in protectionism shape the macro environment, using local content in every way possible is having an effect on the newbuilding industry. Following the success of building using local content, it seems logical to implement this in the R&M department of Damen as well. This would add to the need for a flexible service to counter the highly changing market conditions following the SO_x regulations that will be operational on January 1^{st} 2020. The following sections will describe how this thesis will help in finding a solution to this problem for Damen Shiprepair & Conversion.

1.2. Problem description

The problem definition consists of three parts. First, a short problem analysis combining the previous section and a continuation of the current state of the shipping industry is conducted. This analysis leads to a research objective and corresponding tasks that will be followed by the scope of the thesis.

1.2.1. Problem analysis

The first decade of the third millennium ended with a world-wide financial crisis. World trade in 2009 fell by 22.9% compared to the year before and this strong downturn affected seaborne trades likewise. Trade over sea decreased with a staggering 4.5% compared to 2008. The consequences of the crisis for the shipping market were severe, mainly because the year before had been an extremely favourable one and many investments had been made accordingly. A dent in the financial health of the shipping market was felt by the companies supporting this same market likewise. When there is fewer money being made in the shipping industry, less money is being available for the maintenance of the fleets that make up that industry. The consequence of this is that shipping operators are looking for low-cost options for the conservation of their fleet with regards to the mandatory docking periods set by classification companies. With Damen Shiprepair & Conversion having most of its repair yards in relatively high labour cost countries as said above, it is a dis-advantage in these times. For this reason as well, Damen is always looking into starting new enterprises in different area's of the world services, including its R&M department. The other reason for Damen to always be on the lookout for new yards in different locations of the world is to be able to meet the demand of its clients in terms of the minimization of the downtime of their vessels. The sometimes long route to a suitable dry dock can cost a ship operator a significant sum of time and money. The more time a vessel is available per year, the more money can be made per year. The normal way of beginning a new yard is to either build a completely new facility or to buy existing facilities and to convert them to the 'Damen Standard'. Both methods require a vast amount of resources. Not only does such an operation cost an enormous amount of capital, the time needed for this is substantial as well.

Combining the above conclusion with results from the previous section gives enough evidence to look into the possibility of using a flexible option for supplying the Damen Repair & Maintenance services with the 'Damen Standard' in new markets and area's of the world. The flexible service of a Mobile Ship Repair Facility does not only shorten the time and capital needed for deployment, it also makes sure that the services can be removed in a relatively easy way if the demand for those services is not available anymore. This last feature can be extremely beneficial, because of the unpredictable nature of the ship repair market. The plan of using a vessel or floating structure as a dry dock and repair facility has been investigated before. Although with the purpose of docking a highly specific type of floating structures, A. Hellinga and T. Terpstra, both working at the Dutch company 'Dockwise' (now called 'Boskalis Transport'), investigated the potential of using the heavy lift vessel 'Vangaurd' as on offshore dry docking facility for Floating Production, Storage and Offloading (FPSO) facilities. The practical feasibility of this operation has not yet been proven, since such an activity has not yet been fully achieved.

To investigate the potential of such a mobile service for Damen Shiprepair & Conversion, this research is being conducted. By investigating a new way of recognizing a potential market for such a service together with the economic feasibility, both on the short term and the long term, recommendations can be made regarding the total feasibility of a Mobile Ship Repair Facility. The results will help in future investment decisions that will ensure profit maximization for Damen.

1.2.2. Objective and tasks

In general, this research aims to explore the economic feasibility of a Mobile Ship Repair Facility for Damen Shiprepair & Conversion by analysing the added value of the proposed services and comparing the added value to the differences in cost with regard to a land-based facility needed to be able to supply these services. The development of a Mobile Ship Repair Facility may lead to numerous benefits such as (but not limited to): less ship emissions, an increase in fleet availability for shipping operators and potentially a lower levelised cost of energy. Ultimately it will lead to profit maximization for Damen Shiprepair & Conversion. Analysing the economic feasibility of a concept that might be able to utilize the benefits described above and possibly more leads to the following research objective;

"To make recommendations on the total feasibility of a Mobile Ship Repair Facility by gaining insights in the economic viability of the concept using a comparison between the added value and the expected costs of the to be provided services."

Achieving this objective requires multiple stages with each their own goals. A research framework has been set up to derive the stages needed, which is displayed below (Figure 1.6). The different stages will be discussed individually.

- *Background research:* Different background studies are needed to be able to perform the actual analysis at the end of the research. Some of these studies can be seen in Figure 1.6 on the left, but not all are included. Many of them serve to study the base that is needed to perform the desired ship repair services. The possible competitive advantages of the proposed concept will show up in these studies as well. The financial planning of the existing yards will be taken as a benchmark for the determination of the cost and revenue structure of the proposed concept. Together with the background studies, the comparison between both will serve as the Research Perspective and they will be one of the inputs for the case studies in a later stage of the research.
- *Quantification of added value:* The business case made in this chapter, together with simulated global demand and supply for dry docking services, serve as the input for the quantification of the added value of the competitive advantages found in the previous part. The cost structures that are distinguished before can then be compared with the added value by means of case studies that have been carefully chosen. The added value, in this case the Research Object, will in other words be compared to the Research Perspective in this stage.
- *Evaluation:* Certain evaluation methods will be used for the determination of both the short-term and the long-term (economic) feasibility of the proposed concept. This will be done for all case studies utilising the same methods to be able to compare the outcome first to each other and afterwards to the benchmarking done in a previous part. The results of this evaluation serve as input for the final recommendations that answer the Research Objective.

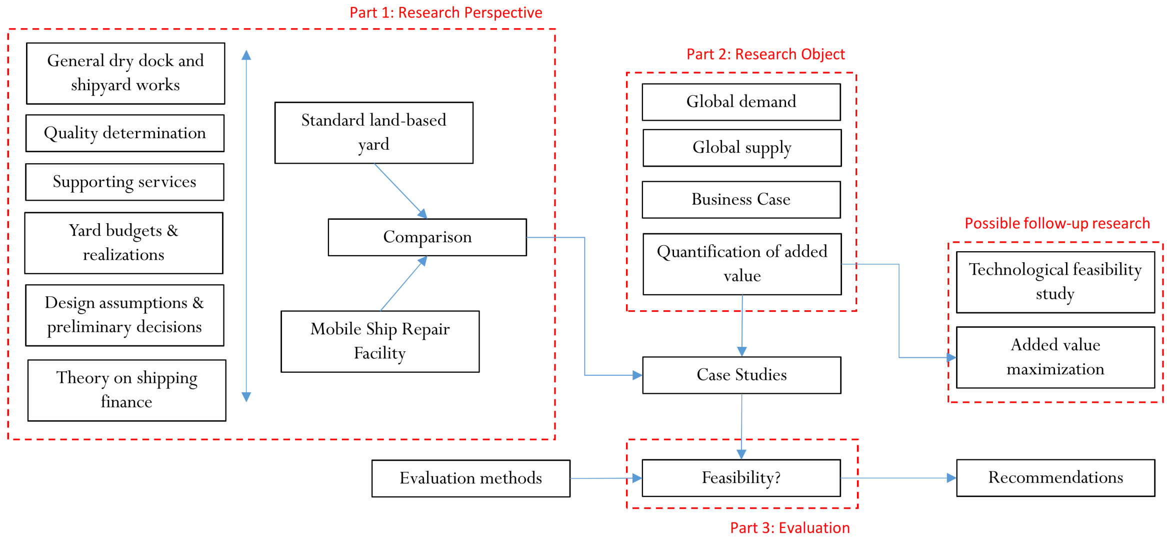


Figure 1.6: Research Framework

1.2.3. Scope

This section describes the most essential part of the research design. By demarcating the scope of the thesis, it is being assured that the needed attention is going to the right places. Firstly, the nature of the research will be given. The degree of the cost comparison and evaluation will be discussed next.

Nature of the research After expert consultation (see Table 1.1) it has been decided that the detailed technological challenges and difficulties will not be the main issue when evaluating the total potential of a Mobile Shiprepair Facility at this stage. Because of this, it has been chosen to assess the economical feasibility firstly in order to give a suitable picture of the overall feasibility of such a project. Certain technological factors that can not be missed shall be mentioned and analysed, but the financial feasibility will have the upper hand. When a negative conclusion has to be drawn, technical innovations that might change this outcome in the future can be given. Recommendations on future technical design aspects will only be briefly mentioned because of the fact that this research is still in the concept stage and thinking about the detailed design of the facility itself would skip important stages. This means that a detailed design of the actual facility is also not included in this research. Certain recommendations will be made based on the findings of this report and the thought process during the build up of the concept.

Relative vs. Absolute Due to time and resource limitations, making a cost comparison based on the relative changes in cost will give the highest possible outcome. Exact numbers on the increase or decrease of the cost associated with a change from a land based facility to a mobile facility will require more in detail research that should be conducted when the feasibility of a Mobile Shiprepair Facility has been proven and the decision has been taken to go forward with the project. This goes for the determinations of the capital expenditures as well.

1.3. Research methodology and thesis outline

This section describes the approach of this study. It explains in which way the objective and its tasks are handled in every particular chapter. Additionally, the goal of each chapter and the connection of the individual chapters are discussed. Where this first chapter introduces the problem description and the resulting research objectives, the second chapter introduces the concept that will be proposed to fight the problems that have been found. To start of the description a summary about the industry in which the concept will be operating shall be given to provide the reader with a needed background for understanding the final description. With this summary comes a statement on the essential services, equipment and certificates that the proposed facility will need to perform its tasks. This will all be done to allow for a better understanding of the needs that will be fulfilled. Chapter two will be concluded with the concept proposal, which will be described by individually setting up the words that are given to the concept; "Mobile Ship Repair Facility".

The concept will be the first in its class, but it is based on existing facilities. Damen Shiprepair & Conversion owns numerous shiprepair yards all over the globe of which the financial numbers can be analysed to determine the cost structure that makes up both the overall yearly picture and the finances of individual projects as well. Doing this while keeping the differences between a land-based shiprepair yard (existing facility) and a mobile shiprepair yard (proposed concept) in mind produces a proper base for the determination of the cost structure of the concept. Apart from the cost analysis, a comparison of the production value, the term used in the financial numbers maintained by the company itself for the revenue, has been made. Together they provide a benchmark for the concept, that should at least be improved to reach feasibility. The second part of this analysis concerns the finances of shipping companies, which are possible clients for the proposed concept, to determine the percentage of their annual cost that is reserved for the maintenance of their vessels. This will be done to see where and if there is any room for improvements that can be filled up by providing the proposed services using a mobile facility.

A benchmark method needs an analysis to compare it to, which will be the subject of chapter four. The indexing of cost items that have been described for benchmarking the cost and revenue structure shall be (mostly) maintained in providing the method for establishing the (relative) cost and revenue structure for the proposed concept. The model that connects all cost items will be described in this chapter. Not only will the model result in a yearly balance sheet, it will be used for the answering of the research objectives as well. Both the short term (yearly income) and long term (Net Present Value) feasibility of the concept can be determined with the results coming from this model. Two different sensitivity analyses shall be introduced to finalise all.

The model, described in chapter four, needs case studies to be tested and to evaluate the concept by means of the sensitivity analyses that have been introduced. Two studies have been chosen that differ in such a way that both the model and the concept can be tested in a proper way. Both case studies will be introduced with a short market study after which certain variables will be fixed and the distribution for the others will be established. The financial model can then be run. The observations that result therefrom will be the input for the final chapter.

To conclude the research, final recommendations will be made on the total feasibility of providing shiprepair services using a mobile shiprepair facility. The inputs from the previous chapters shall be the bulk of the base of these conclusions. Both a negative and a positive answer to the overall feasibility will be a satisfying one, of which the former is being hoped for. Possible future research subjects shall be proposed, either in the form of the further (detailed) design of the facility/concept for a positive answer or possible ways of improving the concept for it to be feasible when the answer would be negative. Before any answers can be given, the mobile shiprepair facility concept will be developed.

2

Development of the MSRF concept

This chapter provides a description of the proposed mobile shiprepair facility that has been introduced in the previous chapter. By firstly supplying an introduction to the shiprepair industry, together with its characteristics and the services needed to supply its clients with the desired results, a basis will be build for this chapter and the next. This basis will be completed by analysing basic shiprepair facilities and the quality (together with the maintaining of these qualities) of the services to provide.

2.1. The Shiprepair Industry

The shiprepair industry has a certain amount of characteristics that make it both an interesting and complex industry to work in. Some of the characteristics have been described in the previous chapter already. Quoting Jan Kees Pilaar, the managing director of the recently bought shiprepair yard Damen Verolme, the industry is a highly competitive market with high risks, a high fluctuation in work load, where time is money. Excelling in this industry requires a decent amount of flexibility and creativity because it involves changing requirements and most of the time unreliable work scopes. The word that summarizes the industry is 'uncertainty'. One side of the industry contains more uncertainty than the other two, but all three must work hard to, on one hand, secure enough work to fill their docks and, on the other hand, manage the mostly currently low margins on the work being done. Firstly the 'repair' side of the industry will be analysed, after which the 'maintenance' side and the 'conversion' side shall be discussed. This analysis gives an understanding for the reasoning behind the preference chosen for the proposed concept. The different sides and their characteristics have been visualized in Figure 2.1.

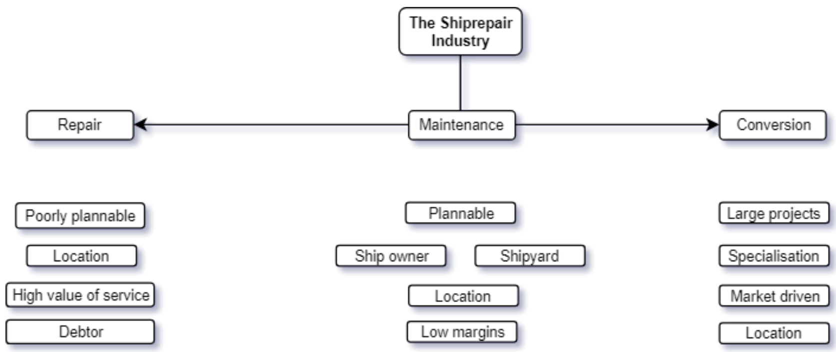


Figure 2.1: The Shiprepair Industry
Source: Own composition, based on both the work of [Dussan, 2007], expert consultation and the experience generated during the internship

2.1.1. Repair market

The left side of the diagram in Figure 2.1 describes the first term of the shiprepair industry. By briefly discussing the individual characteristics, an analysis can be made of this part of the industry. The nature of the industry is clear at the end of this section and a proper comparison can be made with the other sub-industries.

- *Poorly plannable:* One of the major differences regarding all sides of the industry is related to planning. Being an important part of every business, it is not desired to let the planning of the activities that earn your business a revenue depend on luck. For the shiprepair side, this is partly the reality however. Although some decisions can help luck, collisions between ships or ships and another obstacle are extremely hard to forecast. This has a number of consequences for the management of a shiprepair yard, of which the two most important ones will be discussed.

  The first consequence is related to the docking capacity of the yard. When a collision happens that needs immediate attention and requires a dry dock, a shipyard can only be chosen when it has a dry dock available that meets the dimensions of the vessel or floating device that needs repairing. One of the decisions to be made is to either leave one dry dock available at all times and hope for a collision to happen near the yard, or to always fill the docks and hope for a collision to happen when no docking is scheduled in a suitable dock. For Damen, having several shipyards including dry docks with different dimensions in for example North-West Europa, it is easier to play with this than for a single shipyard with limited resources and facilities.

  The planning and employability of the workforce is the second issue related to the uncertain and unpredictable nature of this side of the industry. Mentioned before already (Section 1.1), the amount of work needed depends on the occupation of the dry docks and type of work needed to empty the docks again. The division between the yard's workforce and third party labour depends partly on the distribution between jobs related to unplanned repair work and planned maintenance jobs. Both consequences and the reactions to it depend on the location of the yard, both in a positive and negative way.

- *Location:* Being as unpredictable as described above, choosing a location that suits the repair market well is a difficult job. Factors like busy shipping routes or a large trade harbour nearby can be an advantage, as well as having limited competition in the area. Using data on previous collisions might give information about areas where the chance of an accident is relatively high, but the exact location can never be planned. Companies that have a repair service for jobs that do not require a dry dock need to be able to act swiftly for a flexible service.

- *High value of service:* The main reason for companies to rely (partly) on the business of repairing vessels is the high value of that service and the big margins that come with it. When a vessel desperately needs the help of a shipyard and its dry dock, it is prepared to pay more for that service than it would when the jobs are planned ahead and for example the shipping schedule has been planned around the docking. The margins of a shipyard for jobs coming from a collision is higher than for scheduled work, which accounts for the difficulty to rely partly on luck to occupy the docks.

- *Debtor:* The party responsible for the financing of the work is different for this side than the others. Most of the vessels or owner/operator of these ships are insured for a number of occasions, of which collisions and accidents that result in damage to the vessel is one. The costs incurred are to be paid by the insurance company under the pre determined boundaries, which results in a slightly different scenario then when the shipowner has to pay for the work itself. Most of the time, work being done as a result of the collision and thus paid by the insurer will not be mixed with planned maintenance work.

To summarize, luck (or bad luck in the case of the clients) plays an important role. For companies that repair vessels without the use of a dry dock, flexibility and the ability to move to the vessel with their equipment is vital. Businesses that are equipped with a dry dock can get lucky when the location of their yard is well situated. High margins can be earned on the back of an uncertain and unpredictable occupation rate of a company's facilities or services.

2.1.2. Maintenance market

The middle of the diagram contains the information and the characteristics of the side of the industry related to planned maintenance work. The gross of the work done at a shiprepair yard falls under this type of jobs. Opposite against the repair side, this side of the industry can be characterised by well planned work that is being regulated by independent agencies and (currently) low margins for shipyards. Before individually discussing each characteristic, some general information about the mandatory surveys that vessels are bound to undergo will be given.

The International Association of Classification Societies (Hereinafter: IACS) is the umbrella organization that covers around 90% of all commercial tonnage involved in international trade worldwide by the use of its members."Dedicated to safe ships and clean seas, IACS members make a unique contribution to maritime safety and regulation through technical support, compliance verification and research and development [IACS, 2015]. 'Class', which is a commonly used word that depicts a classification society, writes rules and regulations that aim to ensure the building integrity of all vessels. By complying to these rules during the building phase, a ship can be assigned a certain type of classification that shows the quality of the build. More importantly for this specific industry, the assigned classification society subjects each classed vessel to a specified programme of periodic surveys after delivery. These are based on a five-year cycle and consist of annual surveys, an intermediate survey and a class renewal/special survey. Annual surveys may take from several hours to a few days to complete, depending on the type and age of the vessel, and do most of the time not require drydocking services. The special survey is intended to assess whether the structural integrity remains in conformance with the standards contained in the relevant Rules and requires out-of-water examinations, with a small number of exceptions, and takes roughly between the 7 and 14 days. According to the type and especially age of the vessel, drydocking may also be required for the intermediate survey that is being held approximately half way between special surveys and will keep a vessel for anywhere between three and five days in dock. This opens up opportunities for shiprepair yards, with and without dry docks. The Rules and their time stamps are to be kept on a strict base, which makes the planning of such events quite manageable.

- *Plannable:* Because of the strictness to conduct the surveys within a certain time frame as described above, shipowners have to plan these events ahead and incorporate them into their sailing schedule. This has both consequences for the planning of a shipyard and shipowners. After speaking to persons responsible for the vessel management of several Dutch shipowners (Table 1.1), it became clear that two different strategies are being applied when planning (special) surveys[1]. The difference between both strategies is the priority; the choice of shipyard to do the work on one side and the shipping schedule on the other side. The common factor is the target of shipowners to conduct the total operation as cost effective as possible, which can be interpreted in a number of ways as well. Some yards perform better work than others, which is most of the time represented by the price they ask for those services. Being dependant partly, for both the quality and price, on the location of the yard (see Section 1.1), the choice for a shipyard and the quality and price of the work it performs can be the leading factor when determining where to conduct a special survey. When this is the case, the sailing schedule of the specific vessel needs to be adapted to the location of the yard. More boundary conditions like the availability of goods to ship, available charters and more of such are of influence of this decision. That is why the location of a shipyard is of high importance. Other vessel managers prefer to prioritize the sailing schedule when deciding on a yard to conduct their special survey. Influenced among others by the type of charter agreements the vessel is sailing on, a shipyard being in the same area will be chosen that is able to operate above the minimum requirements set by the vessel managers. Minimizing the time needed to sail to a yard is tried to be kept to a minimum to cut cost. What to prioritize is different for every single vessel on every single survey, but always planned and discussed with the chosen shipyard beforehand. This means that the occupation of a yard's docks is known earlier than for the repair side. It is even possible to trace the survey dates and plausible locations of vessels and build commercial actions around this data.

[1]The interviews have been conducted without a strict schedule of questions and in the presence of Klaas Kuper, a sales manager from DSC. This style of interviewing has been chosen because of the open nature and resulted in critical discussions that yielded useful answers. Because of the open nature, no exact records have been taken of the interviews.

- *Location:* With both priorities, the location of a shipyard is vital for its success. When it is located next to a large port or busy shipping route, both options can lead to that specific shipyard. This is not only because of the large amount of ships that come with a busy port, but mainly depends on the fact that a vessel has to be empty to go into a dock. When the yard itself is the priority, having the availability of quality charter contracts nearby gives the yard more value. If the priority is with the sailing schedule, being around a port that is included in a high percentage of those schedules increases the change for vessel managers to visit your yard. A different side to the importance of a location is the supply chain of parts and third party labour and the speed and price at which this is available. It is not uncommon that unforeseen problems surface during a maintenance period and quick action, from both the yard and the supply chain management, is required.

- *Low margins:* Due to the fact that most work done during a special survey does not necessary consist of specialised or difficult jobs, the margins on this type of work are relatively low. Also based on the large amount of time available to plan all events and the generally high competition, it is difficult for a yard to ask a price for their services that includes a high margin. Real numbers are hard to come by and it will unfortunately not be able to provide them. The low margins however are covered by the possibility to plan ahead and manage a high occupation rate of the docks that keeps the workforce busy.

To summarize, the fact that classification societies make it mandatory for vessels to renew their class every five years and to conduct other surveys within a shorter time frame, a constant flow of business can be generated. Choosing a location that suits the requirements from vessel managers should yield a high occupation rate for projects that generally have relatively low margins.

2.1.3. Conversion market

A market that is different from the rest and is currently seeing a dramatic increase in projects is the conversion market. As can be seen in the name of the company, Damen Shiprepair & Conversion, there is a clear distinction between on one hand the repair & maintenance side and on the other hand the conversion side. While the specifications for the former are in many ways standard, partly because of the rules set by class, the latter offers mostly so called 'one-of' projects. The following characteristics describe the nature of this market.

- *Large projects:* 'One-of' projects are characterised by their size. Most projects consist of the conversion of a vessel in terms of its use and the services & facilities it needs for that. The conversion of a research/survey vessel to an expedition yacht is one example. In this case, the use of the vessel is not being altered that much, but the accommodation and facilities will receive an upgrade. A second example is the Bokalift 1, operated by the Dutch company Boskalis. This vessel used to be a semi-submersible heavy lift vessel and it is being converted into a self-propelled crane vessel with a 3000 ton revolving crane. Although being used for roughly the same purpose of hauling specialised freight, the conversion enables the company to serve a different upcoming market. These projects characterize themselves by the size and length of the events. They are more cost effective than a new-build project, but they are still extremely large in terms of cost and time involved. The latter goes not only for the time the vessel is at a yard, the engineering beforehand takes up at least the same amount of hours.

- *Market driven:* Conversions of vessels happen due to a changing market. A change in a company's strategy might be a leading factor as well, this is however the result of a market that is evolving as well. The rise of the offshore wind industry is a fine example. The Bokalift 1 has been outfitted to install jackets and monopiles for offshore wind turbines, a scene that is not uncommon in today's industry. The increase in the size and therefore weight of offshore windfarms results in vessels and jack-up barges to increase their size and lifting abilities as well. The Aeolus, a transport and installation vessel operated by the Dutch company Van Oord, has seen a dramatic increase in lifting power done at a Damen yard only three years after is has been launced to keep up with market demand of bigger wind turbines. Identifying the (future) needs of a market and making a yard ready for this can give a yard a head start when the market trend is actually happening.

- *Specialisation:* The market changes due to the new SO_x regulations set by the IMO have been mentioned before, including the possible advantages for shiprepair yards and the sub-contractors involved in their projects. This type of projects can be classified as conversion projects as well. One way of positioning your company into the market is by choosing a specialisation. Installing (in house engineered and manufactured) scrubbers for vessels to comply to the new regulations as a specialisation might give that shipyard a competitive advantage over other yards. Increasing the lifting power and size of jack-up barges, upgrading the lifting capabilities of cranes on lift vessels or the conversion from fossil fuels to Liquefied Natural Gas (Hereinafter: LNG) or other alternative fuels can be chosen as a specialisation as well. The more specialised and higher quality service, the higher the value of that service can be.

- *Location:* Due to the specialised work involved in such projects, yards rely on third party sub-contractors to do a large part of the job. Having high quality services available close to the yard increases the attractiveness of that yard for clients. The shiprepair yard of Damen located in Schiedam, the Netherlands, is a decent example. Surrounded by Huisman Equipment, a market leader in large cranes, and Mammoet, a company specialised in moving large objects, it is surrounded by high quality companies that can assist in the conversion projects that the maritime market needs today.

To summarize, large projects that ensure a high occupation rate of the docks and facilities of a yard and involve specialised services characterize this side of the market. Timely projects, both in time spent at the yard and during the engineering phase for the client and the shipyard, can yield high margins. Especially when the shipyard favours a good competitive advantage over other due to its choice for the specialisation into specific market needs.

The choice for the sub-industry to target with the new concept will be made in the last section of this chapter using the conclusions found above. One of the factors to think about is the structure of the entire industry and the competitive advantage of the concept and within which sub-industry it can be maximized.

2.1.4. Competitive structure

Based on the competition model proposed by Porter in his book 'Competitive Advantage' written in 1980, Robert Castrillon Dussan [Dussan, 2007] composed the competitive structure of the shiprepair industry. His structure illustrates the industry quite well, including the five forces use by Porter [Porter, 1985]; Competition, Buyers, Substitutes, Supplier and Entrants. All will be discussed briefly based on the findings of Dussan.

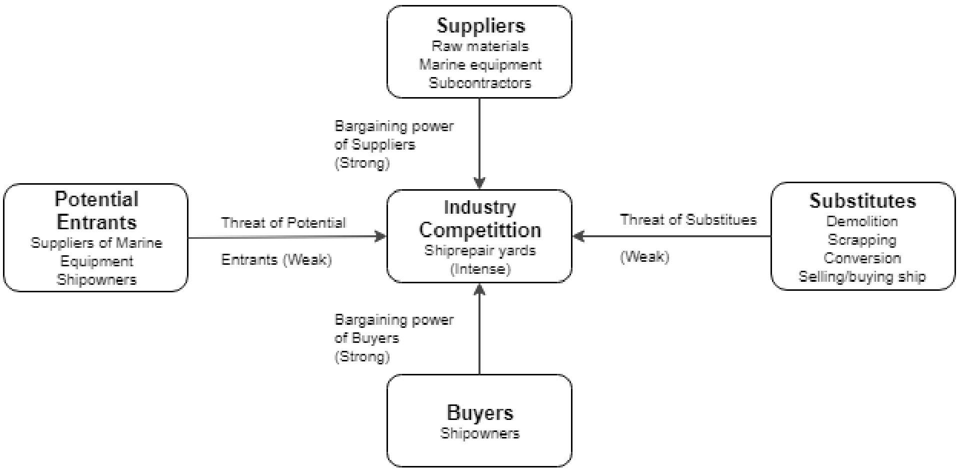


Figure 2.2: Competitive structure of the shiprepair industry
Source: [Dussan, 2007]

- *Competition:* Within the shiprepair industry, competition depends largely on factors described above. They include: location of the yard (number of competitors and proximity of major ports), price and quality for the service they provide and the regulations that apply in the area. The state of the shipping industry and therefore the money available for the maintenance of the worlds fleet influences the decision for a shipyard greatly, because it determines which factors are being prioritized over others.

- *Buyers:* It is not surprising that the buyers in this perspective are the shipowners. Shipowners see the R&M industry as a key activity to operate theirs ships efficiently and as a vital part in achieving productivity and profitability. For some shipowners at specific times however, a stop at a shipyard can be seen as a mandatory unwanted procedure. From a shipowners perspective, six fundamental considerations can be identified; Safety and seaworthiness as a legal obligation, extension of the economic life of the ship, improvement of the ship's resale value, performance in carrying cargo, efficiency on operating expenses and the environmental impact of a ship's operation.

- *Substitutes:* The substitutes for a shiprepair yard can be categorised into two sides; Inside and outside of the industry. Companies that offer the same sort of services for which a dry dock or visit to a yard are not needed have been mentioned before already 1.1. The options other then a mandatory visit to a shipyard are scrapping or selling of a vessel. The conversion of the vessel is another option, this involves a shipyard as well. Factors influencing this decision can be: Financial status of the company, scrapping and new-building prices and the state of the second hand ship market.
- *Supplier:* Crucial suppliers in the shiprepair industry are the suppliers of steel, spare parts of all sorts of engines and maritime equipment. The reason that the bargaining power of this force has been qualified as strong is the option for them to integrate forward into the supply chain. A trend that might be stronger in the new-building market, but relevant in this industry as well. Setting up service networks around the world makes them less dependant on shiprepair yards requisitions.
- *Entrants:* Since the resources needed to start a new shipyard are substantial, the thread of new entrants in the form of new yards is weak. Supplier and shipowners tend to work together sometimes to bypass the service of a shiprepair yard and can in that sense be categorised as an entrant. Regulations prevent certain ways of integrating in house personnel of shipowners into the workforce on a yard. This decreases the bargaining power of the form of new entrants based on the cooperation of suppliers and shipowners.

To summarize, due to the active internal competition within the industry itself together with the strong bargaining power of the buyers that goes with it, the margins are quite low. Adding the fact that suppliers have the power to make deals with a shipyards client directly makes it a tough business to work in. Specialising the yard for market driven activities to suit the market needs the best way or to be cost effective for the clients in all possible ways generates the biggest competitive advantage and makes the market an attractive one for the proposed concept.

2.2. Shiprepair yard essentials

To understand the processes of a shiprepair yard for further implementation, all significant facilities, services and boundary conditions have been investigated. The mapping of these services for different Damen shiprepair yards around the world will be discussed firstly, including the distinction between having these services and facilities based on in-house expertise or third party experts. The certification applicable to businesses that proof a certain level and consistency of quality shall be briefly mentioned secondly. Implementation of these findings and the connection with the cost assessment part of this research will be analysed afterwards.

2.2.1. Mapping of facilities

Table 2.1 displays the facilities and services that are essential for nearly all projects done in the dry docks of a shipyard, both for small jobs and larger conversion works. For different yards it shows whether these services are present on the yard itself or the specific yard relies on subcontracting it out to third part experts. Three yards have been chosen that differ from each other in such a way that the right information can be taken from the differences between them. For clarity; 'DSR' stands for Damen Shiprepair Rotterdam, 'DSAm' represents Damen Shiprepair Amsterdam and 'DSCu' stands for Damen Shiprepair Curacao. The 'X' means that the specific yard uses own or hired labour at the yard to execute the work and the 'O' means a reliance on third parties to perform the jobs. Below are listed several points that can be concluded from these findings together with several explanatory notes.

1. The first observation is related to the difference in the percentage of in-house expertise on each yard. The highest percentage belongs to the yard in Curacao and the Rotterdam yard uses the most third party labour looking at the facilities on the yard. A note has to be made that the paint workshop in Amsterdam is not actually on the yard itself, but it belongs to overall sub-company running the yard. Taking this into account, the percentages for both DSR and DSAm can be considered the same. The reason that their percentages are lower than the one from the yard in Curacao is the location. When

companies that specialise in a specific niche surround the yard, a lower dependency is needed on own personnel to do specialised jobs. This does not only account for the availability of the service, but the time in which it can be done and transported as well. When such services are not available it can be cost efficient to perform them on your own yard, even if that means that the services and facilities might be idle from time to time.

2. It is beneficial to explain the difference between the facility 'engine workshop' and 'shaft machining', not only for the overall picture but also to understand the above observation and the differences between yards and the possibilities for the investigated concept. The workshop for engines incorporates the facilities to perform minor lathe and milling jobs and can be described as semi-specialised. The facilities needed for (propeller) shaft machining require highly specialised lathe machines and personnel and the machinery tends to be larger than in a regular engine workshop. Although primarily used for the machining of propeller shafts, it is a vital part of the maintenance schedule of a ship and thus for the provided services of a repair yard. Being more isolated than the others, the yard in Curacao needs this service to be in-house.

3. Some services are being subcontracted out by every yard. These involve specialised jobs and are not required for every job. Some are only needed for a short time during the entire yard visit (scaffolding) and others have a slight chance of not even being included in the work schedule (Electrical works & isolation/carpentry/upholstery). Because the latter are only minor but essential for a high quality service, it is vital to have them near. Not needing specialist all the time, having them around on a mobile platform might be extremely cost-inefficient. Trying to solve these issues while maintaining a quality service might require personnel capable of performing multiple jobs. More on this will be mentioned later in the report.

4. Included in the environmental services is the storage, cleaning and disposal of hazardoes materials. This can be the gasses that come out of the fuel and oil tanks, the grid that is used to de-paint a vessel and all garbage that can not disposed in a normal trash can. The rules about these items is quite strict and the moral standard of the Damen group is taken into consideration as well.

Table 2.1: Yard facilities & Services

Facility/Service	DSR	DSAm	DSCu
Pipe fittery	X	X	X
Steel cutting workshop	X	X	X
Surface/tank cleaning workshop	O	X	O
Warehousing	X	X	X
Electrical workshop	O	O	X
Engine workshop	X	X	X
Scaffolding	O	O	O
Shaft machining	O	O	X
Isolation/carpentry/upholstery	O	O	O
Cranage	X	X	X
Docking facilities	X	X	X
Environmental services	X	X	X
Total in-house	7/12	8/12	9/12

These services and facilities serve as a base for providing the right service to clients to cater their demands. Most repair & maintenance jobs involve the bigger part of the above mentioned services and they would need to be available as a minimum for a new yard, including a possible mobile shiprepair facility.

2.2.2. Certificates

To ensure a global standardised playing field, the International Organization of Standardization (Hereinafter: ISO) produces standards that give world-class specifications for products and services to ensure quality, safety and efficiency [ISO, 2018]. These standards show clients a willingness to strive for a high level of quality that can be measured globally and is recognised easily. High quality shipbuilding and shiprepair is a trademark of Damen and one of the ways to show this fact is the dedication of making sure that every Damen yard qualifies for having certain ISO standards. The two standards that are required as a minimum by Damen will be discussed.

ISO:9001 "ISO 9001 is a standard that sets out the requirements for a quality management system. It helps businesses and organizations to be more efficient and improve customer satisfaction" [ISO, 2015b]. It builds on seven quality management principles, that are not only useful for a client's view of the company but help the overall management as well; Customer focus, leadership, engagement of people, process approach, improvement, evidence-based decision making and relationship management. Complying to these principles as a company means that potential clients know exactly what to expect from a shipyard and its management in terms of the quality of its service and more importantly the consistency of the quality. In other words, complying to the ISO 9001 means the promise to clients that the quality of the work today will be the same as of that of work in the future.

ISO:14001 "ISO 14001 is an internationally agreed standard that sets out the requirements for an environmental management system. It helps organizations improve their environmental performance through more efficient use of resources and reduction of waste, gaining a competitive advantage and the trust of stakeholders" [ISO, 2015a]. In a world that is becoming more and more aware of environmental issues and the consequences of their actions related to the environment, this standard gives potential clients an ensuring feeling about a company. Some clients might even make it a rule to conduct business only with partners that comply to such standards in order to maintain their own green standard.

The aim of Damen is to have all yards, newbuilding and repair, to comply to both standards. A potential new yard, being a 'standard' land-based or a mobile facility, should do as well. It is partly what sets Damen apart from the competition in terms of quality and the service that it provides.

2.2.3. Implementation of learned facts

The understanding of the (quality of) services and facilities required and the different ways of providing those connects to the further research in a number of ways. The physical design of the actual mobile shipyard depends naturally on the facilities to serve its clients demands, this is however not yet part of the research. To determine the economic feasibility of the concept it is necessary though to get a grip on both the amount of capital needed to finance the entire project and the direct and indirect cost of running a yard. The facilities needed to supply the required services are part of this process and part of the operational feasibility that comes later in the process. For this reason, mapping the yard facilities in the beginning of the concept phase can be beneficial. A more in detail examination can then be executed at a later stage, including exact pricing.

A more fitting connection at this stage of the research is the implementation of the learned facts into the benchmark of cost and revenue that will be the subject of the next chapter. The differences in the way a specific yard serves its clients can be the cause of a variation in costs and income. These differences can impose both positive and negative effects that can be exploited in many different ways into the design of the concept of a Mobile Shiprepair Facility.

2.3. Mobile Shiprepair Facility

This section describes the concept of the Mobile Shiprepair Facility of which the economic viability is being investigated in this report. The concept is based on the findings in the previous chapter and above sections and illustrates the services that the proposed facility will be able to perform without going into too much detail in terms of its design. It is extremely crucial to state that the idea is still in the concept phase and no design decisions are to be made at this point. Recommendations about the design and technical aspects will be made at the end of this report based on the conclusions made in the research. The concept will be described based on the map in Figure 2.3. The concept on which this research is based will be the subject of this section. The term 'Mobile Shiprepair Facility' will be broken down in parts by describing the conceptual choices related to every individual word. Again will be stated that specific design choices or technical aspects that need further investigation will not be mentioned and postponed to a next phase in the research based on the recommendations from this report.

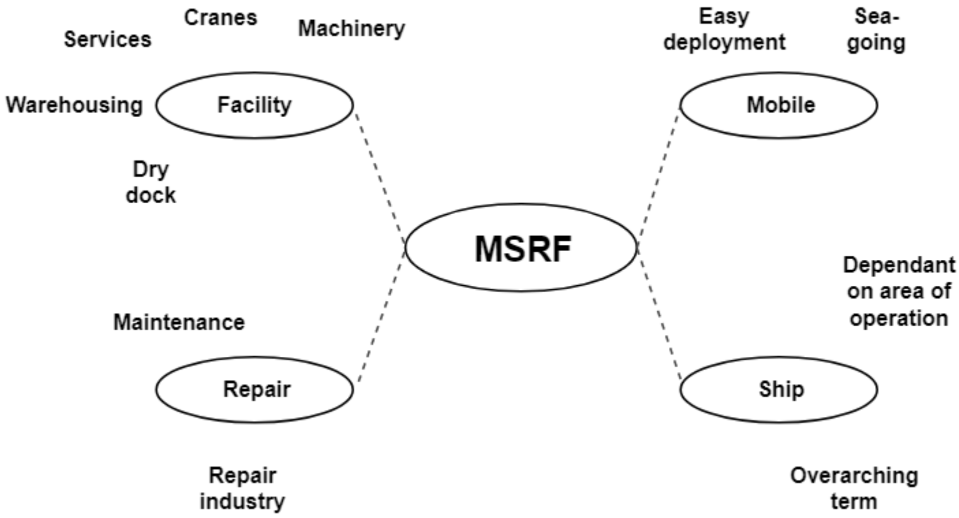


Figure 2.3: Mobile Shiprepair Facility concept

Mobile The first part of the describing term relates to the mobile nature of the concept. Being the most significant difference compared to a 'standard' shipyard, it is crucial to supply a fitting description of the advantages of this characteristic based on the findings stated in the previous sections. The ease of deployment and the flexibility of the entire service is mentioned first, followed by the difference between a floating dry dock and the proposed concept.

The main advantage of this concept is the fact that the deployment of an entire shipyard is being made accessible. Whenever the shiprepair service is needed, it can be given. Where the resources (capital, time, workforce etc.) needed for the setting up of a 'standard' shipyard are extensive, bringing the MSRF to its clients is much more efficient. When a potential market or specific client/project has been identified, it is just a matter of telling the captain where to sail. This comes with the fact that when a market or area of deployment is becoming unfavourable, it is just as simple to go somewhere else. This design philosophy should be in the back of the minds of everybody involved in the concept.

Mobility of a facility that can service the underwater area of a vessel can be achieved with a floating dry dock as well. These type of docks can be towed or shipped to a different yard quite easily. Towing a floating dry dock has its limitations, shipping a dry dock has less. An example of the latter is the shipping of 2 floating dry docks from the Netherlands to Curacao done by Damen in recent months using a semi-submersible heavy lift vessel. The characteristics of both methods is the fact that an additional party is involved. The amount of mobility, and the possible dependency on third parties, will rely on the chosen case studies and needs to be assessed individually. Self-propulsion can be an option but the added value of this should then outweigh the associated cost.

Ship The business where this concept will be operational in is going to be the shiprepair business. A ship is being defined as "A large boat for transporting people or goods by sea" by the Oxford dictionary [Hanks et al., 2010]. This means that a large proportion of the floating structures that need repairing can be housed by the facility. The word 'ship' is the overarching term that is being used in all the descriptions for the industry, which is the reason why the word is used at this point as well.

The type and size of the to be serviced vessels depend on among others the area of deployment, the eventual size of the facility and the type of services that can be supplied. This is a sort of iterative process where apart from the length and width of the facility (which would be able to be subjected to an increase or decrease as well), all can be adjusted according to the results of a market research into the most fitting way of deployment.

Repair This individual part will be related to the specific market within the shiprepair industry where the concept will operate in and will be linked to the findings summarized in Section 2.1. Partly because of the complexity needed for jobs within the conversion industry, it is chosen to focus on the repair and maintenance industry to find work for the MSRF. Although repair jobs are difficult to plan ahead, both in terms of workforce and third party material needed, the flexible nature of the concept can be exploited in this industry. The main market, especially in the early stages of the operational time of the concept, will be the maintenance market. Fairly simple work, planning that can be done some time ahead and the same jobs that come back at most maintenance periods related to the mandatory stops for class renewal make this market the most suitable for the MSRF concept. All reasons mentioned above make it a market that experiences a huge amount of competition, but it is believed that the competitive advantage that can be generated by the flexible employability is large enough to compete.

Facility No decisions will be made yet concerning the number and capacity of the individual facilities. The ones that are substantial for operating as a shipyard shall be mentioned however. Based on the findings in Section 2.2 it is possible to identify which type of services a shipyard needs to fulfil the minimal duties required by its clients. The primary facility is the dry dock that makes it possible for the concept to put a vessel out of the water. The techniques used for this service have been in place for a long time and the one used on the MSRF will probably not differ too much from the existing ones. The dimensions (length, width and depth) shall be based on a more thorough market study that incorporates the size and type of the grand proportion of the vessels sailing in a specific area or the niche market that will be used for future clients. The method of dry docking is part of future research as well. To maintain the high quality of the service and low environmental footprint that is sought after, the dry dock should not pollute the surroundings of the MSRF in any way. By being able to have vessels safely moor alongside the vessel, either before/after the docking or just for simple (voyage) repairs, more income can be generated.

To maintain the independence and the flexible nature that is the advantage of the concept, it should be able to perform its own lifting operations. The cranes should be capable enough to perform lifts needed to maintain and repair the vessels that come into the dock are essential for the entire concept. The capabilities of course are dependant on the size of the concept and its dry dock and the potential vessels coming in. Incorporating the cranes into the design can be done in multiple ways. The eventual solution will however be done in future research having the flexibility of the cranes in mind.

The services needed tot be able to perform the required jobs and the machinery that come with these services should be incorporated into the concept as well. The type and capacity can be flexible, depending on the area of operation and the degree of independence related to it, but a certain base of services should always be maintained. This base has been identified above and involves services that are needed for a high percentage of repair jobs. One of these that should be highlighted is the warehousing of spare parts. Done in different ways for different yards, a supply of frequently used elements aids in the speed and quality of the repair service a yard offers. If the goal is to maintain a certain degree of autonomy, the warehousing should be adapted to that. Whether this means a bigger warehousing facility or an adapted supply chain management depends on the area and type of deployment. A possible different way of thinking is a new way of the relationship with clients, where the spare parts, if known before-hand, can be transported by the future clients.

MSRF All comes together in the MSRF concept. A mobile shiprepair facility that can operate autonomously and has the competitive advantages that it can sail to its clients and provide a higher efficiency and therefore minimizes the time needed for the mandatory docking periods of the vessels of its clients. Being part of the larger Damen Shiprepair & Conversion operation, it adds to the already capable service that the company provides. The flexible nature of the concept suits the currently changing market and this report provides recommendations for the total feasibility of the concept based on the economic viability.

The methodology to assess the economic feasibility starts with an analysis of the cost and revenue structure of the existing Damen Shiprepair & Conversion yards. This analysis then serves as a benchmark for the rest of the research, in particular the same analysis (cost and revenue) made for the proposed concept.

3

Establishing of a cost and revenue benchmark

Before being able to analyse the advantages of the proposed concept it is important to analyse the services that the concept will be compared with. In this case, those services are the shiprepair services that are currently provided by the existing yards. These yards are land-based, this is the main difference with the proposed concept. This chapter includes both the cost and revenue benchmarking for the repair yards currently operated by DSC&C and shipping companies. The latter are analysed because they will ultimately become the clients of the proposed concept, but a start will be made with the existing Damen yards.

3.1. Shiprepair yard finance

Understanding the financial situation of a shipyard and possibly the new concept starts with looking at the overall shiprepair yard finance, or at least at how these yards have been budgeted for the current year. Based on the preceding years, the budget for 2018 for all Damen Shiprepair & Conversion yards provides a clear image of the different cost associated with running a shiprepair yard. Comparing the budget of multiple Damen yards makes it possible to determine certain factors that can be used for optimizing the theoretical and physical design of the proposed concept based. By focussing on the budgeted revenue, later in this report, a more in detail examination of interesting factors can be executed from which meaningful conclusions can be drawn to further improve the design. A start will be made with the 2018 budget and the lessons to be learned from it for three Damen shiprepair yards that have been chosen for their similarities and relevant differences that will be elaborated on later in this chapter.

3.1.1. Cost budgeting of relevant existing yards

Figure 3.1 shows the 2018 budget for the yards located in Amsterdam, Rotterdam and Curacao including a comparison made with the budgeted numbers of the total DS&C group. The comparison has been done using normalised values in two steps. This means that, for a specific yard, the value for a cost item has been divided firstly by the equivalent value of the total DS&C group to find the percentage of that cost item to the total cost of the entire DS&C group. To be able to accomplish a satisfactory comparison, the result of the first step is then divided by the normalised value of the production value of that specific yard to counter for the differences in size. The material cost for DSR will be used as an example; Dividing €1.415.000,- by €13.274.343,- yields 0.11, which is the result of the first step. The second step divides this number by 0.16, which is the normalised value for the production value, and results in 0.66 as can be seen in the Figure 3.1. For extra clearance, equation 5.4 sums up the above mentioned calculations. A side note should be kept in mind that these numbers are the budgeted numbers for 2018 and they do not specifically need to resemble the exact numbers at the end of the budgeted year. Because of the fact that the budgeted numbers have been based on the financial results of the previous years, they do give a fitting image of the different costs intended to examine.

$$\frac{€\ 1.415.000,-}{€\ 13.274.343,-} = 0.11\ /\ 0.16\ \text{(Normalised production value)} = 0.66 \tag{3.1}$$

Budget 2018	Total DSC	Percentage on Sales/ Indirect Cost	Normalized to Total DS&C	Damen Shiprepair Rotterdam	Percentage on Sales/ Indirect Cost	Normalized to total DS&C for PV	Damen Shiprepair Amsterdam	Percentage on Sales/ Indirect Cost	Normalized to total DS&C for PV	Damen Shiprepair Curaçao	Percentage on Sales/ Indirect Cost	Normalized to total DS&C for PV
Production value (PV)	**445,380,433**		**1.00**	**71,565,000**		**0.16**	**45,818,976**		**0.10**	**41,426,676**		**0.09**
				-								
Direct Labour	(84,824,353)	*19%*	1.00	(10,391,646)	*15%*	0.76	(10,062,757)	*22%*	1.15	(12,295,640)	*30%*	1.56
Work contracted out and materials	(239,788,947)	*54%*	1.00	(42,900,000)	*60%*	1.11	(24,165,551)	*53%*	0.98	(11,370,765)	*27%*	0.51
Contribution Margin	***120,767,132***		***1.00***	***18,273,354***		***0.94***	***11,590,668***		***0.93***	***17,760,271***		***1.58***
Percentage	*27%*		*1.00*	*26%*			*25%*			*43%*		
				-								
Salaries and Wages Indirect Staff	(27,322,967)	21.9%	1.00	(3,915,500)	21.3%	0.89	(2,373,853)	21.3%	0.84	(2,081,023)	12.0%	0.82
Social Security & Pension Indir. staff	(7,402,230)	5.9%	1.00	(978,875)	5.3%	0.82	(502,449)	4.5%	0.66	(581,853)	3.4%	0.85
Indirect cost of direct staff (maintenance/idle)	(17,183,829)	13.8%	1.00	(2,078,329)	11.3%	0.75	(1,168,757)	10.5%	0.66	(3,101,659)	17.9%	1.94
Depreciaton and amortization	(11,685,947)	9.4%	1.00	(3,250,000)	17.7%	1.73	(747,815)	6.7%	0.62	(1,378,595)	8.0%	1.27
Personell related expenses (excl staff on loan)	(6,976,647)	5.6%	1.00	(1,230,000)	6.7%	1.10	(789,000)	7.1%	1.10	(495,143)	2.9%	0.76
Housing cost	(17,364,271)	13.9%	1.00	(2,520,500)	13.7%	0.90	(1,199,000)	10.8%	0.67	(2,439,706)	14.1%	1.51
G&A	(11,787,467)	9.5%	1.00	(2,147,000)	11.7%	1.13	(1,362,819)	12.3%	1.12	(1,579,467)	9.1%	1.44
Machinery and installations	(7,401,511)	5.9%	1.00	(800,000)	4.4%	0.67	(1,075,000)	9.7%	1.41	(1,498,223)	8.6%	2.18
Car expenses	(2,081,347)	1.7%	1.00	(146,000)	0.8%	0.44	(197,500)	1.8%	0.92	(135,513)	0.8%	0.70
Material cost	(13,274,343)	10.7%	1.00	(1,415,000)	7.7%	0.66	(1,374,500)	12.4%	1.01	(3,649,372)	21.1%	2.96
Sales expenses	(1,560,034)	1.3%	1.00	115,000	-0.6%	(0.46)	(278,724)	2.5%	1.74	(323,146)	1.9%	2.23
Public relations	(550,182)	0.4%	1.00	(10,750)	0.1%	0.12	(55,000)	0.5%	0.97	(63,492)	0.4%	1.24
Cost to be covered	***(124,590,774)***	100%	***1.00***	***(18,376,954)***	100%	***0.92***	***(11,124,418)***	100%	***0.87***	***(17,327,194)***	100%	***1.50***
				-								
Result	**(3,823,641)**		**1.00**	**(103,600)**	**0.03**	**0.17**	**466,250**	**(0.12)**	**(1.19)**	**433,077**	**(0.11)**	**(1.22)**
				-								
Movement in provisions for WIP/etc				-								
Other Operating Income	3,932,947		1.00	768,400		1.22	27,500		0.07			-
Other operating expenses	155,931		1.00	(35,000)		(1.40)	1,100,000		68.57	(101,398)		(6.99)
Financial income and expenses	(1,919,508)		1.00	(830,000)		2.69			-	(47,382)		0.27
Result before tax	**(1,654,271)**		**1.00**	**(200,200)**	**0.12**	**0.75**	**1,593,750**	**(0.96)**	**(9.36)**	**284,297**	**(0.17)**	**(1.85)**
Result / Production Value	**-0.37%**		**1.00**	**-0.28%**	**0.75**		**3.48%**	**(9.36)**		**0.69%**	**(1.85)**	
HR					**Normalized to Total DSC**			**Normalized to Total DSC**			**Normalized to Total DSC**	
Number of direct FTE	1,217		1.00	157	0.13	0.80	67	0.06	0.54	271	0.22	2.39
Number of indirect FTE	470		1.00	64	0.14	0.85	37	0.08	0.76	68	0.14	1.55
Number of FTE	**1,687**		**1.00**	**221**	**0.13**	**0.82**	**104**	**0.06**	**0.60**	**339**	**0.20**	**2.16**
Salaries and Wages Direct Staff	-55,232,445		1.00	-8,394,500	0.15	0.95	-4,444,190	0.08	0.78	-8,678,512	0.16	1.69
Social Security & Pension Dir. staff	-15,371,397		1.00	-2,098,625	0.14	0.85	-782,475	0.05	0.49	-2,451,552	0.16	1.71
Staff on Loan (direct)	-31,404,340		1.00	-1,976,850	0.06	0.39	-6,004,849	0.19	1.86	-4,267,235	0.14	1.46
Direct wages	**-102,008,182**		**1.00**	**-12,469,975**	**0.12**	**0.76**	**-11,231,514**	**0.11**	**1.07**	**-15,397,299**	**0.15**	**1.62**
Direct hourly rate total	32.16		1.00	41.57	1.29		37.39	1.16		17.80	0.55	
Direct hourly rate own	32.95		1.00	40.29	1.22		37.86	1.15		19.78	0.60	
Direct hourly rate hired	30.52		1.00	50.00	1.64		37.00	1.21		14.11	0.46	
Investments	**33,202,938**		**1.00**	**2,185,000**	**0.07**	0.41	**1,402,000**	**0.04**	0.41	**17,621,448**	**0.53**	5.71
Cashflow												
Available hours own staff	2,089,283		1.00	246,333	0.12	0.73	133,083	0.06	0.62	562,650	0.27	2.90
Other hours	-9,130		1.00	-14,130	1.55	9.63		-	-		-	-
Hired labour	1,028,946		1.00	39,537	0.04	0.24	162,293	0.16	1.53	302,414	0.29	3.16
Hours												
Available hours	3,171,486		1.00	300,000	0.09	0.59	295,376	0.09	0.91	865,064	0.27	2.93
Indirect hours	-532,671		1.00	-43,720	0.08	0.51	-26,244	0.05	0.48	-174,260	0.33	3.52
Hours booked on projects (own)	1,702,150		1.00	214,305	0.13	0.78	116,197	0.07	0.66	448,873	0.26	2.84
Hours booked on projects (hired)	936,666		1.00	35,695	0.04	0.24	152,935	0.16	1.59	241,931	0.26	2.78
Direct hours	2,638,816		1.00	250,000	0.09	0.59	269,132	0.10	0.99	690,804	0.26	2.81
Direct % of available hours	**83%**		**1.00**	**83%**	**1.00**		**91%**	**1.10**		**80%**	**0.96**	

Figure 3.1: Normalized budget of 2018 for three relevant yards

The basis of the financial modelling used in the budget in the above mentioned figure can be shown using two simple formulas. The terms in the formulas have been modified to be the same as used in the budget in Figure 3.1. All terms and the reasoning behind the chosen numbers for the 2018 budget will be mentioned in more detail further in this section. The first equation deals with the revenue made and cost incurred directly (DC) related to the projects that provide that revenue. In our case, it is the revenue earned and cost made with a direct relation to the ship repair jobs executed by a yard. The revenue budgeted to be earned by a yard is depicted as the 'Production Value' (PV). The direct cost comprises of the salaries and related expenses of owned and hired labour and the work and materials contracted out to perform the jobs that earn revenue. Subtracting the direct cost from the production value yields the 'Contribution Margin' (CM) (Equation 3.2). The contribution margin determines the leverage left over to cover the indirect cost (IC) that need to be made to keep a company running. The indirect cost are comprised of both salaries and related expenses of indirect personnel and cost related to the company itself. The result before tax, in this budget the earnings before interest and tax (EBIT), of the company can be formulated as the contribution margin minus the indirect cost (Equation 3.3). All individual factors and cost items will be discussed separately using the division between direct and indirect cost.

$$CM = PV - DC \tag{3.2}$$

$$\text{Result before tax} = CM - IC \tag{3.3}$$

Direct Cost

The cost that can be directly connected to the projects done at the yard are the direct cost. These are the cost that are only made when a project is being performed, in contrast to the indirect cost that have to be made regardless of projects being executed or not. The direct cost are divided into two general cost items for the financial statement of Damen Shiprepair & Conversion, to be direct labour and the cost for work that is contracted out. Both will be examined in more detail and the division between the two will conclude the analysis of direct cost.

Direct labour Work that is being done using (semi) in-house expertise is categorised under direct labour. The reason that 'semi' has been put between brackets is that a distinction can be made between own labour and hired labour. Both fall under direct labour because both are employed by the yard to do work directly related to the work done at the quays and in the docks. Looking at Figure 3.1, it is possible to make a couple of notifications.

The number of direct full time employees (Hereinafter: FTE) normalized to the differences in production value, read revenue, between the individual yard and the total DS&C group differs greatly between the three yards. The numbers can be seen in the right most column of all individual yards and are 0.80, 0.54 and 2.39 for respectively DSR, DSAm and DS&Cu. Both Dutch yards have fewer direct employees working for them compared to the total DS&C group, where the yard in Amsterdam employs almost half when normalised. Damen Shiprepair Curacao has almost a quarter of the total number of FTE which is around 2.5 times the normalised amount. This on itself is an interesting finding, comparing this with the 'direct hourly labour rate' however gives the possibility to execute a further analysis. A difference can be seen between the labour rates from the Dutch yards, which would be strange when both yards cooperate with the same employment agencies and fall under the same labour laws. The reason for the different rates is the type of work that is being hired. Damen Shiprepair Amsterdam employs more higher level employees by itself, being project managers and financial controllers, which means that they hire more practical labour than the yard in Rotterdam. This explains the lower labour rate paid in Amsterdam as can be seen in the table. This difference is also to be seen when looking at hours booked on projects by own manpower and hired labour for all yards. Where the yard in Amsterdam utilises more hired than own labour and Damen Shiprepair Curacao uses its own labour force for two thirds of the total hours booked, DSR budgets to directly connect more than six times as much own labour than hired manpower. The differences are extensive and can be partly contributed to a difference style of working that is being maintained by all yards. Looking at the results of the individual yards, it is not surprising that the tendency of the overall management is to decrease the amount of own labour and increase the amount of hired manpower. This makes it able for the yard to mitigate a large part of the (financial) risk. The price of this way of acting is a decrease in the consistency of the quality of the work and the loss of skilled labour that is loyal to your company. Both are vital and can in some ways outweigh the importance of the mitigation of (financial) risk.

Although the normalised direct labour cost seen in Figure 3.1 are only around 1.5 times more for Damen Shiprepair Curacao, it utilizes a bit under three times as much working hours. When comparing with the differences in the hourly labour rate, it works out however. The amount of hours worked on projects is a large number any way, that would need further explaining. After consultation with several people working within the Damen Shiprepair & Conversion in an open discussion, a number of reasons can be given for the inefficiency that can be concluded from the above. The matter will not be discussed in too much detail since this research does not have the purpose of analysing the quality of the labour forces of all DS&C yards, but short points of which a lesson can be taken will be named. The quality and reliability of the material and equipment from the yard and the quality and versatility of the direct personnel are the main actors in this inefficiency. Both observations will be looked into further in this report.

Work contracted out and materials When expertise and/or materials are not available at the yard itself, it is necessary to engage with third parties to deliver these services. The dependency on sub contractors is a choice that is being made on management level as has been described in Section 2.2. The points mentioned about the availability of these services can be seen in the normalised budget as well. Yards that are situated in an area with a high density of quality services need to really less on direct labour than others. The percentage of sales from third parties of the yards in Amsterdam and in Rotterdam are respectively 60% and 53%, which is between two and four times more than the percentages for direct labour. Damen Shiprepair Curacao on the contrary depends only 3% more on direct labour than on sub contractors in terms of cost.

Division between types of direct cost For further analysis in this chapter the division is made between both types of direct cost. It is thought of that this division can be used to analyse the amount of several cost items that are part of the indirect cost and might be used for forecasting methods. A new variable will be introduced, to be the 'workforce division' variable. It is calculated by dividing the cost for the work contracted out by the cost for direct labour. The lower this number is, the more reliant a yard is on their own people. As will be seen in the rest of this chapter, this variable might become a useful one.

Indirect cost

The indirect cost, also called overhead cost, relate to the cost that can not directly be connected to a specific project and that have to be made independent of the type and number of vessels that come into the docks. DS&C has classified the indirect cost in the budget into several items that will all be individually explained. The relation with the direct cost or production value, if present, shall be discussed as well.

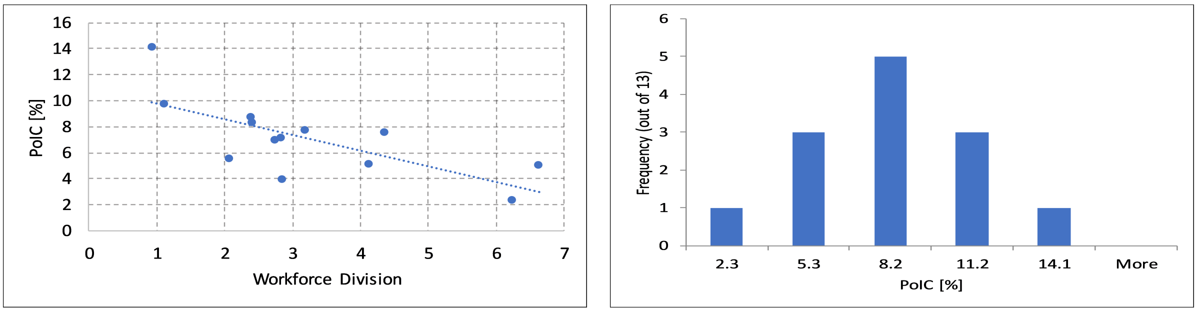
Material This cost item includes everything that is related to the materials used in the yard that are generally needed for all jobs executed, including energy required. Personnel protective equipment, the safety equipment being worn by workers and also knows as PPE, small production tools and gasses and fluids needed to perform small jobs fall under the material cost. An obvious observation is that this item should increase when more work is done by workers that are employed by the yard itself. Thus a relation between the workforce division can be made. This term describes the division between work that is being contracted out (WCO) and the direct labour (DL). To come up with a number that can be used for further analysis, the cost for the former has been divided by the cost of the latter. The yard in Curacao will be used as an example; Dividing 27% by 30% (see Figure 3.1) gives a workforce division of 0.92. The relation between this number and the material cost can be proven by the correlation coefficient, a statistical measure that calculates the strength of the relationship between the relative movement of two variables [Investopia, 2018c]. This coefficient can be calculated by the equation seen below (3.4) and results in a number between -1 & 1. The outcome of the calculation should be below -0.7 or above 0.7 to represent a significant correlation between two variables [Montgomery et al., 2001]. The variables that have been used are the workforce division mentioned above and the percentage of Indirect Cost of the material cost. It has been chosen to work with the percentage instead of the actual cost to make it possible to compare different yards independent of the size of the yard and the accompanying differences in production value. In this and the following statements, the terms 'sales', 'revenue' and 'production value' represent the same. It has been chosen to work with 'production value' since this is the term that is being used by the financial controllers that provided the numbers. The σ, the variance, in the formula describes the expectation of the squared deviation of a set of variables from its mean. The correlation factor for the above described variables for all yards is -0.716 (Table 3.1) and can thus be described as significant. The fact that the coefficient is negative means that this is a negative correlation, meaning that the variables move in opposite directions.

$$\rho_{xy} = \frac{E(y-\mu_x)(x-\mu_y)}{\sigma_x \sigma_y} = \frac{\sigma_{xy}}{\sigma_x \sigma_y} \tag{3.4}$$

Further analysis has been done to prove the relationship between both variables. The scatter plot seen in Figure 3.2a shows the percentage of Indirect Cost (PoIC) on the vertical axes and the workforce division (WCO/DL) on the horizontal axes. The linear trendline that best fits all points has been plotted in the graph, showing a linear regression. A simple linear regression will be used in this analysis since the PoIC of the material cost is only dependant on one variable in this research. This type of regression can be visualised by equation 3.5, where β_0 and β_1 represent the regression coefficients. The variable β_1 is the change in the mean of the distribution of y produced by a unit change in x [Montgomery et al., 2001]. The x in our formula represents the workforce division. The error in this case, the ϵ in the formula, is negligible because the variables used in this analysis are not measured and have therefore no error in their determination. A simple analysis tool from Microsoft Excel has been used to determine the regression coefficients and the results can be seen in Formula 3.6. The method used is the least squares method, which defines a line that minimizes the sum of the squares of the vertical distance between each point and the resulting line. For a proper linear regression including relevant calculations that contain information about the strength of the correlation, the data should be normally distributed. Figure 3.2b shows a histogram made from the values of the percentage of Indirect Cost for all DS&C yards. The characteristics for both the distribution and the regression have been summed up in Table 3.1. The shape of the distribution seen in the figure hints to the distribution being of a normal nature and the fact that the median and the mean are almost identical endorses this. The last coefficient that is being calculated to check for the strength of the correlation is the coefficient of determination, also knows as R^2. This value justifies how much of the variation can be explained by volume fluctuations and is mainly used for future forecasts [Investopia, 2018b] and therefore of minor value for this analysis. A value of 0.513 is generally seen as a medium fit, but worthwhile to mention in this analysis because of the possibility for using the correlation in future cost calculations. Important to mention is that the PoIC of material cost will most probably not only be dependant on the workforce division, but multiple factors determine to amount of (relative) costs. One example that proofs this is Damen Shiprepair Curacao. It is the point on the scatter plot that stands out the most. The workforce division value for this yard is 0.92 which is the lowest of all yards and it is thus not surprising to have the highest percentage of Indirect Cost of all yards. The value of the latter lays significantly higher than the trendline, caused by other factors than just the workforce division. The quality, efficiency of use and availability of the materials and energy are lower in the, some what isolated, Caribbean country compared to North-West Europe. This will be taken into account in the next chapter.

$$y = \beta_0 + \beta_1 x + \epsilon \tag{3.5}$$

$$PoIC_{MaterialCost} = 11.1 - 1.22 \cdot x \tag{3.6}$$



(a) Scatter plot of the material cost PoIC against workforce division

(b) Histogram of materical cost PoIC

Figure 3.2: Statistical visualization for material cost

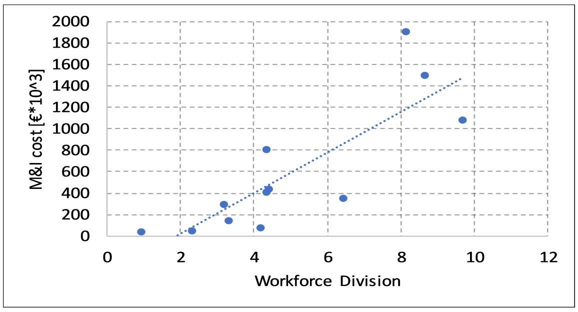
Table 3.1: Statistical characteristics

Characteristic	PoIC material cost
R^2	0.513
P-value	$3.61 * 10^{-6}$
Correlation coefficient	-0.716
Kurtosis	1.86
Skewness	0.823
Mean	10.59
Median	10.65

$$\sigma(X) = E[(X - \mu)^2] \tag{3.7}$$

$$R^2 = 1 - \frac{\sum_i (y_i - \bar{y})^2}{\sum_i (y_i - f_i)^2} \tag{3.8}$$

Machinery and installations Included in the machinery and installation cost is the maintenance, repair and hire of the equipment needed for the general jobs done in the docks and alongside the berths of a shipyard. A similar line of thought can be given as for the material cost, that of the relationship between the percentage of Indirect Cost and the workforce division. The correlation coefficient has been calculated to assess this thinking and the result disproofs. A coefficient of -0.433 shows an insignificant relationship between both variables. It is however useful to look at a different way of plotting the percentage of Indirect Cost, that of graphing it against the actual cost as has been done in Figure 3.3a. A cluster around a percentage of 4% can be seen with several outliers above that number. Two of the three higher numbers are (again) the yard in Curacao and DSAm, which can be contributed to the age of the machinery and installations resulting in a higher capital needed for maintenance. A different factor is the reason for the other outliers, the agreements with sub-contractors to be specific. There are three different ways for naming the cost of machinery related to contracting work out and every yard has a specific agreement with different third parties they work with. The price can either be included in the rented service and can thus be charged in the hourly tariff and contributed to the direct cost or the yard itself rents the equipment and it will be included in the indirect cost. At the end, all comes together, but it is important to mention for the sake of this analysis. Because of the big cluster, the percentage associated with this cluster will be used as a base for the calculation of the cost related to the machinery & installations in the next chapter.



(a) Scatter plot for M&I PoIC against the actual cost

(b) Scatter plot workforce division against PoIC for housing cost

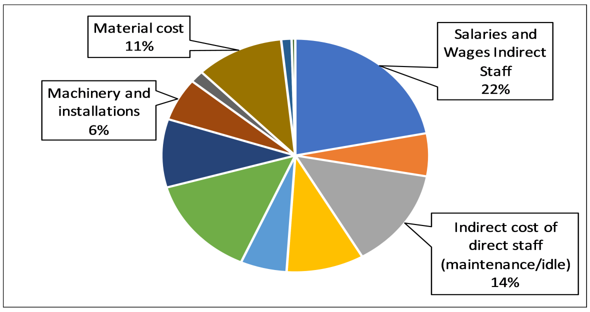
Figure 3.3: Missing correlation for two indirect cost with workforce division

Housing cost Figure 3.3b represents the workforce division plotted against the percentage of Indirect Cost of the housing cost of all yards. The high grade of randomness that can be seen is substantiated by a low correlation coefficient (-0.028) and the large spread does not need a trendline to show this. It does not give a steady base to use in a further analysis. Because this cost item is made up of mainly the maintenance (including rent or a different financial mechanism to pay for the property) of the buildings that make up the shipyard and the fact that this differs much with the managing of/investing in a mobile facility, any relationship or conclusion related to housing cost will not be used in the next chapter.

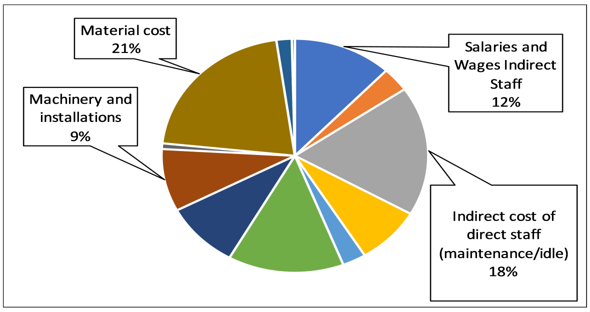
Sales, Car expenses, Public relations and G&A The cost induced by sales efforts and related subjects will not be a major player in the decision leading up to the financial feasibility of the concept and do therefore not deserve too much attention in terms of resources. For all four a little explanation will be given together with the description of the method used to come up with the final relation to the overall cost. The car expenses are cost made related to the transportation of indirect personnel for commuting to the office and for trips related to their work. An average has been taken over all yards (2.27%) as the percentage of total Indirect Cost. The cost for public relations are build up of minor cost items and the average that has been taken is (0.06%) in terms op percentage of sales. It has been chosen to use the sales as variable because the public relation cost item is fully related to sales. Costs related to the general & administration cost item include the basic necessities of running an office that is in this case connected to the managing of a shipyard. This item does not deserve much attention in this chapter, the average over all shipyards (10.53%) in term of percentage on Indirect Cost is however large enough to be looked into in the following chapter. Sales expenses are being generalised as well. The base that is used in the determination of the amount of money for sales purposes for all yards is 2% of the revenue budgeted in that year. Since the mobile facility will be a add-on to the total number of facilities managed by DS&C, generally the same method will be used as a base for the sales expenses described in more detail in the next chapter.

Indirect personnel Not only the direct cost item includes salaries for labour. People and their services comprise a part of the indirect cost as well. A shipyard has to be run just like any other company and differences between all yards can be seen concerning these type of costs likewise. These differences are quite the same as for the direct full time employees. It can be seen that both Dutch yards employ relatively fewer FTE and the Damen Shiprepair Curacao is utilizing more employees for indirect work. The inefficiency is not only visible when looking at the number of full time employees, the indirect cost made by direct staff is twice as high as well. This is mainly due to maintenance on the own facilities, but idle hours are a source of this too. Both serve as a motivation for quality equipment, planning and personnel.

A visual comparison has been made to get a proper decent image of the both the division between the different indirect cost and the differences between the inspected yards. The financial numbers for both the Total DS&C and the yard in Curacao have been chosen because of the average numbers that show from the total numbers and the fact that the yard in Curacao comes closest to the proposed concept. Figure 3.4 shows pie charts of the indirect cost of both yards, displaying clear differences that have been mentioned above. The same visual representation will be given when describing the financial numbers of the MSRF to support the hypothesis of the similarities with the yard in Curacao.



(a) Division of indirect cost of Total DS&C



(b) Division of indirect cost of DSCu

Figure 3.4: Differences in the division between indirect cost items related to existing yards

3.1.2. Production value comparison

At the end of the previous chapter a verbal description has been given of the proposed concept. For the understanding of this section a more illustrative picture has to be given, which has been done in Figure 3.5. It shows a sketch of the top view of the submerged state of the concept with several of the features described in Section 2.3 including two rotating, movable, cranes and the large area that serves as a dry dock. This view is deemed necessary for understanding the following analysis that compares the above mentioned yards by their productivity in terms of the surface area available. The dimensions of the dock and the berths can be seen in Figure 3.6. The topview serves merely as illustrative for the analysis and no conclusions should be gathered from it.

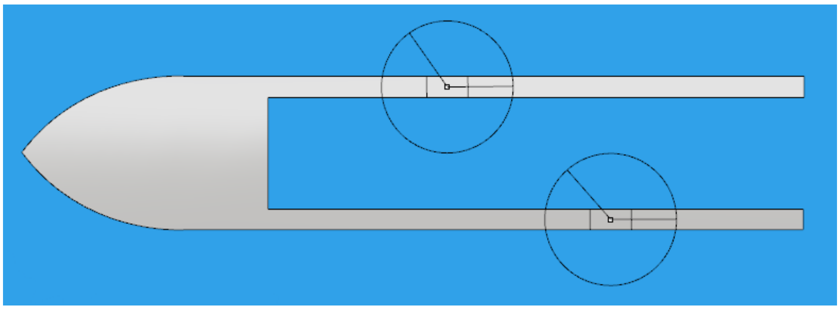


Figure 3.5: Topview of preliminary concept

The production value based analysis serves two purposes. Firstly, it analyses the productivity of the three relevant yards and secondly it allows the opportunity to give a first try in forecasting the production value of the proposed concept. The analysis will be based on the table seen in Figure 3.6 that shows the comparison done for the yards in Amsterdam, Rotterdam and Curacao, just as the budget comparison in the previous

Production Value Comparison	DSR	DSAm	Normalised to DSR	DSCu	Normalised to DSR	DSCu, fully operational	Normalised to DSR	MSRF
Production value	€ 71,565,000	€ 45,818,976	0.64	€ 41,426,676	0.58	€ 41,426,676	0.58	€ 8,411,807
Production value per dock & meter berth								€ 14,202,627
Floating docks	2	0		1		2		1
Graving docks	3	4		2		2		0
Berths total	4	5		3		3		2
Berth length (m)	880	900		975		975		400
Dock length (m)	1066	760		638		804		150
Total dock surface (m^2)	34297.90	20811.25		21323.70		26910.30		4050
Total hours booked on projects	250,000	269,132	*1.08*	690,804	*2.76*	690,804	*2.76*	
Third party spending	*42,900,000.00*	*24,165,551.42*	*0.56*	*11,370,765.22*	*0.27*	*11,370,765.22*	*0.27*	
Production value per meter dock	67,134.15	60,288.13	*0.90*	64,932.09	*0.97*	51,525.72	*0.77*	
Production value per meter berth	81,323.86	50,909.97	*0.63*	42,488.90	*0.52*	42,488.90	*0.52*	
Production value per total meters	36,775.44	27,601.79	*0.75*	25,683.00	*0.70*	23,286.50	*0.63*	
Production value per dock surface	**2,086.57**	**2,201.64**	*1.06*	**1,942.75**	*0.93*	**1,539.44**	*0.74*	
Production value per day	**196,068.49**	**125,531.44**	*0.64*	**113,497.74**	*0.58*	**113,497.74**	*0.58*	
Production value per dock surface per day	5.72	6.03	*1.06*	5.32	*0.93*	4.22	*0.74*	
Production value per dock per day	**39,213.70**	**31,382.86**	*0.80*	**37,832.58**	*0.96*	**28,374.44**	*0.72*	
Production value per meter berth per day	222.81	139.48	*0.63*	116.41	*0.52*	116.41	*0.52*	
Production value per dock & berth per day	7,951,667	5,090,997	*0.64*	6,904,446	*0.87*	5,918,097	*0.74*	
Production value per hour booked	286	170	*0.59*	60	*0.21*	60	*0.21*	
Production value per *third party spending*	1.67	1.90	*1.14*	3.64	*2.18*	3.64	*2.18*	
Value of productivity compared to DSR			***68%***		***46%***		***46%***	

Figure 3.6: Production value comparison

section. The difference with the table used for the budget is the double use of DSCu. Since the production value that is being used in the analysis is a budgeted number for 2018, all other (exterior) factors in the budget have been budgeted as well. One of these exterior factors is the amount of docks available for DSCu. The docking facilities of the yard in Curacao have been enlarged in the course of 2018 by modifying two older floating dry docks in the Netherlands and transporting them to the other side of the Atlantic Ocean. The docks arrived at the yard at the beginning of may 2018 and will only be operating when the year has already past its half way point, meaning that only half of the gained capacity has been taken into account in the analysis. This is to be seen in the first column associated with DSCu, whereas the second column for the yard in Curacao serves merely as a benchmark for the future by taking into account both new docks. One matter to consider is the fact that the production value for 2019 for DS&Cu will become larger as well with two new docks ready for deployment. The following further considerations will be given in this section; Productivity by dock surface, productivity by different direct cost, and a simple formula for establishing first estimates.

Productivity by dock surface and meter berth The production value by dock surface [m^2] does not differ too much between all relevant shipyards. It can be seen that this value is the lowest for the shipyard in Curacao, which can both be seen as a surprise and an unexpected finding. Before discussing this it is relevant to explain the reason for choosing the dock surface for analysing the productivity. The length of a dry dock is of major importance when choosing a suitable yard as a ship manager, but the breadth of this dock can cause a dry dock to not fit the dimension of a vessel as well. To check for both, the docks surface, which is the length times the breadth of the dock, has been taken as a variable. The productivity by meter dock will be used as a comparison. The surprising part of the finding is caused by the competitive location of the yard in Curacao and the result that the yard can quote with higher margins than yards that suffer from a dense competitive area. This would call for a higher productivity factor when comparing the production values. One of the factors that reduces the productivity originates in the length-breadth ratio (192 meter x 23 meter) of the smaller graven dock (Beatrix Dock). Ships that would fit the length of the dock but are too wide therefore have to deviate to the larger dock resulting in a inefficient filling of the docking capacity. A second consideration that confirms the above made note is the comparison of the productivity measured by meter dock, where the sequence is opposite. Where the yard in Amsterdam is highest in the first case, it is the lowest in the latter.

Another way of looking at productivity is measuring the production value per meter berth. For both this method and the previous the same number for the production value has been used. A better way would be to divide this value up into two parts related to work done in the docks and when on berth and dividing that part by respectively the dock surface and meter berth. This division is unfortunately not available with the current administrative facilities and therefore the less optimal but also interesting option of using the entire production value has been used. When analysing this type of productivity, it can be seen that the yard in Curacao is almost half as productive as the yard in Rotterdam, whereas the yard in Amsterdam sits in the middle of both. One of the reasons might be the fact that the berths in Curacao are frequently used by vessels operating in the offshore business that are idle at that moment, but it calls for not overseeing the total meter berth in the analysis.

Productivity by different direct cost Mentioned already in the previous section, the different types of direct cost can be measured into productivity as well. Since it has gotten much attention before, this will just justify the previously made conclusion. The production value per hour booked is almost five times lower for the yard in Curacao whereas the production value per third party spending is only twice as high, both when normalized to the production value of Damen Shiprepair Rotterdam. The product of both normalized values gives a value for the productivity of the yard by comparing the direct cost relative for DSR. For the yard in Curacao, the cost of labour is twice as low, which makes this value come close to the productivity value of DSR. The yard in Amsterdam has a significant lower value, which has been concluded before already as well.

First estimates The last but most exciting consideration of this section is the first estimate for the production value of the proposed facility. Many different factors that will influence this value will be described in the following of this research, but it is valuable to have a baseline to start from. Two different ways of establishing the first estimate of the budgeted production will be used; Firstly, the average is taken and secondly the number of docks available shall be taken as a variable. Both will be discussed in more detail and examined using different case studies. For this analysis, the numbers seen in Figure 3.6 have been used that have their roots in a small market analysis and the current facilities.

The first two numbers in Figure 3.6 take the average of the relevant shipyards and apply that to the dimensional characteristics of the MSRF. The length and the breadth of the dock has been taken as respectively 150 meter and 27 meter, whereas the length of both berths, located at both sides of the vessel, are taken as 200 meter. This makes for a total dock surface of 4050 m^2 and a total berth length of 400 meter. Using the average of the production value made per day by the three relevant yard yields an estimated production value of the MSRF of just a bit less than 8,5 million Euro. A huge difference can be seen when the above described productivity factors are being practised for the estimation of the production value. Incorporating both the meters berth and the dock surface into the equation, larger numbers result. Increasing the dependency on the meters berth increases the estimated production value of the MSRF. This can be explained by the high ratio of berth meters over dock length compared to a standard land based yard, visible in the table as well. After consultation within the company, a 90% dependency on the dock surface and a 10% dependency on meter berth has been used. Just over 14 million is the estimate when both the dock surface and the meters berth of the concept are taken as a variable for the calculation.

Having established an overview of the cost that are associated with the running of a shiprepair yard and the projects that make money to keep such a yard running, it is now time to evaluate where that money is coming from. The finance of potential clients will be looked at and the two will result in a complete view of the shiprepair business and ultimately aid in the feasibility research.

3.2. Overall shipping finance

The costs made by shipyards for providing the service they give has been analysed above, which leaves the cost structure for the clients of a shipyard, the shipping companies. For the sake of simplicity in favour of this analysis, the term 'shipping company' covers the party paying for repair & maintenance work done at the yard. In a real scenario, this can be either a ship owner or manager, charter company or insurance party. Making the distinction between all does not enlighten this overview and would only make it more complicated, is has therefore been chosen to cover them in one term. The financing of such a company including the earnings and cost made, while focussing on the money transferred to a shipyard, will be discussed below.

Stopford [Stopford, 2009] teaches us that the cost of running a shipping company depends on a combination of three different cost factors that can afterwards be classified into six categories as done by Stopford in the 2009 version of his Maritime Economics book to counter the often occurring confusion over terminology. The six categories are; Operating Cost, Voyage Cost, Cargo-handling Cost, Capital Cost, Interest and Periodic Maintenance,. The last one in this list, as described by Stopford, "are [costs] incurred when the ship is drydocked for major repairs, usually at the time of its special survey. In older ships this may involve considerable expenditure, and it is not generally treated as a part of operating expenses. Under international accounting standards an assessment must be made of the total periodic cost over the maintenance cycle and this is capitalized and amortized. The costs when actually incurred are treated as cash items separately from operating cost". Stopford classifies these cost to be 4% of the total cost. The operating cost include voyage repairs or small maintenance jobs that can be done by the crew on board the vessel. The reason for pointing out the

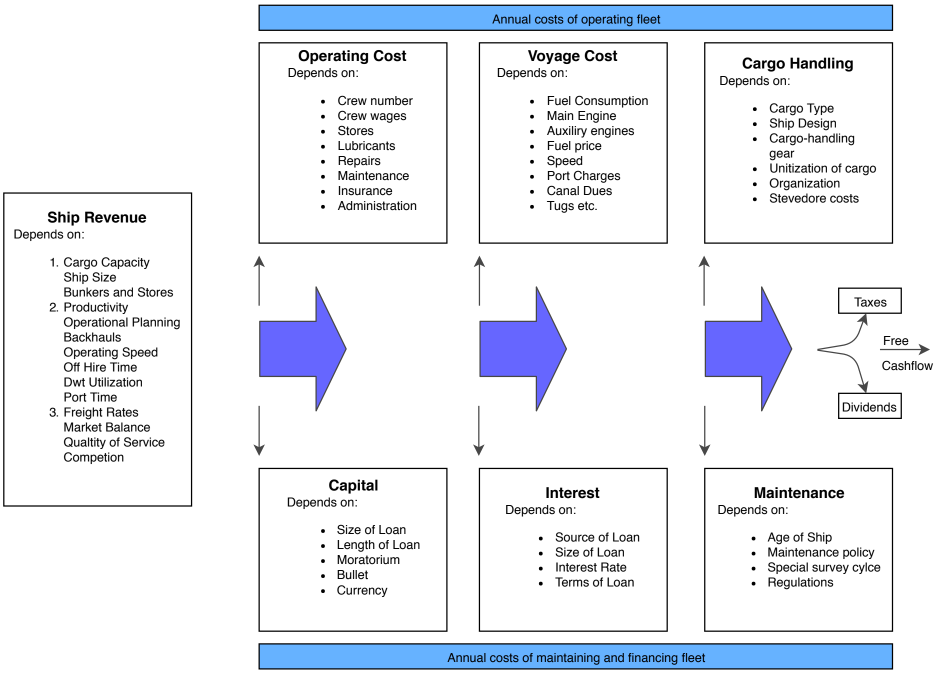


Figure 3.7: Shipping cashflow model [Stopford, 2009]

Periodic Maintenance category is that the money spend on these cost should eventually end up in the account of a shipyard and this research should find out whether that can be a mobile shiprepair platform. The breakdown used by Stopford has been adapted by Dhanisetty et All. [Dhanisetty et al., 2018] as well in their research into making a model for ship structural optimisation during the conceptual design stage based on the maintenance/repair and production-oriented life cycle cost/earning of that ship. The total model includes five different sub-models, of which the second one covers the periodic maintenance of a shipping company and is therefore interesting to consider in more detail. Not only will the methods used in the cited paper be interesting for this chapter, the following ones will build on them as well. The main conclusion made in the analysis of the periodic maintenance is the fact that the total cost of dry docking is build up by the cost of the actual repairs plus the cost of unavailability. Because the paper is based on repair & maintenance work on a tanker only the steel repairs have been taken into account for the first part and the latter shows just a formula based on a database that is not further elaborated on. This means that the data can not be used, but the method can be adopted altogether. As said briefly before in Chapter 1, the dependency on either of the cost factors depend on the type of maintenance policy implemented. Being a mobile shiprepair facility, the cost of unavailability of potential clients should considered to be decreased. The costs mainly include two items; the cost of fuel (if a sailing trip is needed to the yard when it is not located in the last port of call) and the missed earnings of the days the vessel spends in the shipyard and on the voyage to the yard. The cost of unavailability will be the first matter to be discussed and will be followed by a brief look at the cost of repairs.

3.2.1. Cost of unavailability

As said before, the cost of unavailability consists mainly of two components; Continuing cost of fuel and labour and missed earnings. Only the latter will be discussed in this chapter, since the cost of fuel is dependant on multiple factors that will be the subject of next chapters when discussing the economical model that will gain inside in the feasibility. The missed earnings however can be discussed here because they are less dependant on vessel specifications and it is easier to discuss them using global trends. One source of data that is valuable when talking about the earnings of a vessel, or in this case the missed earnings, is chapter three of the 'Review of Maritime Transport', an annual report of the United Nations Conference on Trade and Development [UN, 2017]. This chapter describes the trends and changes in the freight rates and maritime transport costs globally for different types of freight markets. Independent of the choice of clients for the proposed facility, looking at the events on the freight market gives a fitting image of the current markets and an idea of the missed earnings of possible future clients and how these earnings can change in the (near) future. Some factors influencing the trends in trade markets have been discussed in Section 1.1 and the impact of those is, generally speaking, a decrease in the time charter freight rates. For the container market, only three average rates out of the 13 markets shown have seen an increase. The spot freight market connecting Shanghai with South America has risen with 261.3% to $1644 per 20-foot equivalent unit, while for example the market connecting Shanghai and the United States East Coast dropped with 33.9% to $2102 per 20-foot equivalent unit. Looking at the New Contex Index (Container Ship Time Charter Assessment Index), an company-independent index for time charter rates of container ships made by the Hamburg Shipbrokers' Association (Hereinafter: VHSS), different numbers showing the same trends can be seen. The rate for the 1100 TEU type, a vessel characterized by the VHSS with dimensions that would fit those of the proposed facility, is $7202 per day for a 12 month charter at the time of writing [VHSS, 2018]. The number is higher than the average of the previous years, but largely lower than the rates in for example 2015 and before. The New Contex index itself combines all types of container vessels and shows a decline. Both the rising individual rate and the descending index are valuable considerations. The Intermodal Weekly Market Report [Markinos, 2018] shows the indices and time charter rates for among others the dry bulk market. Of this market, mainly the handysize vessels will be of interest for the proposed facility. Both the Baltic Handysize Index and the charter rate per day have not moved much in the last year. The latter is of the most concern and stands at $8553 per day according to the Baltic Exchange. This London based company produces daily indices that are being composed of the prices paid for the transportation of dry bulk on the 25 busiest shipping routes. The graph of the Baltic Dry Index itself can be seen in Figure 1.5. The reason that these numbers are important to look at is the way they can be used to determine the missed earnings. All days that are spend in the shipyard and travelling to and from the yard can not be used to make money. All vessels and their managements have this consideration implemented in their company strategy, but the difference can be made when the number of days spend without making money can be decreased. More on this follows in the next chapter.

3.2.2. Cost of repairs

In this section an extremely generalised picture will be sketched of the lifetime periodic maintenance costs as presented by Martin Stopford. This will be done for two purposes; The division between the different cost items and the way the cost evolve as a ship ages. Table 3.2 shows the numbers as calculated by Stopford, using the Capesize Qaulity Survey of Clarkson Research, for a standard capesize vessel with 1993 dollar prices that have been converted to current prices in Euro. The difference with the current dollar price is substantial and it is therefore only reasonable to utilize the connections between the numbers instead of the exact amounts. It is evident that the costs rise when the to be serviced vessel becomes older, this is because of two reasons. Some cost items, such as general services and dry-dock charges, are based on the time in dry dock or at the yard. The older the vessel, the more days spend at the yard and therefore the higher cost. The other type of cost items that increase with age are related to the service of parts of the vessel that deteriorate with age such as the steel replacement and cargo spaces. These items are extensive in this example because a capesize vessel is a dry cargo vessel and the cargo holds need serious maintenance. Different cost items are the main source of cost for different ship types, but every type has several that increase dramatically with age. Multiple cost items stand out and should be considered here to be used later in the research. Because the cost shown cover the cost of both the interim dry dockings and the special survey, the survey item is extensive. These items consists mainly of transporting and paying surveyors for doing their work at your yard. Because the proposed facility is mobile, these cost should be looked at more closely later. Roughly the same amount of money is spend on dry-dock charges and port charges, tugs and agencies, these items are relatively volatile as well when looking at the mobile nature of the proposed repair service. Where some cost items are mainly dependant on the price of materials, such as steel replacement and piping & valves, others are build up mostly of the price of labour. The chances are large that all cost items will differ when considering a mobile service and next chapter will cover the way they possibly do.

The cost items above do not only give information about the actual cost and the percentage of those cost on the total maintenance cost, they give an image of the work done during periodic maintenance as well and therefore determine the needed facilities on board of the MSRF. Part of this has been covered in Section 2.2.1 already before, the table above merely highlights it again.

Table 3.2: Periodic maintenance cost of a capesize vessel, prices converted from 1993 dollars to 2018 Euro's [BLS, 2018], [Economics, 2018]
Source: Martin Stopford, Maritime Economics [Stopford, 2009]

Age of Ship	0-5	6-10	11-15	16-20	Total	Percentage
Time out of service (days)	20	23	40	40	123	
Time in dry dock (days)	10	14	23	18	65	
Cost items						
Dry-dock charges	93.656	102.720	123.113	111.783	431.270	3.84%
Port charges, tugs, agency	105.741	110.726	138.974	138974	494.413	4.41%
General services	120.847	138.974	241.693	241.693	743.205	6.62%
Hull blast, clean & paint	155.288	194.563	277.343	149.548	776.740	6.93%
All dry-dock paint	247.886	265.107	312.690	293.204	1.118.885	9.98%
All steel replacement	105.741	528.703	1.797.588	1.268.886	3.700.916	33.00%
Cargo spaces	33.535	96.980	190.333	226.587	547.434	4.88%
Ballast spaces	54.986	35.046	39.276	71.753	201.058	1.79%
Hatch covers & fittings	42.297	85.076	91.481	91.481	310.334	2.77%
Main engine & propulsion	69.487	63.445	72.508	72.508	277.947	2.48%
Auxillaries	40.786	51.360	202.418	66.466	361.029	3.22%
Piping & valves	27.191	55.892	75.529	51.360	209.971	1.87%
Navigation & communications	13.596	16.617	16.617	16.617	63.445	0.57%
Accommodation	9.064	12.085	10.575	10.575	42.297	0.38%
Surveys & surveyors	105.741	118.581	170.696	163.143	558.159	4.98%
Miscellaneous	151.058	151.058	151.058	151.058	604.232	5.39%
Spare parts & subcontractors	105.741	151.058	151.058	181.270	589.126	5.25%
Owner's attendance	35.952	38.671	54.079	54.079	182.780	1.63%
Estimated total	**1.518.584**	**2.216.653**	**4.117.020**	**3.359.314**	**11.211.569**	
Averaged annual cost	303.717	443.331	823.404	672.165		
Averaged daily cost	833	1.215	2.256	1.842		

The time that the example vessel is out of service due to the mandatory docking is quite large. Dividing the total days out of service by four times the days in one year yields a result of 8.42% that the vessel is out of service in the year that the dry docking has been planned. Dividing the total time out of service by the total years that are in between all services yields a smaller number of course, but this does not chance anything for the analysis. Improving the efficiency of the repair service can decrease the time a vessel is out of service and should therefore be considered as an added value of the concept. The quantification of the added value will be done in the remainder of the research, but the necessity can partly be seen in the table above. The other added value of the concept, being the reduction of the deviation time of clients, can also be subtracted from the table. Part of the difference between the time in dry dock and the time out of service comes from the deviation that needs to be made for reaching a proper repair yard, as has been mentioned already in Chapter 2. The other part comes from the preparation and mobility of the vessel before and after the docking period.

3.2.3. Annual reports analysis

One way of verifying whether the claim from Stopford that 4% of the cost made by a shipping company are related to the periodic maintenance of their fleet is by comparing it to numbers taken from the companies itself. When these companies are listed on a stock exchange it is possible to consult their financial statement included in the annual reports. Some companies that are privately owned share their financial numbers as well, but they are not obliged to do so. The first report that has been looked at is that from a company named Tidewater, an American stock exchange listed company that owns and operates one of the largest fleets of Offshore Supply Vessels. Their financial statement tells that for subsequent periods the percentage of sales for the repair & maintenance cost is respectively 8.2%, 15,7% and 10.1% [Tidewater, 2018]. The average of these three numbers is 11.3%, which is almost three times as high as pointed out by Stopford in his analysis. Two comments can be made on the these number. Since the type of vessel is different in both situations, the percentage of the earnings reserved for the repair & maintenance of the fleet in both situation will be slightly different as well. Offshore Supply vessels are generally been used for quite intensive work and might need more care. The difference is large however and can also be attributed to the fact that Stopford only incorporated the periodic maintenance, and the numbers from the annual report of Tidewater include smaller maintenance jobs and voyage repairs as well. Gulfmark Offhore, another company operating Offshore supply vessels comes with numbers close to the one Stopford is using [Offshore, 2018]. The dry dock expenses have been documented in 2014 as being 5.4% of the total revenue of that year, while the average of that year and the four preceding ones comes down to 5.9% of total sales. Both would generally verify the statements made by Martin Stopford.

The above sections have shown two things. First of all, the cost and revenue structure of the existing Damen Shiprepair & Conversion yards have been analysed. This has not been conducted with the aim of improving the cost efficiency of the yards or any of that kind, it has merely been done to provide a benchmark for the coming chapter. Next chapter, the description of the financial model, uses this benchmark in the development of recommendations into the economic feasibility of a mobile shiprepair facility. Part of next chapter is the quantification of the added value of the proposed concept, for which the base has been given in the second section of this chapter. It has been shown that there are enough opportunities to decrease the time out of service of clients and therefore improve the efficiency of the repair service.

4

Description of the financial model

This chapter includes the description of the financial model describing the proposed concept that will be the base for the rest of the research. This model will in the end be used to generate results that aid in the making of recommendations on the feasibility of a mobile shiprepair facility for DS&C. The methods for establishing the cost structure of the proposed concept will be described individually, for both the direct and the indirect cost. Two important factors come with every description; the differences with the benchmark of previous chapter and the variables or fixed values that will in the end be used for the sensitivity analyses. The last two sections of the chapter will mention in which way the financial model will yield results on the economic feasibility. Both the short term and the long term feasibility will be mentioned, including the mathematical sensitivity analyses and the Monte Carlo simulation that will put the concept to the test in the next chapter using results from the model. To provide a clear picture of the benchmarking executed in the previous chapter, the overview of the budgeted financial numbers for 2018 for the total DS&C group has been shown in Figure 4.1. These are the same numbers as have been shown in the beginning of the previous chapter and should solely be used as reference material for the benchmarking of the previous chapter and the illustration of the differences mentioned in this chapter. At the end of the chapter, the same overview will be given for the proposed concept including the values that have been used for the variables and fixes values to finalise the illustration of the mentioned differences. For the description of the financial model the same indexing is used as in the first section of the previous chapter by beginning with the direct cost. A small description of the information sources used for the analysis of the individual items of the model proceeds this.

Multiple information sources have been used in the different analysis in this chapter, of which many have been people within the entire Damen Group. The information that they have provided is gathered by conducting personal conversations with them as well as extensive contact via email throughout the entire research. The conversations are not logged, due to the fact that they have not been in the form of an interview with fixed questions. The information that they have provided would not have been possible to gather from any white or grey papers or other scientific sources. Table 4.1 below highlights the experts that have been consulted for the information needed in this chapter.

Table 4.1: Expert consultation for the computing of the financial model

Name	Function	Company
Rik Duker	Project manager	Damen Shiprepair & Conversion
Joey Vredebregt	Project manager	Damen Shiprepair & Conversion
Jozeph Quak	Managing director	Damen Harbour & Voyage
Rinke Wesseling	Commercial director	Damen Harbour & Voyage
Robert Oostergetel	Operations manager	Damen Shipyards
Paul van de Craats	Manager operations	Damen Shiprepair Amsterdam
Maarten van Willigen	Sales manager	Damen Trading & Chartering
Nikki Oelrich	Marketing advisor	Damen Shiprepair & Conversion
Nard Brandsma	Design and proposal engineer	Damen Shipyards Bergum

Budget 2018	Total DS&C
Production value (PV)	**445,380,433**
Direct Labour	(84,824,353)
labour cost on sales	*-19%*
Work contracted out and materials	(239,788,947)
Third party cost on sales	*-54%*
Workforce Division	*2.83*
Contribution Margin	***120,767,132***
Percentage	*27%*
Salaries and Wages Indirect Staff	(27,322,967)
Social Security & Pension Indir. staff	(7,402,230)
Indirect cost of direct staff (maintenance/idle)	(17,183,829)
Depreciaton and amortization	(11,685,947)
Personell related expenses (excl staff on loan)	(6,976,647)
Housing cost	(17,364,271)
G&A	(11,787,467)
Machinery and installations	(7,401,511)
Travel expenses	(2,081,347)
Material cost	(13,274,343)
Sales expenses	(1,560,034)
Public relations	(550,182)
Cost to be covered	***(124,590,774)***
Percentage	*27.97%*
Result	**(3,823,641)**
Percentage	
Other operating income	3,932,947
Financial income and expenses	(1,919,508)
Result before tax	**(1,654,271)**

Figure 4.1: Budgeted finances of the Total DS&C group for 2018

A short note needs to be made before the listing of all cost items. The differences between a mobile facility and a land-based yard have been talked about much, but the similarities should be considered also. The biggest one is the fact that the service the proposed concept provides should be wanted by the customers, which is the same for all repair facilities. Fleet managers need to want to pick the mobile facility for the maintenance of their vessels and it should therefore be able to supply everything that their clients require. This has been kept in the back of the mind when the particulars are described in the analysis of all the cost items below.

4.1. Direct Cost

Following the indexing of the previous chapter and the financial overview used, a start will be made with the direct cost and the corresponding cost items: direct labour and work contracted out. Both items will be individually explained including the differences with the assessment of last chapter. The way in which both influence the final result will be mentioned, including a highlighted analysis of the variables used for the sensitivity analysis. One of the largest differences between the proposed concept and a standard shipyard is the labour used for the repair & maintenance work, which will be analysed first.

4.1.1. Direct Labour

The first major cost item to be accounted for is the labour that is directly connected to the repair and maintenance jobs executed at the facility. Seen in the last chapter, the percentage on the total sales of this cost item depends greatly on the strategy applied by the specific yard. For the MSRF, it is anticipated that this cost item will result in a large percentage of the total cost. This is mainly because of the great differences between the method of recruiting and deploying personnel associated with direct labour of the mobile facility and a standard land based yard. Recalling from previous chapters, the trend that can be seen in relying mainly on sub-contractors does not apply to this mobile facility. Own, either hired or employed by the facility itself, labour will be a major part of the direct cost since the mobilization of personnel is associated with a large amount of money. This calls for a different kind of calculation of the direct labour cost. As has been done previously, by looking into the estimated sales and the proposed yard strategy to come up with a percentage on sales, this will not apply here. This will only be possible when own and hired personnel can commute to and from work in a easy and cost effective manner. When exploiting a mobile facility that is frequently situated offshore or at difficult to reach area's, the personnel has got to be accommodated at the facility for a pre-arranged amount of time. This is not uncommon for ship's crew or people working at facilities that are operated in the offshore and gas industry. The persons responsible for the repair and maintenance work will therefore be part of the ship's crew. To come up with a total number for the direct labour, firstly a list of job functions, needed for (nearly) every kind of repair or maintenance job, has got to be made. These are the functions that should be manned at all times to be able to perform the repair and maintenance work that has been agreed on in Chapter 2. Table 4.2 summarizes these functions together with the amount of personnel per shift that would be needed to perform these tasks.

Table 4.2: Job functions and their particulars

Job Function	Nr. per shift	Level of responsibility	Day rate if hired	Annual rate pp	Hourly rate pp
Yard project team					
Project manager	1	High	€ 1000,-	€ 70.000,-	€ 37.39
Quality manager	1	High	€ 1000,-	€ 70.000,-	€ 37.39
Purchaser	1	Medium	€ 500,-	€ 50.000,-	€ 26.71
Total	*3*		*€ 2500,-*	*€ 190.000,-*	€ 33.83
Yard personnel					
Engine fitter	4	Low	€ 300,-	€ 20.000,-	€ 10.68
Engine & Steel Foreman	1	Medium	€ 500,-	€ 50.000,-	€ 26.71
Steelworker	3	Low	€ 300,-	€ 20.000,-	€ 10.68
Pipe fitter	2	Low	€ 300,-	€ 20.000,-	€ 10.68
Cranage	2	Low	€ 300,-	€ 20.000,-	€ 10.68
Electrician	1	Low	€ 300,-	€ 20.000,-	€ 10.68
Insulation	1	Low	€ 300,-	€ 20.000,-	€ 10.68
Painting Foreman	1	Medium	€ 500,-	€ 50.000,-	€ 26.71
Cleaning, scaffolding & painting	5	Low	€ 300,-	€ 20.000,-	€ 10.68
Total	*20*		*€ 9400,-*	*€ 460.000,-*	€ 14.25
Grand total (day/annual)	43/66		**€ 21.300,-**	**€ 2.212.500,-**	**€ 17.25**

The job functions have been compiled by studying two different resources that together illustrated the above seen functions as being vital for a large part of the repair jobs executed at a shiprepair yard related to the special survey docking of a vessel. The general price list for both the yard in Rotterdam[1] and the yard in Curacao have been examined for this purpose. These lists show the price of certain jobs done at the yard, mostly depicted as a price based on a variable such as squared meters for cleaning and blasting or kilograms for the removal/renewal of anodes. The reason that they have been used as an example, is the fact that the jobs listed on them have been picked for the high percentage of times that they have been executed when a vessel entered the yard and its docks. Also, they do not require highly specifically trained personnel and can therefore be handled by the yard's (hired) labour. The lists are generally being send to clients when they are awaiting a personally made offer based on the clients specification for them to assess the general cost that will have to be made. To verify, the accounting software used by Damen Shiprepair & Conversion has been explored. For a number of projects, related to the need for a special survey by the client and on different DS%C yards, the percentage of the above jobs on the total quoted jobs has been checked. A comparison between the percentage of direct labour available on the MSRF and the hours spend on different jobs for an example project, (Table 5.1), shows the correctness of the distribution of the direct labour. The example project that has been used is a visit to the yard in Rotterdam by tanker 'Coolwater' for its special survey. The executed jobs are the ones that are expected to be done on the MSRF.

[1] The pricing lists for the yard in Rotterdam and Amsterdam are very similar. This is the reason that the pricing lists of only two of the three yards that have been examined in the previous chapter are used.

Table 4.3: Direct labour distribution comparison

Type of job	Example project	MSRF
All cleaning & painting	21.38%	21.74%
All fitting works	36.44%	43.48%
Project management	4.54%	4.35%
Scaffolding	4.03%	4.35%

It can be seen that the distribution matches well and that a slight margin has been build in. This, together with the desired versatility of the direct labour, decreases the risk of loosing the sought after efficiency when a small error or unforeseen event occurs. The findings done in the research have then been tested by means of expert consultation. Table 4.2 shows two different methods for determining the salary of the direct personnel. The rate per person is being determined by the level of responsibility that comes with the job for both methods. These levels have been listed in the third column. The level of responsibility is determined by both the specialisation of the job and amount of education needed to be able to perform that job. The 'day rate if hired' column corresponds to the hire of personnel on a daily basis. This includes the surcharge for being offshore but excludes the cost of transporting personnel. Having the daily workers staying on board means that cost needs to be charged for the accommodation and living. The highest level of responsibility equals to € 1000,- per day, the medium type to € 500,- and € 300,- per day is being used for the jobs that require the lowest responsibility and skill set. These rates apply for the workers that are being hired on a short basis from local agencies. The second to last column depicts the annual cost of paying the salaries of the direct labour when the personnel is living on board and is being treated as ship's crew. This method will primarily be used for the calculation of the total annual cost for direct labour. The hourly rate per job function is shown in the last column. This is non-essential information for now and will be elaborated on in Section 5.1.

Since the direct labour will be part of the ship's crew, a different type of working scheme needs to be maintained. Where a conventional yard, at least the ones operated by Damen in the Netherlands and on Curacao, work with three shift of eight hours of which only two are used most of the time, repair & maintenance workers on the proposed concept will work in 12 hour shifts for a longer amount of time. All will be within the rules and & regulations as set in the Maritime Labour Convention (Hereinafter: MLC) [MLC, 2006], meaning that a maximum of 14 hours per day and 72 hours per week will be maintained. These work hours are not any different from the hours made by ships crew of the vessels sailing around the globe and delivering everybody's needs. The rotating schedule that will be used is based on three crews who will be working for four months, having 2 months off in between. This means that the time off the job stays within both the limits set by the MLC and moral standards. By rotating every two months, two crews will be on board of the facility by all times. In this way, two shifts of 12 hours can be made per day with a maximum of 72 hours per week per person, possibly reducing the time of a docking. Table 4.4 sums up the above, where the coloured cells depict the time on board and the empty cells show the time off. Important to notice is that this scheme applies for the direct labour only, the scheme used for (part of) the indirect personnel will be slightly different but based on the same principle.

Table 4.4: Working schedule for the direct labour

Crew	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1												
2												
3												

Several points need to be made before finishing the description of the direct labour cost item. The working ethos of the personnel on board needs to be of a certain standard, where everybody is willing to work and willing to take over jobs even if the skill and responsibility level is lower than theirs. Because only one dock will be used and everybody is on board for the entire time, such versatility and flexibility is needed. The selection process by which the personnel will be chosen is going to include this, since it is being seen as one of the most important factors for this concept to work. Together with this flexibility comes a versatility in skill set as well. Although it would be possible to select for this, Damen Shiprepair & Conversion will offer to supply the necessary training on their cost. This makes it less hard to find suitable labour. Part of the reason also is the training centre that is located on the Damen Verolme yard in Rotterdam. The cost for the training will be carried by the project itself. Some examples include: A foreman who does a scaffolding job (for which proper training is needed), a captain who is the dock master as well and the cranage labour that can sail the auxiliary vessels. As can be seen, this flexibility does not only apply for the direct labour but for all personnel that is part of the concept. The cost for these trainings have been taken as €2500,- per person per year. To come up with such a price, different trainings of different skill/responsibility levels have been compared and a best fit price has been chosen. The reason for it to be calculated every year is the fact that all personnel needs to be able to get the chance to improve and learn and new crew might be taken on board.

Determination of frequent Special Survey works Pointed out in Section 2.3, the main target market will be the jobs related to the need of clients to lift their vessels out of the water for periodic mandatory work that is being determined by both Classification Societies and the flag states. One of the reasons for this is the fact that knowing beforehand what the type of projects are executed at the yard will aid in the mitigation of the problems that relying on own workers bring. Listing the type of jobs that are on one hand deemed necessary for the renewal of class papers and on the other hand done frequently because the vessel is out of the water anyway is another overall input for future case studies. Moreover will it aid in the decision for initial investment cost due to the insight in the material and equipment needed to perform all jobs. This listing can be seen in Table 4.5. Many of the information has been gathered by conversations with different yard personnel and the studying of both the Rules & Regulations set by different Classification Societies ([BV, 2018], [LR, 2017], [ABS, 2016]) and one of the pillars of the Master study [Dokkum, 2011]. The other useful sources of information have been the standard price lists that are used by the different yards. The prices are calculated for the standard jobs, which form the bulk of the work for a special survey project. A large part of the maintenance of a vessel can be done by the ship's crew during the normal operation of the vessel, it is mostly the inspection and maintenance of the underwater parts that are done while in dry dock under the surveillance of a qualified person. Section 7.2 elaborates on possible future solution to minimize the dependency on third persons for this. Depending on the examination results found by the Classification surveyor, repairs will have to be done. Emphasis shall be put on rudder and propeller, tail shafts, dents and damage on the outside hull, paint-condition, corrosion, fractures, welding, anchor chain and inlet and outlet pipe stubs. For everything to be examined, some parts need to be (partly) removed (propellers and tail shafts) or lowered (rudders). Other parts can only be seen when the paint has been cleared away, either on the outside hull or inside cargo holds or chain lockers. Scaffolding needs to be placed for most of the work, while several jobs only require an ordinary cherry picker. The older a vessel gets, the more extensive the repairs that follow from the inspection will be and the longer a vessel generally spends in the dry dock. This has been highlighted before in Table 3.2 and will be apparent and important when choosing case studies. Apart from the required jobs, technical managers frequently perform maintenance work that can only be done when the vessel is out of the water during the special survey docking. These type of jobs will depend partly on the ship type that is being docked. "Typical repairs are common to certain ship types. Bulk carriers always have work to be done on hatch covers, crude carriers [or tankers in general] to pipelines in the tanks and pump room, and to valves, hopper dredgers to bottom-flaps, container ships to container guides, etc"[Dokkum, 2011]. Almost all vessels require a fresh new paint job on their underwater parts, generally anti-fouling paint to reduce the extra drag caused by fouling from marine life, and the renewal of anodes. The hull needs a clean and most of the times a high pressure washing (water or grid) before paint can be applied.

Table 4.5: Listing of typical jobs related to vessel maintenance
Source: Listed by author, taken from both [LR, 2017], [BV, 2018], [ABS, 2016], [Dokkum, 2011] and conversations with yard project teams

Jobs required for class inspection	Frequently executed jobs
Lowering of rudder	Anodes renewal
(spot) Blasting of outside hull and holds	Application of (anti-fouling) paint, including cleaning
Extracting of tail shaft	Pipe repairs
Lowering of anchor chains	Steel repairs
	Engine(s) service
	Tail shaft seal renewal
	Sea chest (valves) overhaul
	bow thruster overhaul

Something that is as important, maybe even more, as listing the frequently executed jobs is the listing of the repair & maintenance work that will not be provided on the mobile shiprepair facility. This means that the possible future clients will not be able to have these jobs done while visiting the dry dock. This can have two consequences; Either they choose a different yard for their special survey or they decide to perform that particular job somewhere else at a different timing. Obviously, this means that some clients will be lost. It will however be inevitable due to the dimensional limitations of the facility. The determination of the list that can be seen in Table 4.6 has been based on personal conversations with yard project teams and the conclusions of Section 2.1. All jobs will be mentioned individually. The milling of a tail shaft is sometimes needed to straiten the shaft to reduce vibrations. The decision to perform this job lays either with the vessel's technical manager or with the Class surveyor, but the necessity is becoming rarer. This is one of the reasons to decide not to provide this type of jobs. The other reason is the lack of space; Only one dock surrounded by several workshops fitted on a boat does not leave enough space to completely extract the shaft and house a milling machine that is big enough for the job. Due to innovations in this field, it is now possible to perform this job while being afloat and ballasting the vessel in the right way. Where minor steel repairs, that mostly follow from failed thickness measurements and thus failed checks by Class, will be provided, extensive steel repair will have to be done elsewhere. The main reason for this is the limitation in space and quality of the warehouse that is on board. As has been said before and will be mentioned more in the remaining of this research, this means that younger vessels are more likely to be targeted and visit the dock. The cranes that are on board of the facility will be enough to assist in the listed frequently executed jobs, but heavy lifting will not be possible. When these type of jobs need to be done, either a third party needs to be involved or the client can decide to conduct their repair or maintenance somewhere else. Where it will be really expensive to transport a heavy lift crane to the facility, this will probably only be the case when a fast repair is needed.

Table 4.6: Listing of several repair & maintenance work that will not be provided on the mobile repair facility
Source: Listed by author, taken from both [LR, 2017], [BV, 2018], [ABS, 2016], [Dokkum, 2011] and conversations with yard project teams

Jobs that are not provided	Reason for choosing not to provide a service
Milling of tail shaft	Equipment dimensions and the increasing rarity of the job
Extensive steel repairs	Limitations in primarily warehousing capacity
Heavy lifting jobs	Only possible when heavy lifting third parties are involved

Difference with benchmark Although the method for calculating the direct labour is completely different for the proposed concept than for the benchmark, the numbers do not differ that much. In fact, the difference is only one percent for the example shown at the end of this chapter. While relatively more work is being done by the direct labour, their hourly rate is less than the benchmark. This adds up to a similar percentage of the cost of direct labour on the production value. Since the workers that are involved stay on board of the facility at all times, this cost item can be thought of as fixed cost. More on the division between types of cost will be given in Section 5.1. This means as well that the percentage on sales will only differ due to the possible changes in the projected production value. The amount of work that is carried out by the direct labour is more however and it will be sought after that as many are working at the same time. Because of their versatility, this work does not have to be the same every day of the project.

4.1.2. Contracted client specialists

Seen in Table 2.1 in the second chapter, the yard in Curacao utilises the most in-house facilities of all three yards that have been compared. Even given this fact, three disciplines of the standards works are being subcontracted. These include painting/cleaning works, scaffolding and the isolation & carpentry services. Table 4.2 above shows that these works are planned to be done in-house. This however does not imply that no specialists or third parties will be needed to supply the promised services. Specialised work, flag state and class society survey work and possibly extra crew for standard work will still have to be flown in. The calculation of the associated cost will be done in two fold. Firstly, the actual cost of hiring them will be shown. These cost will ultimately be paid by clients and therefore fall under the indirect cost item on the financial overview. The added cost due to the fact that this concept it is not land-based will then be calculated. All will be discussed after listing possible specialised work that needs to be contracted out.

Table 4.7: Listing of the possible client specialist services
Source: Listed by author, taken from conversations with yard project teams and example projects

Type of specialised work	Type of specialist	Workshop, machinery or installation required
Rewiring of electrical engines	Electro motor specialist	Engine machining workshop
Class survey work	Class surveyor	Installations to reach desired parts of the clients vessel
Flag state survey work	Flag state surveyor	Installations to reach desired parts of the clients vessel
Specialised software work	Software (radar, gps, vessel specific) specialist	Electrical and general workshop
Specialised engine work	Engine specialist	Engine machining workshop
Vessel specific work	Client specialist	Dependent on the type of job

The table above needs to be evaluated together with Tables 4.5, 4.6 and 4.9. These tables list respectively the required jobs for a special survey, the jobs that can not be performed on the facility and the required machinery, installations and workshops to perform all jobs. The workers on board of the facility shall be trained for and skilled in the maintenance of widely used electrical engines, propulsion engines and software packages. When the clients vessel is equipped with specialised machinery and installations, contracted specialists need to be brought in. Before the actual docking of a vessel, the sales and tendering team need to evaluate if the required job scope can be carried out at the facility by a combination of the own and sub-contracted specialist. Apart from living space and other daily needs (food, drinks and entertainment), the contracted workers need workshops and tools to perform their jobs. If their jobs are specialised, they will bring the latter themselves. Independent of the jobs that they are hired for, it is evident that all the workshops, tools and warehousing that are on board of the mobile facility can be used by everybody, including both the contracted workers and the crew of the docked vessel itself (provided that clear agreements have been made on the for example responsibilities, required skill set and safety rules). If the contracted specialists need extra equipment to be shipped to the facility, the logistics of this will be incorporated into the supply chain logistics of the facility itself which is highlighted in Section 4.2.8.

The determination of the amount of hours that third parties work on board of the facility is based on a comparison on the amount of hours spend by the direct labour. Based on example projects executed at the yard in Rotterdam[2] and the yard in Curacao and given the fact that third parties work for 12 hours per shift as well, it has been estimated that 20% of the hours worked by the direct labour is the amount of hours worked by third parties per project. The calculation has been based on the maximum amount of 72 hours of work per week as described above and using the twelve hour workdays for third parties yields a total number of eight third party workers on board. This has been taken as the average for all days of the year, partly to simplify the calculations but also because of the difficulty of forecasting the work that is going to be executed. The other average that has been taken is the cost of hiring one client specialist to work on the facility, which is the day rate of the medium skill & responsibility level seen in Table 4.2. Multiplying this with the amount of hours that are being worked on an annual base results in the cost of hiring third party labour. This is however only one part of the the second cost item within the direct cost. The materials, or purchases as it has been called in the software used by DS&C, account for roughly half of the cost of the hiring of client specialists for the example projects mentioned above. The same division will be used here due to the right similarities and differences between a land-based yard and the proposed concept.

The extra cost that will have to be taken into account shall be the second step of the calculation. The amount of extra specialist on board has been taken as eight at all times, meaning that this number needs to be multiplied by the cost of living on board. These cost will be determined in the remainder of the chapter (Section 4.2.5 and Section 4.2.8). The transportation to and from the facility is one that has to be taken into account as well. Details about the calculation of the cost of a round trip will be shown in a section that follows, but the amount of round trips per project has been determined as four. These trips include both the transport of people and equipment and are dependant on the distance between the facility and the service hub from which part of the supply chain operates. The example projects have been taken as a base for this estimation. The cost of the transportation, the cost of living and the total cost of client specialists and materials is then added together. The last factor that determines the final cost is the amount of projects executed in the dock per year, which is itself a factor of the occupation rate and efficiency. This factor does not affect the direct labour, meaning that the workforce division might differ from year to year since the occupation rate is budgeted to change in the course of the first years.

[2] Projects executed at the yards in Rotterdam and Amsterdam are similar in terms of the cost calculations and due to the stationing of the author only projects in Rotterdam have been taken into account.

Difference with benchmark The third party cost on sales are drastically lower for the proposed concept than for the benchmark. Although the cost of hiring one hour of specialist work is more expensive in the case of a mobile shiprepair facility, the plan is to be less dependent on third parties as a mobile shiprepair facility. The exact division between the hours produced by the own workforce and specialists will be mentioned in Section 5.1. Where the direct labour can be seen as a fixed cost, the third party cost is the most prominent variable cost to account for. The workforce division, cost of third parties divided by the cost of the direct labour, is lower than the benchmark as well. This is not a surprising result and has been anticipated already. It can be seen that the workforce division is higher than that of Damen Shiprepair Curacao, which might not have been anticipated. This can be explained by the fact that the division is taken over the cost of both items. A different workforce division, that of the hours worked per year by both, might be more suitable for some purposes and will be introduced in 5.1.

4.1.3. Contribution margin

The contribution margin is being calculated the same way as has been done in the previous chapter, by subtracting the sum of the cost for direct labour and work contracted out from the total income. This gives the leverage that is left to cover the indirect cost needed to run the company. As expected, the contribution margin comes out much higher than the benchmark example. Mainly based on the fact that the percentage on sales of the third party cost item is so much lower, the margin for making up the indirect (fixed) cost is bigger. A different method for the division between the accommodation cost of the own personnel working on the facility is also a source of the large difference between the projected contribution margin for the MSRF and the benchmark example. The way in which this percentage can change is mostly the amount of production value that is being generated. Because of the fixed cost of the direct labour, the cost for direct labour will not change, and there will be a large difference in the total contribution margin if the revenue increases. When the amount of projects that are being carried out per year changes, both the production value and the cost for work contracted out differs and the contribution margin shall chance less dramatically than in the first situation. Example of the change in the contribution margin for different situations will be shown in Section 5.1.

Some indirect cost items require a better understanding of the concept in terms of a visual representation. For this purpose, an artist impression has been made as can be seen in Figure 4.2. A converted vessel (a drill ship in the case of this drawing, because of the availability of the 3D model), with 2 rotating cranes, a dock bed, living quarters and an heli-deck can be seen in the drawing. The cutting plane that results in only the top part of the vessel to be shown is the expected waterline. No hard design decision can be drawn from this impression however. The preliminary design decisions that produced this visualisation are fuelled by the statements made in the following section.

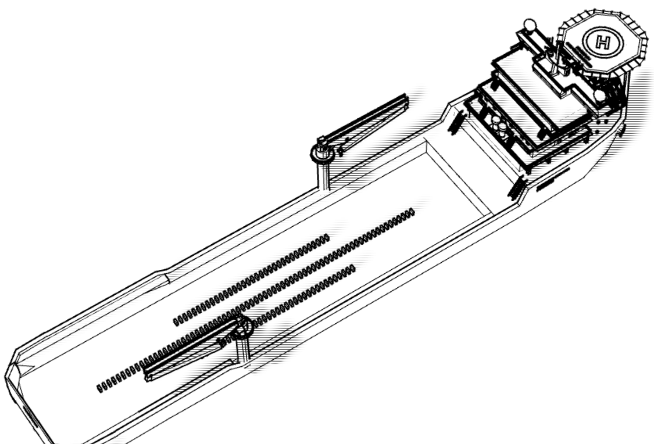


Figure 4.2: First impression of the MSRF with an empty dock

4.2. Indirect Cost

The cost for the direct labour and the contracted client specialists leaves only a portion of the total expected sales to cover for the cost that have to be made independent of the amount of work that is being executed to generate that income. The cost items that are part of the indirect cost shall be discussed next. Every item and the way they differ from a land-based facility will be described individually, staring with the indirect labour.

4.2.1. Indirect Labour

Because the concept consists of a mobile facility, the total amount of indirect labour will be part of the ship's crew as well. Work that is normally being done by people working in the office, at the specific yard or at an office that is part of the chain of yards as is being the case with DS&C, can now be done partly from the facility itself. This means that those people work on the same schedule as the yard personnel mentioned above. Table 4.8 lists the personnel needed for the indirect work, that mainly includes the running of the facility. The sailors can help out and do multiple jobs on the dock floor that can be done by non-skilled labour when this is needed.

Table 4.8: Indirect labour for the safe manning of the facility

Job Function	Amount needed	Level of responsibility	Annual rate pp
Captain & dock master	1	High	€ 90.000,-
Mate & HSE manager	2	High	€ 60.000,-
Sailors	2	Low	€ 20.000,-
Engineers	2	Medium	€ 35.000,-
Kitchen & housekeeping	4	Low	€ 20.000,-
Grand total	**13**		**€ 702.000,-**

The list of personnel has been made up to comply to the safe manning of a vessel. The safe manning, which is the minimum amount of crew on board the vessel, is among others based on the following matters: Size of the vessel, sailing area, purpose of the ship and the installed power. This means that the facility will be run just like a normal vessel. The rotation scheme is slightly different than for the direct labour, meaning that the crew listed above will not work in two shift of 12 hours a day. With this crew they would be able to both run the ship, which will need much less guidance than a normally operating vessel, and man their positions as dock master and/or HSE manager. To determine the rotational scheme a division is made between the high level of responsibility and the other two levels. This means that both the captain and the mates sail two months on and two months off, while all the other indirect crew sails on the same scheme as the direct crew. Using these schemes, the grand total for the annual salaries of the indirect crew can be calculated. Important to notice is the nationality of the indirect personnel will be the same as the larger percentage of ship's crew that occupy such functions. The functions with the highest level of responsibility will be manned by men or women from the Netherlands, as is the country of Origin of Damen Shipyards. The other two, medium and low level, functions shall be manned by personnel coming from developing countries. Examples of these are The Philippines and Indonesia, two countries where many able seamen originate from.

The same type of versatility is needed as for the direct labour, which is already mentioned in the table and in the direct labour section. The captain will have to act as dock master for instance. The cost of training required for such operations has been taken as equal to the ones for the direct labour because of the average that has been taken, meaning that the €2500,- per person per year will be taken into account. This will then be added to total for the salaries mentioned above and just one more item is needed to end up with the total cost for the indirect labour. As can be seen in the financial benchmarking done in the previous chapter, the social securities and pension needs to be taken into account as well. The percentage of this cost item relative to the salaries and wages for indirect labour for the total DS&C account, which is a form of the average, has been used to calculate for this concept and comes down to a percentage of 27%. All together make up the total cost for indirect labour.

Difference with benchmark Two different conclusions can be made for the indirect labour cost item; one based on the percentage on sales and the other on the percentage on indirect cost. The back office work that needs to be executed to be able to perform shiprepair services does not differ that much when assessing a mobile facility or a land-based facility. This is the reason for the similarity in the percentage on sales of the two. Both differ when looking at the percentage of the indirect cost, but this can be easily explained as well by looking at the differences in the percentage of the indirect cost on the total production value. This percentage will be analysed in more detail later in this chapter.

4.2.2. Personnel related expenses

Some additional cost are made that are related to the personnel working for the repair yard, both direct and indirect. Examples of events that are linked to these cost can be a Christmas party or drinks organised for the retirement of a long lasting employee. To calculate these cost, the cost item from the Total DS&C group has been taken as an example. The percentage of that cost item on the total cost for both the direct and indirect labour has been calculated and then divided by two to result in the percentage to be used ultimately for the proposed concept. The division by two relates to the fact that such activities are of a different nature when assessing a ship's crew in stead of a land-based repair yard that is connected to offices and such. The difference with the benchmark is hard to make based on a different income structure, different labour structure and higher indirect cost margin. Being below one percent on sales, it is also a cost item that does not deserve that much attention.

4.2.3. Material Cost

As has been determined in the previous chapter, there exists a correlation between the amount of work that is being executed on the yard, in particular the percentage of work done by direct labour, and the amount of material cost of that specific yard. This linear regression formula has been established in Equation 3.6 and will be used here to determine the amount that is being budgeted for the material cost of the MSRF concept. A number of remarks and assumptions have to be made however, which all result from the differences between the proposed concept and a land-based repair yard.

Firstly, a closer look has to be given to the cost items that compromise the overall material cost item. As has been said in the previous chapter, the material cost includes everything that is related to the materials used in the yard that are generally needed for all jobs executed, including energy required. Because of the differences in the setting up of the total indirect cost, the energy cost will be taken as a separate cost item. This means that only the percentage of the total material cost excluding the cost for energy needs to be taken into account for finding the material cost of the proposed concept. To determine that percentage, the profit and loss statements of the yard in Curacao has been taken as an example because its workforce division comes closest to that of the MSRF. The percentage of the cost of energy on the total material cost is 33%, meaning that for getting to the to be used material cost only 67% of the value total material cost had to be taken into account when determining the linear regression in the previous chapter. The cost of the energy supply will be incorporated in the housing cost item (Section 4.2.5).

The second matter to consider is the type of sales to use for the calculation of the material cost based on the percentage on sales determined by the linear regression. As will be apparent a bit later in this chapter, the budgeted revenue will be made up of two parts. The first part of the income results from the projects executed at the yard and is not extremely different than for a land-based yard. The extra income that can be generated because of the added value of a mobile yard will comprise the second part of the revenue. The latter is only (a percentage) of the cost that is saved by the clients and does not make any use of materials whatsoever. There, only the former shall be used for the determination of the material cost based on the percentage on sales. As a reminder, the percentage of sales is a function of the workforce division. Since the hourly rate of an own worker and a contracted worker are quite similar for the example yards, the division in cost between the two has been taken as the workforce division before. Because the rates differ much in the case of the proposed concept, a different approach has been chosen. The amount of hours that are made by either workers and the division between that is used from now on. This still works as a benchmark for the amount of material that needs to be used of the own supply and warehouse, but fits the picture of the concept better. By firstly executing the linear regression for the determination of the percentage on sales, this can then be multiplied by the normal income of the estimated production value to result in the total material cost.

Difference with benchmark As expected, the material cost item is relatively larger than the benchmark. This is solely because of the lower workforce division found on a mobile facility. As has been described above and in the previous chapter, it has been chosen to estimate the material cost solely on the workforce division. A difference in the relative size of the cost item can therefore only be attributed to this variable.

4.2.4. Machinery and Installations

Seen in the previous chapter, the percentage on the total cost to cover of this cost item is clustered around the 4% for all yards within the DS&C group. The maintenance, repair and hire of equipment is included in this cost item. Similar costs need to be made when considering a vessel, or floating facility, just like the proposed concept. For the determination of the percentage on total cost of the maintenance of a vessel, Martin Stopford is being consulted once again [Stopford, 2009]. He states that the periodic maintenance on a vessel can be taken as 4% of the annual cost, which is the same number as has been seen in the previous chapter. This can however only be attributed to coincidence. But the fact that both numbers are generally in the same range seems reasonable. Next, he states that 16% of the operation cost, itself 14% on annual cost, can be attributed to the voyage repairs & maintenance, coming down to 2.24% on the total annual cost. The analysis by Martin Stopford has been done for a bulk carrier. A mobile shiprepair is different to a bulk carrier in a number of ways. First of all, much more equipment is installed on board in terms of the shiprepair services that would be needed on the facility than on a bulk carrier. This inflicts a higher percentage for the concept than for the example given by Stopford. If it will be chosen to not include self propulsion, this decision will take down the percentage again. This means that, depending on the method for transporting the facility, the percentage used for the machinery & installations cost item will either be the same or higher than the example. When it has been chosen to use a tug, and then in specific the additional tug described later, cost for the maintenance of the facility will be the same as Stopford uses. It will however include a surcharge for the maintenance of the additional vessels, as is described below.

The next challenge arrives from the possible circular reference when one of the cost items depends on the total indirect cost, which sums all indirect cost items to a total. To prevent a circular reference, the total cost associated with the machine & installations is taken over every other indirect cost, except itself. The direct cost are not taken into account for the calculation, since these cost are not to be considered normal for a vessel. As will be shown later in this chapter, the concept involves having two additional vessels for transporting crew and material to and from the shore and a tug for docking assistance and possibly the transportation of the facility itself. The maintenance cost of these vessels needs to be taken into account as well. The same percentage as described above, 16% of the operational expenses, will be used. The total amount of hours that both vessels sail, as will be calculated in the travel expenses cost item, and the associated fuel cost will be used as the operational expenses. The M&I cost for these vessels is going to be taken into the total machinery & installations cost and adds to the cost described above to finish the cost calculations. This cost will be taken annually to build up a base for the mandatory docking of the facility itself, which is inevitable. Doing such explains why no capital expenditure has been budgeted every 2,5 years for the docking.

Difference with benchmark The machinery & installations cost item is larger than the benchmark, in a relative way of course and as expected. Since the facility itself, the high volume of machinery on board and the auxiliary vessels all need to be maintained and repaired, the cost for this should be higher than for a land-based facility. Where a regular shipyard is mostly quite old and therefore needs regular repairs as well, this does not add up to the additional work that needs to be taken into account for a mobile service.

Required machinery & installations Stated above is that more equipment shall be installed on the mobile facility than on a normal vessel and therefore an increase in the machinery & installation cost is to be expected. To further enhance on this, a list of the required machinery and installations to provide the demanded shiprepair services has been made. Conversations with different yard project teams and managers and visits to the facilities at several existing DS&C yards have concluded this list, that not only shows the required equipment but also the personnel that will mostly use that equipment and the jobs for which it is required. When the amount of different sets of equipment is listed, welding equipment for example, this is based on the amount of personnel per job per shift as has been listed in Table 4.2. One extra set will be taken on board to ensure the possibility for every worker that is on shift to perform his or her job. Again will be stated that all personnel should be able to perform multiple jobs. The jobs that they are able to perform outside of their expertise will mostly consist of jobs that do not require much skill or training. The building of scaffolding or the washing of the hull can be taken as an example and can very well be perform by a steel worker if there is no need for his or her service at that time. The required training and the associated cost have been taken into account as described above. The operation of a cherry picker is another example and everybody should be able to do this and to help his or her colleagues when their service is idle for a moment.

Table 4.9: Listing of the required machinery and installations to provide the demanded services
Source: Listed by author, taken from both [LR, 2017], [BV, 2018], [ABS, 2016], [Dokkum, 2011] and conversations with yard project teams

Type of machinery or installation	To be used by	Required for which jobs
Cherry picker	All personnel	Assisting in elevated jobs
Forklift	Indirect crew mainly	Assisting in the placement of the dock blocks and heavy transport
Lathe installations	Engine fitters mainly	Refitting of engines and machining of various equipment
Pipe bending installations	Pipe fitters	Piping works
Steel cutting and bending machines	Steel workers	Fabrications of steel structures
Welding equipment (6 pax)	Steel workers, pipe fitters, engine fitters	Welding of various materials
Painting equipment (6 pax)	Painters	Painting of various surfaces, both inside and outside of the vessel
Power washing/Grid washing equipment (6 pax)	Cleaners	Cleaning of various surfaces, both inside and outside of the vessel
Scaffolding equipment	Cleaners/painters mainly	Assisting in elevated jobs
Ventilation equipment	All personnel	Ventilate confined spaces during several works
Workshops		
Pipe bending and machining	Pipe fitters	Fabrication of pipe work
Steel machining (plus warehouse)	Steel workers	Fabrication of steel work and welding works
Engine machining	Engine fitters	Machining of engine parts and small machine work
General (to be combined with general warehouse)	All personnel	Small fabrication work and general works
Liquid storage		
Power washing (grid) material	Cleaners	
Oil, paint and other contaminating liquids	All personnel	
Fresh water supply	client's vessel	

The second part of the table consists of the type of workshops that will be needed and that will house most of the equipment, machinery and installations. The space that is required for the different workshops can be combined to save space. The steel workshop can for example house the lathe and pipe bending machines to form one large workshop. When the detailed design will be made, it is going to be necessary to give much thought on the logistics and supply chain of materials within the facility. A large part of this is the warehousing of materials. It has been chosen to mainly service vessels that come in for their special survey duties because of the relative easy planning of this type of maintenance. The amount of stock that needs to be kept in the warehouse of the facility can be reduced in this way also, but a certain amount needs to be kept at all times. Example of the materials that need to be kept in stock are small items such as nuts and bolts, safety gear, piping and steel. Sea chest seals, widely used tail shaft seals and common parts for the maintenance of widely used engines are more examples. These items take up more space, but will aid in the possibility of the MSRF to serve its clients demands.

To elaborate more on the workshops listed in the table, the workshops situated at the yard in Rotterdam have been investigated. Keeping in mind both the differences and the similarities, the requirements for the workshops on board of the proposed concept can be given. The conclusions that result from this can after wards be listed in the design criteria part of the concluding chapter (Section 7.1). On the proposed concept, there will only be part for one big workshop that incorporates all the machinery and equipment that is needed to support the crews in the dock for the work that has been listed before. The warehousing (for steel plates, steel girders and piping material) is calculated on being able to supply the needed material for the first days of vessel's visit in the dock. The amount of days that need to be covered are based on the amount of time it takes to have new steel supplied to the facility. This should be taken into account when detailed plans about the warehousing are made. Because of the fact that no big steel repair work is going to be executed, the warehousing of steel can be less as well. Steel plates of 6 meter in length each[3] need to be moved across the workshop, for which an overhead crane is needed. A thickness between 6 and 30 millimetres, with a 2 millimetre step, needs to be maintained to perform the needed jobs. The cutting of the steel will be done by plasma cutting primarily, since that involves less risks in a confined space. This workshop shall not only be used for steel works, but also for the work on piping and lathe machines. The latter are mostly a consequence of the overhaul of engines, valves and bow thrusters. Because of the length of the steel plates, an height of 10 meter needs to be maintained. This means that the workshop will take up multiple decks and will be the main part of the front of the facility, together with the accommodation. Since the efficiency of the work depends on the size of the workshop as well, it will be tried to maximize this space as much as possible. If the size of the workshops in Rotterdam is compared to the differences between this yard and the proposed concept, around 40 meter would be the minimum lenght of the workshop if the width is to be taken the same as that of the vessel. This involves the storage of materials as well. These conclusion have been incorporated in the first impression that can be seen in Figure 4.3. The workshop is the large rectangular shaped volume in front of the dry dock, with a direct connection between both.

[3] This is the common minimum length for a steel plate and the common other lengths for the supply of steel plates is a multiple of this number

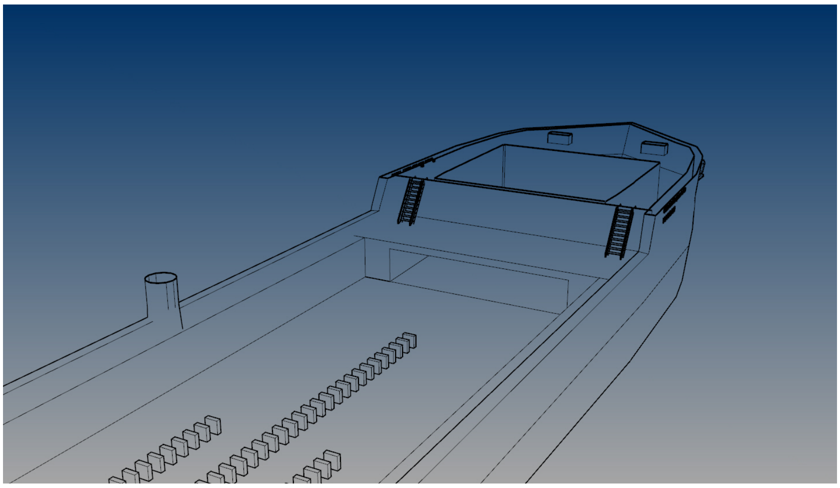
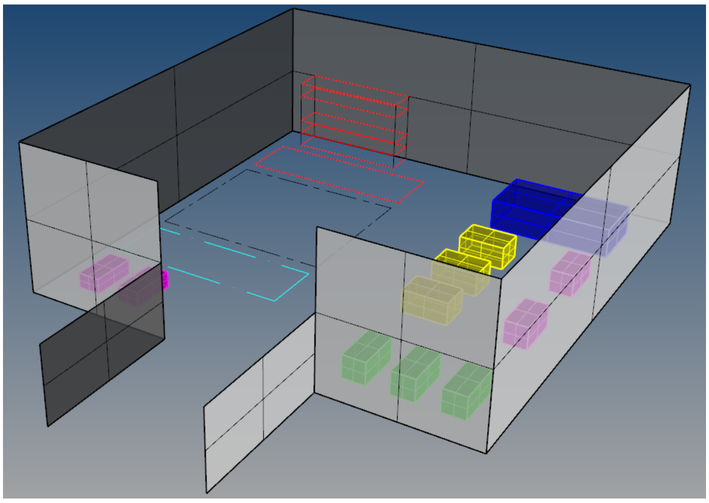


Figure 4.3: First impression of the connection between the dry dock and the proposed workshop

Table 4.9 and the above figure can be combined for a closer look into a possible configuration of the workshop. This visualisation is just an option to combine all and only shows the fact that thoughts have been given to a part of the technical feasibility in this stage of the design. Figure 4.4a shows a 3D model of the workshop. Different machinery & installations can be seen, as well as storage space and possible locations for workbenches and empty floor space for assembly. The legend in Figure 4.4b helps in understanding the 3D model. The connection between the workshop and the dry dock should be watertight in the case of submerging the facility for the (un)docking of a client's vessel. A watertight door[4] gives the best security in this case. The storage space for the transportation equipment inside the workshop can be used in this case. An overhead crane installed in the workshop makes the handling of equipment possible.



(a) A 3D model of a possible workshop configuration

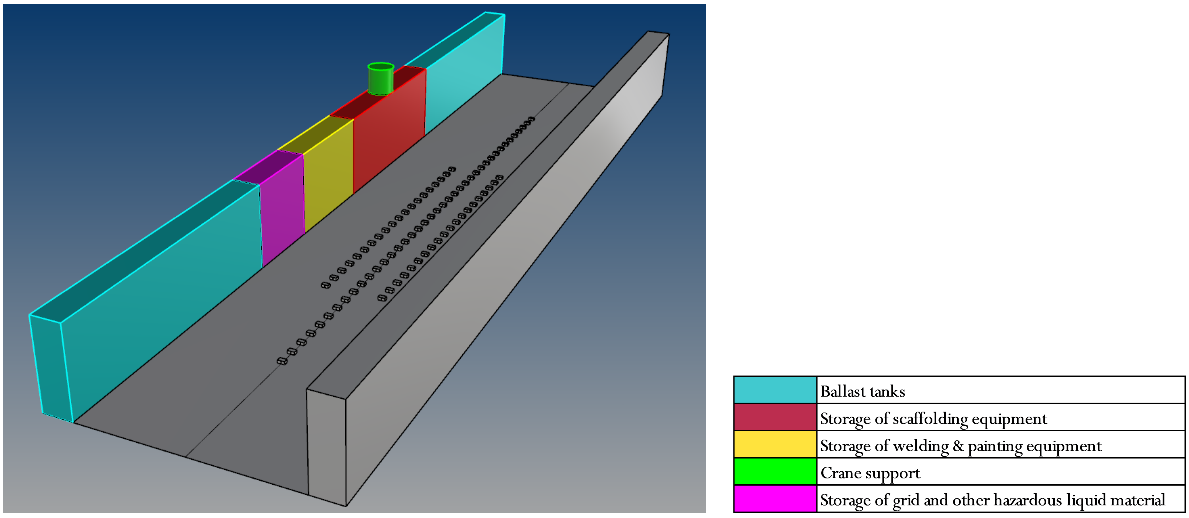
	Steel storage (plates & profiles)
	Transportation equipment storage
	Bending & cutting equipment (piping & steel)
	Lathe machines
	Work benches
	Plasma cutter
	Work space

(b) Legend connected to the 3D workshop model

Figure 4.4: A possible workshop configuration of the MSRF

[4] A proper study into the most suitable width of the connection should be made in a further design. The price of a watertight door increases dramatically with the width, but enough space should be maintained for the handling of equipment coming in and out of the workshop.

Knowing which materials are being used on a to be serviced vessel, and ideally also the materials that break down the most, aids in the ability to have the right materials in stock. It is however inevitable to depend on the delivery of materials, which is why there will have to be a supply of materials from outside of the facility to be able to perform the demanded works. The consequences of this come in two fold; An additional vessel needs to be taken into account (see Section 4.4) and cost will have to be calculated for the supply of these materials. The latter is going to be discussed in Section 5.1. As will be elaborated on more in the case studies of next chapter, servicing Damen build vessels aids in the planning of materials and thus the reduction of the cost that come with it. One of the types of supply will be elaborated on more here. Many jobs that are related to the maintenance or repair of a vessel require the use of 'dirty' liquids or materials. The grid material that is needed to clean the outer surface of the vessel or the oil and lubricants needed to repair a tail shaft seal are just two examples from a list of many. The storage of such materials, both before and after they have been used, needs to be available on board of the facility. Because this happens on land at a standard land-based facility, there are fewer risks involved in the case of spillage. In the case of a mobile facility, that needs to be able to work at various locations, the risks and consequences related to the spilling of such materials is larger. The storage of these materials needs to be of the highest standards and it should be tried to keep the used material on board as short as possible. The supply runs, around four times per project as will be seen later in this analysis, should therefore contain methods to dispose of the used materials and bring back new. Once at the service hub on land, the disposal of the hazardous materials can be finalised. One possible method of storing dirty grid and other hazardous materials on board of the MSRF has been visualised in Figure 4.5a, together with other methods of utilising the dock walls. This again, like the workshop configuration, is just a visualisation of a possible usage. Ballast tanks, for stability and submerging the vessel, can be housed in the walls as well. The side walls can not be the only place in the vessel for such tanks, the front of the vessel should contain them as well. Both for the ballast tanks and dirty material thanks goes that open liquid tanks have a large influence on the stability of a vessel, both positive and negative. Apart from storing clean or dirty liquids or materials, the side walls can also be used for the storage of machinery & installations. Welding equipment, painting equipment (pumps and paint guns) and scaffolding material can perfectly be stored in the walls of the dock. The legend in Figure 4.5b helps in understanding the 3D model of the possible dock wall configuration.



(a) A 3D model of a possible workshop configuration

(b) Legend connected to the 3D workshop model

Figure 4.5: A possible sidewall configuration of the MSRF

4.2.5. Housing Cost

A relation between the housing cost and the workforce division has not been found for the existing DS&C yards. In the financial numbers shown, the cost items that comprise the housing cost are primarily the rent for the facilities. Because of the differences in the division between the cost items within the indirect cost between the MSRF and a land-based yard, the content of the housing cost will be different. Because the rent of a vessel/floating facility is the maintenance of that asset and depreciation, the housing cost will be comprised of the energy needed to facilitate the services that is provides. The maintenance of the vessel will be included in the material & installations cost item, since that covers the maintenance and repair of the total asset as well. The depreciation that comes with the investment in a facility has its own cost item and will be dealt with later.

To be as accurate as possible when determining the amount of money that is needed to provide the service it promises, the energy cost have to be divided into two parts. One of those parts is the energy needed to keep the vessel/facility running and should therefore be classified under the indirect cost, while the other is dependant on the amount and type of works that are being done and can therefore be related to the direct cost. Since the cost of energy is included in the price that is being asked to the client, the total housing cost item (in the case of the proposed concept) will fall under the indirect cost. To calculate it, two parts are being added however. For both parts, a vessel that is similar to the proposed concept has been taken under investigation.

Firstly, the demand for power to supply the services that generate income need to be determined. To calculate the demand for power, the energy use of Damen Shiprepair Rotterdam has been taken into account. This has been done in two different ways. First of all, the power usage of every docking in the year 2016 has been gathered, including the days the vessel has spend in the specific dock. The average has been taken over the dockings in the two smaller docks. This number has been divided by the average length to result in a energy usage per meter dock per day, which has than been multiplied by the targeted length of the dock on the MSRF. This is only the power that is being consumed by the dock pumps and other small pump work that occurs during the course of a docking. All supporting facilities had to be mapped as well to get an insight into the power usage of a yard. The supporting facilities are among others; Welding equipment, steel and engine workshop, pipe fittery, specialist works, cranes and the water pumps for the supply of fresh water to the vessels. It incorporates the linking of vessels to the power net as well when they are not able to supply their own power while in dock. Although the data has been gathered long time ago, the required data was only available for the year 2005, it is believed to be not extremely changeable data. To calculate the required power for the shiprepair services of the proposed concept, the power usage of DSR in 2005 has been divided by the difference in length between the proposed dock and the sum of all the docks in Rotterdam. Important to notice is the fact that the total amount of kWh is only being used for the calculation of the cost. Due to the peak energy demand of for example cranes and dock pumps, it does not say anything valuable about the total installed power. The precise energy demand for the individual equipment, and the combination of these machines and the distribution between them, is part of future studies when a design design of the facility will be made if the total feasibility turns out te be positive. To calculate the total cost, the required energy is divided by two calculation steps and then multiplied by the fuel price for MDO diesel. This type of fuel is being used to be able to comply to the environmental standards in all parts of the world. The first conversion rate is from kWh to litre fuel, which is based on the energy density of MDO fuel. The second rate is the conversion from litre fuel to tons, which is based on the density of MDO fuel. The price of the MDO fuel is one of the variables that will serve as the input for the Monte Carlo simulation. The final number is the cost for the energy of providing shiprepair services.

The second part concerns the energy needed to run the facility itself. The air conditioning should supply cold or warm air, the kitchen has to be up and running and the media room can not go without power to keep the crew happy. The same conversion from kWh to Euro has been used as for the first part to come up with the cost for the consumption of energy for the hotel services. Several accommodation units have been evaluated for the determination of the required kW per person staying on board a vessel, of which one can be seen in Appendix A. The average for these type of vessels comes down to 8.8 kW installed generator power per person. During personal conversation with Damen employees it has been determined that it is better to use a value of 12 kW required energy, since the layout of the proposed concept and the accommodation units differ in such a way that more power will be necessary per person. To come up with a total annual price for the cost of energy needed for a comfortable stay on board, the number of both the direct and indirect crew that are actually on board has been multiplied by the value found, done for every day of the year. Not only the energy needed to supply the accommodation makes up the cost of living on a vessel. Other life needs such as food, drinks and entertainment need to be considered as well. A general price per person per day living on board of the vessel has been considered. This price, €12,- per person per day, is a general number used in the maritime industry and is gathered from personal conversations with several persons working within the Damen Group with experiences as ships crew. The total number of full time employees simultaneously on board, both direct and indirect, has been multiplied with this number for the amount of days that is spend on board of the vessel to come up with a final number to be added to the housing cost calculated above. All can be seen in Table 4.10.

Table 4.10: Justification of the housing cost items

Activity	Annual kWh
Dock activity	577664
Ship usage	146342
Technical services	26585
Workshops	182927
Cranes	18293
Water pumps	60976
Compressors	182927
Sub-Contractors	18293
Activity	Cost per day
Price per person	€12,-
Energy cost per person	€1,50
Total annual cost of living for MSRF	**€479.154,-**

Difference with benchmark The energy cost as well as the cost of living have been included in the housing cost for the mobile facility. The differences with the benchmark, an unexpected lower percentage, comes probably from the fact that the cost items have been calculated in a slightly different way. Although the housing cost are somewhat dependant on the price of energy (fuel in this case) and can therefore be relatively bigger or smaller than the benchmark, comparing the two is not extremely useful due to the differences in the calculations.

4.2.6. Sales expenses, Public relations

The general rule for the estimation of the sales expenses is 2% of the total estimated revenue. This is included in the fee that is paid by all yards to the overall holding of Damen Shiprepair & Conversion every year. When the average sales expenses are taken of all yards, it adds up to a negative number. This means that less than 2% is spend on average by the yards. The actual percentage comes down to 1.58%. For the calculation of the sales expenses for the proposed concept it has been determined that this number will be divided by two and a percentage of 0.8% will be used. The reason for the lower number is the fact that the facility and its services will be part of both the sales apparatus of the total DS&C group and the Harbour & Voyage division. Also due to the facility being the first of its kind, it will attract enough attention to do its own sales. The last reason for the lower percentage is the less amount of work that needs to be done by the cost estimators. By doing mostly special survey work, most of the jobs are relatively simple to estimate. The sales expenses include the cost for public relations as well and the management fee has been taken out of the general & administration cost item. Above mentioned considerations give enough information for the understanding of the differences between the mobile facility and the benchmark example.

4.2.7. General & Administration

Looking at the percentage of the total indirect cost of the GA cost item, this is a considerable number. It is therefore important to look into this item in more detail, as has been stated in the previous chapter. Because of the difference expressed multiple times before, there might be the chance that some of the items that comprise the overall cost item do not apply for the proposed concept. Doing this shows that only 58.32% of the total GA cost items apply, meaning that only this percentage of the average percentage on total sales found in the previous chapter should be used. This includes the insurance, which deserves a bit more attention. A shiprepair yard is insured for the projects that are being executed as well as the facilities itself. For a mobile repair facility, the latter will increase. This means that an additional percentage needs to be added for the insurance of the vessel itself. For this purpose, the analysis of Martin Stopford will be used once again. Although he takes a ten year old bulk carrier as an example, the percentages seem representable for our purpose. According to Stopford, 12& of the operating cost are covered by the insurance. The total general & administration cost item will therefore be calculated by adding up the two different parts that are described above.

Difference with benchmark Due to the fact that not all items that make up the total general & administration cost item have been included in the calculation for the MSRF, the number would be expected to be relatively lower. Adding up the insurance cost apparently equalizes this to roughly the same percentage on the production value.

4.2.8. Travel Expenses

The normal content of the travel expenses cost item is the cost for car leases and mileage compensation. These do not apply for a mobile facility that is possibly being exploited offshore, but similar items do. The transportation to and from the shore will be done by an auxiliary vessel of which the details are being described in a coming section. The installed power of that vessel, a Fast Crew Supplier build by Damen, is used to determine the cost of transportation. Both the direct and indirect labour and the third parties (specialists and material) will need to be transported. In the financial overview, only the former will be included in this cost item as the third party cost fall under the direct cost. To calculate the price of sailing for one hour at cruising speed, the installed power (75% MCR for cruising speed) will be converted by using the rules of thumb that have already been mentioned above. Due to the rotational scheme that has been determined, only six large crew changes are needed. These changes involve 3 round trips and cost of this transportation depends on the distance to shore and the associated hours of sailing and the fuel price. Transporting the ship's crew from shore to the facility is only one part of the total crew change expenses. Getting them to the shore pick-up point from where they spend their time off is the other part. It has been assumed that half of the crew can be sourced by local content, meaning that flight expenses need to be taken into account for the other half. It has been assumed that € 1200,- per flight covers the average flight expenses. This includes both the expensive flights for the high skilled labour taking into account the necessity to pay this labour for the days that they are flying and the cheaper flight expenses for the low skilled labour that can be found locally. These cost are to be added up to the fuel cost for transporting the entire number of changed crew to the facility itself. The other fuel expense that comes with the repairing of vessels in a dry dock is the amount of hours a tug boat assistance is required. This is the second auxiliary vessel and the calculation has been done in a similar way. Taking projects on the yard in Rotterdam as an example, it has been estimated that 2 hours of sailing the tug boat is necessary for both the docking and the un-docking of a clients vessel. Adding both together yields the total travel expenses. The cost of moving the facility itself will be part of next chapter.

Difference with benchmark Where the travel cost item is not even a half percent for a land-based repair yard, it comes down to almost three percent on total sales for a mobile facility. This is roughly six times more, but it does not come as a surprise. When the added value of your service is to reduce the travel time, and thus cost, of your clients, it can be expected that the cost for your own travels will be more. Said again, this cost item only includes the travel cost for the transportation of personnel, goods and supplies and not the facility itself. This will be analysed in the next chapter.

4.2.9. Depreciation

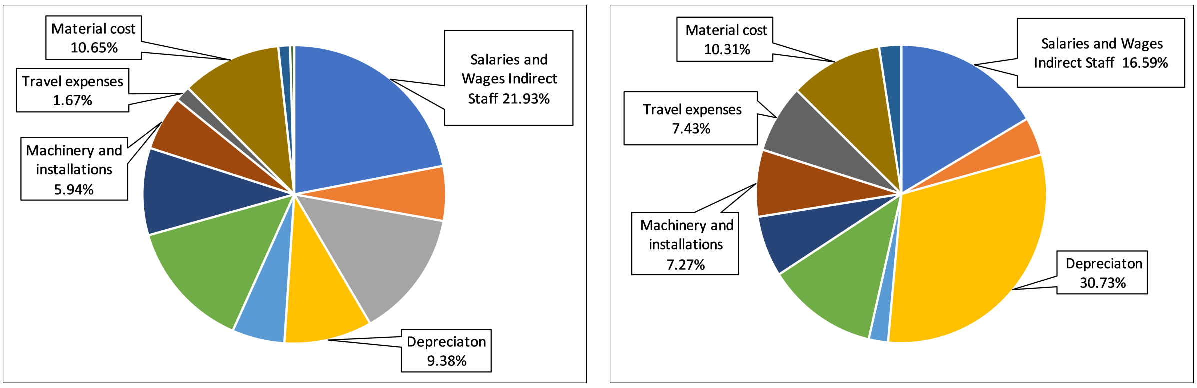
A linear method is used for the depreciation of all assets that are involved in the project. These assets do not only include the vessel that makes the facility itself, but is also incorporates the machinery & installations and the additional vessels (Section 4.4). Since they are all included in the capital expenses, incorporating them into the total depreciation does not require extra work. Although this method is not the most accurate, it is the generally being used because of its simplicity. The elementary formula that defines a linear depreciation strategy can be seen below.

$$\text{Annual depreciation} = \frac{C_0 - C_T}{T} \tag{4.1}$$

The initial investment minus the left-over value of the asset is divided over the running years of the project to result in the annual depreciation. The reason that this method is not the most accurate is the fact that is does not take the chances of the market value of the asset into account [Stopford, 2009]. If the non-linear strategy is being used, the rest value of the initial investment depends on the market value that the asset has at the particular moment of calculating the depreciation. Because such market movements are extremely difficult to predict (and that falls outside of the scope of this research) the rest value is determined by taking a percentage of the initial investment. Due to the nature of the facility, the amount of steel that is part of the structure in comparison with the total weight and the diversity for which is can be used after the life-time of the project, this percentage is taken as 20%. Important to notice is that this is actually only a virtual cost item and is only on the balance sheet to show the in and outflow of cash reserves. The virtual cost item is included in the calculation for the final after tax income, but will be cancelled out for the free cash flow calculation that will be described later in this chapter.

Difference with benchmark One of the biggest difference in terms of the percentage of a cost item on the total sales and total indirect cost is the depreciation. Because of the fact that this cost item is only virtual one and thus of minor importance to the determination of the free cash flow that in the end yields results in terms of the net present value, one should not pay too much attention to the large difference while reading either this text or viewing the different pie charts seen in the figure below.

4.2.10. Total cost to cover



(a) Division of indirect cost of Total DS&C (b) Division of indirect cost of the proposed concept

Figure 4.6: Differences in the division between indirect cost items related to the proposed concept

All conclusions on the differences in the percentages on total indirect cost between a land-based shiprepair facility and the proposed mobile one can be seen in Figure 4.6. The figure does not need much explanation due to the fact that all the differences have been mentioned before. It is however important to keep two things in mind when analysing this figure. Firstly, the pie charts that can be seen together with the overview in Figure 4.7 have been made using several chosen variables. These variables can be seen in Table 4.12 and the input for them can be chosen arbitrarily. When different inputs are chosen, the pie charts and overview will differ slightly due to the change in the absolute values. The relative changes will stay roughly the same however and therefore these pie charts can be seen as an useful example. Secondly, do not let the large chunk taken up by the depreciation mess up the view. This cost item is virtual and is added up again to the net income for the calculation of the free cash flow. With the cost structures covered, the next section will describe the method for calculating the projected production value including the difference with a normal land-based shiprepair facility.

4.3. Production Value

The cost described above have to be covered by income, just like any other project or company. Because of the special operational profile of the proposed concept, the production value for this project is going to be calculated in two fold. The first part includes the 'normal' income, as has been referred to multiple times in the previous parts of this chapter. The income generated from the service that a shiprepair facility supplies fall under this part and will not differ much from a land-based facility. Depending on the cost of supplying this service, a price can be determined. It becomes interesting when the second part is being calculated. This is being build up by the cost that are saved for the client when the shipyard is coming to them instead of the other way around. To make sure that a profit is being made when the clients chooses for the service of the MSRF, the production value added to the normal income is just a bit less than the cost that those clients are able to safe. Both will be mentioned individually.

4.3.1. Added value

The added value of the concept comes in two fold and both will be mentioned individually. Firstly, the higher rate of efficiency and working pace that can shorten the time a vessel needs to spend in dock is being analysed. The second added value of the concept is the reduction of the travel time a client needs to incorporate to find a suitable yard. Both include the ways of cost saving for possible clients and the opportunity for to ask a higher price of the promised service. The way that the added value sums up to be higher than the additional cost to supply this value is what eventually needs to make this concept a feasible one.

The number of days a vessel stays in dock determines the amount of projects that can be done in one year. The length of a stay, of in this case special survey related works, lays between 7 and 14 days for both the yard in Rotterdam and Curacao with an average of 12 days. This number has been taken as the normal time for a docking and the number that needs to be taken down to improve the efficiency. Due to the ability to work 72 hours per week with two shifts, this should be possible. To determine the number of days for a special survey visit to the yard, multiple factors need to be taken into account. The most important of these is the critical path of the project. This is dependant on the type of works that are being executed and examples are; The painting scheme, steel replacement or the tail shaft removal and machining. All have different factors that determine that path and more on all these will be said in the coming chapter since the reduction of the critical path depends on factor that are different for each case study. An example can be given here however. The dry time required for every layer of paint depends on the outside temperature and humidity of the area. The dryer the air, the faster the dry time and the shorter the critical path. Also, not all paths benefit from longer working days. Another factor is the combination of different critical paths and the space they need to work without interference of something else. Next chapter will elaborate more on the details. Shorter time spend in the dock will however make it possible for clients to have more days available for earning an income and this can be seen as an added value. Also, more projects that generate income for the facility can be housed in the same dock space.

Secondly, by choosing a suitable position that is only possible due to the mobile nature of the concept, the travel time to the yard of potential clients can be minimized. This yields more days for the generation of income. The added value for both the reduction in repair time and the reduction in deviation time is calculated by multiplying the reduced time in days by the day rate of the client. To give an example; When two days of sailing are saved and the project can be executed in 10 days, four times the money that the client can earn in one day of sailing is used as the added value for that project. No mention has been given to the operational expenses of the client, which has been done on purpose. The cost for travelling to the yard will be roughly the same as the cost for transporting cargo. The difference comes from the fact that more fuel needs to be burned when hauling cargo compared to sailing empty to the yard. Since these differences are minimal compared to the earnings, this factor has been neglected. Estimating the reduction in deviation time depends on the choice of location and that can be done in different applications. It can be done on a project base where one client is being saved an enormous amount of time, or multiple clients save just one or two days individually but add up together. The best way of filling the mobile dock should be a mixture of the different application, taking into account the cost of transporting the facility to its clients. The case studies of next chapter will find the best method for this mixture for different areas and opportunities in the world. To illustrate the text above, an example calculation is shown for two different situation.

Table 4.11: Justification of the added value calculations

Variables	Situation 1	Situation 2
Day rate of client	€7.500,-	€9.000,-
Nr. of days per project [days]	8	11
Distance to service hub [nautical miles]	200	100
Deviation days reduction [days]	1	3
Added value per project		
Extra earnings due to efficiency increase	€30.000,-	€9.000,-
Extra earnings due to strategic position	€7.500,-	27.000,-

All depends of course on the technological feasibility of operating the mobile facility. Since the scope of this research leans more to the financial side, an extremely detailed technological feasibility study will not be executed. The factor is however of some importance that several factors concerning it will be mentioned in the next chapter. The outcome of this simple analysis will influence the division between both added values.

4.3.2. Normal Income

For both case studies in the next chapter, the type of vessels that will mostly come to the yard shall be determined. To determine the 'normal' income of such projects, to which the added value (or a portion of it to yield a profit for the client for choosing the proposed concept) will be added, the average income of the promised services will be used. These averages have been determined by using the example projects that have been mentioned earlier. Depending on the case study and the associated area, a reduction or increase of the average needs to be taken into account to counter for the local pricing level of the same services. Also, these prices are based on the cost of the service that is being provided. If these cost are lower, it needs to be determined how much the prices asked for the promised can be reduced. The price needs to be high enough to generate a decent income but low enough to attract clients to the yard. Next chapter aims in finding a solution for both case studies. The similarities between both case studies however is the method for calculating the production value for one year, where three factors have to be accounted for.

The amount of days that are needed to complete one maintenance (special survey) project is apart from one of the added values of the proposed concept also the first factor in the calculation of the annual production value. This is a factor that will be variable in the calculations of next chapter and the result of the annual production value will thus be variable as well. The second factor needed to determine the annual revenue is the amount of days per year that will (or can) be spend on providing shiprepair services or works that are related with it (the transporting of facility for example). The reason that not all the days in one year can be spent on repairing vessels is that the facility, and especially the dock and the supporting facilities, need technical attention as well. Cranes can break down, the dock needs repairing and it will be too optimistic to pretend that 100% of the available days can be spent on repairing vessels. The amount of days that are going to be available per year has been chosen as 350, meaning that 15 days per year can be used for the maintenance of the facility itself. When both are known, the total maximum amount of projects per year can be calculated by rounding down the amount of projects that fit in 350 days. This amount will depend on the number of days for one project and will also determine the total annual production value. Multiplying the revenue for one project, calculated in Section 5.1, with the amount of projects per year yields in the total production value. The only variable that can change these numbers in the occupational rate, which influences the amount of projects per year and does not change the revenue per project. This factor will be mentioned in Section 5.1 as well and will yield many useful insights.

4.4. Capital Expenditure

Capital expenditure stands for the funds used by a company to acquire, upgrade and maintain physical assets. In this case, the CAPEX will include two major items, of which the initial investment is the largest. The funds needed to acquire the actual facility at the beginning of the total running time of the project will be the topic of this section, as the other major item is the money used for the maintenance of the facility. This cost item has been discussed in Section 4.2.4 already and will be analysed differently from investment cost. Although both originally fall under the capital expenditure for a regular company, the fact that the concept entails a maritime asset makes it possible to treat the CAPEX in this way. Since the scope of this research is the concept phase, multiple options for the actual facility will be discussed including their preliminary price. This will be done after the determination of universal equipment that will be needed for all options. Afterwards, the price range for the initial investment shall be determined that will be used in the end. The CAPEX will be a variable in the financial model as well, partly to check for the robustness of the total design. The method of financing the initial investment will be analysed in Section 4.4.3.

4.4.1. Universal equipment

A set of equipment that is minimally needed to perform any type of shiprepair plus the equipment that becomes evident when the repair facility is mobile and possibly offshore can be called universal equipment.

Regardless of the final decision, or price range, of the type of facility that is going to be used, this equipment needs to be on it. Part of this has already been listed in Table 2.1 and comprise of the yard facilities. The below mentioned equipment digs a bit deeper into several of the listed items and sums up the additional requirements. Most of the research executed for this section has been done together with Damen Trading & Chartering, a department within the Damen Shipyards Group that is specialised in the sale, purchase and chartering of any type of used vessel.

Due to the fact that the facility is mobile and needs to have the possibility to work outside of the safety of the harbour, it requires assets to ship personnel and equipment to and from the facility. The best way of doing so is to buy a good quality second hand vessel that can combine both services. The expertise of the people at Damen Trading has led to the choice of a Fast Crew Supplier (FCS) 2610. This is a Damen build vessel, of which the technical information can be seen in Appendix B, that has enough deck strength and space to carry vital equipment and motion compensated seats for 12 persons. A good quality second hand vessel has a price range of between the 2 and 2,5 million Euro and would be immediately usable for the purpose of this concept. The mentioned price would only be the initial investment of the vessel, the cost for maintenance and manning of the vessel has been discussed respectively in Section 4.2.4 and Section 4.2.1.

Additional equipment will be needed for the docking and un-docking of potential clients, regardless of the type of facility that is being used. Depending on certain decisions that will be elaborated on more in the next chapter, the Damen build Stan Tug 2608 & 3011 have been chosen as appropriate vessels. With a maximum bollard pull of 47 tons and 70 tons respectively, which is the main design characteristic to chose a tug boat, the boats will be capable of handling the vessels that are targeted to come to the proposed facility. They thereby have the ability to be used as an asset to assist in the handling of the anchors and other equipment that comes with the repair facility. The technical information of this vessel can be seen in Appendix C and Appendix D, and the price of a quality second hand can be placed at between 2,2 and 2,5 million Euro for the 2608 and 2,8 to 3 million for the 3011.

A vital part of any shipyard, repair or newbuilding, is the cranage available for lifting purposes. Newbuilding yards generally require more lifting capacity than repair yards, with the exception of large conversion projects. Just a limited capacity will be needed for the jobs that are going to be the focus of this concept and the capacity of existing yards will be used a references for the determination of the type and size of cranes that will be part of the overall design. The yards in Rotterdam and Curacao are mainly used as a reference because of the size and location of the cranes alongside the docks. The cranes operating alongside the smaller docks on the yard in Rotterdam measure 15 tons, while the cranes that are situated on the dock walls of the new floating docks in Curacao measure 12 ton for the larger dock and 5 ton for the smaller dock. The jobs that require cranage additional to the small forklift and cherry pickers on the dock floor include among other the lifting of rudders/tail shafts, lifting of cargo hatches, moving of material and preparing the dock blocks for the next vessel. In the case of a mobile facility, the cranes can be employed for the hauling of material on board from for example the FCS 2610 that accompanies the facility. The proposed concept will need two 15 ton cranes to be able to supply its repair & maintenance services. These cranes should have the possibility to reach all parts of the dock together with enough lifting power. The loss of a crane will have severe consequences on the ability to supply the repair & maintenance services and this should be kept to a minimum. Therefore, it is best to have fixed cranes with a large reach to reduce the amount of large moving parts.

A minimum amount of accommodation is needed to house all personnel related to the repair & maintenance service that the concept wants to supply. Direct labour, specialists, indirect personnel and possibly also the crew of potential clients require a place to sleep, eat and rest while they are working. This accommodation will be of the same type as is present on vessels and offshore equipment. The type of cabins will vary for the different levels of responsibility as is being named before in 4.1.1. Higher level of responsibility come with a higher level of luxury, both in terms of space and the sharing of spaces. The cost for the accommodation are divided into two parts, being the initial investment and the direct cost for providing accommodation for people. The former is part of the overall capital expenditure, whereas the latter has been determined before. The total amount of accommodation needed will depend on the operational profile of the concept and this in turn will depend on the case study that is chosen. Next chapter will elaborate more on these individual case studies.

4.4.2. Construction/conversion cost

Multiple individual sub-concepts will be mentioned shortly, including their roughly indicated price. This is to determine a range for the initial investment to use in the financial model. Two options for using a semi-submersible dock ship, the conversion of a floating dock and a jack-up configuration will be analysed. Due to the conceptual nature of the research, only roughly estimated prices can be the result in this stage. A large part of the work has been done in collaboration with Damen Trading & Chartering (Table 4.1).

Semi-Submersible dock ship The first option for a mobile shiprepair facility to analyse is based on the S-Class and ST-Class vessels of the company Rolldock. Although the dimensions are probably too small, the design mentality is an inspiration. The technical information of the ST-Class can be seen in Appendix E, which is a class of vessels that is an example of the sort of float on float off vessels that form the basis of this approach. Two different methods for the construction of such a vessel will be discussed. Firstly, newbuilding a vessel that is based on an existing Damen design is analysed, after which the conversion of a semi-submersible heavy-lift vessel will be mentioned. The design of such a vessel has been preliminary sketched in Figure 3.5. An advantage of such a design to be used as a shiprepair facility is the fact that either one or two vessels, depending on the location of the facility, can be positioned alongside. This makes it possible to do small repairs for which the dry docking of a clients vessel is not necessary.

Because of the fact that Damen Shipyards has such an extensive portfolio when it comes to building ships, a suitable base could be found to adjust for our purpose. The Damen Offshore Carrier has been chosen as base, because this is the vessel within the Damen Portfolio that, taking into account the needed adjustments, comes closest to the ST-Class mentioned above and the alterations needed to suit our purpose. The technical design of the Damen Offshore Carrier 14000 can be seen in Appendix F, which is the design that is being used as the base, meaning without the adjustments. The reason for this design to be the base is primarily the appropriate length/breadth ratio suitable for the use as a dry dock. This ratio is the reason that taking a ST-Class vessel without any adjustments will not be viable for the use of a dry dock vessel. The ratio of these vessels is too large, meaning that the breadth is not wide enough compared to the length of the vessel and thus the dry dock. Enough accommodation, a 4-point mooring system for the anchoring of the vessel, generator sets that comply with the capacity figured out in Section 4.2.5, no propulsion power (in this case, adding propulsion power increases the price) and two 10 ton cranes have been taken into account for the determination of the new build price of such a vessel. The preliminary total price, including margins and profit for the yard, of the vessel is roughly 25 million Euro when it is build at Damen Yichang (China). This price has been calculated for a dock length of 130 meter. As will be seen later in this research, the dock lenght might have to be longer in a particular case study. When evaluating that study, the total investment price will be adjusted accordingly. The lay-out of the cabins and the tanks (change from fuel tank to ballast tanks and storage) and the construction of dock walls need to be imagined when the General Arrangement seen in the technical information is being considered. The breakdown of the cost, margins and profits can be seen in Appendix I.

Another option for getting the same result is the conversion of an existing semi-submersible heavy-lift vessel. The market where these vessels are currently operating in is going through rough times, which opens up opportunities for the ability to buy a second hand vessel at a competitive price. When selecting such a vessel, much interest needs to be paid to the length/breadth ratio that has been mentioned above. Not all heavy-lift vessels maintain a proper ratio for our cause, but it would be possible to select a couple of vessels that are currently operating in the market that would be suitable. The Damen group has several shipyards all over the world that would be suitable for a possible conversion, if such a vessel can be bought. The second hand market of semi-submersible heavy-lift vessels is extremely closed, meaning that the vessels exchange owner's hand without coming on the actual market or a vessel is going to the scrapyard without having the option of buying it. This is because of the highly competitive market and the fact that scrapping used vessels makes it harder for direct competition to enter the market. This makes the determination of the second hand price of such vessels extremely difficult. The experience of several persons within the Damen Trading group has been the only practical reference and that made it possible to determine a range for the price. Including roughly estimated prices for the conversion to a shiprepair yard have been used to get to a rough initial investment of around 25 million Euro.

Floating dock conversion Another product that is part of the portfolio of Damen Shipyards which can be used for the construction of a mobile shiprepair facility is a floating dry dock. This options would seem natural, since the docking option is already there. After consultation within Damen, the preliminary price of a seaworthy floating dry dock with the required dimensions would result in roughly 15 million Euro. For this price, only the dock will be delivered. To turn it into a mobile shiprepair facility, multiple items need to be added. Having been described above in Section 4.4.1, the price for these features has to be added to the initial price of the dry dock itself. Where the cost of buying a new build dry dock is relatively easy to gather due to the portfolio of Damen, the price of the conversion is harder to predict. This makes that the actual price of an initial investment for a shiprepair facility that is based on the conversion of a floating dry dock can only be given in the range of between 20 and 30 million Euro.

The reason that the conversion of a semi-submersible vessel or a floating dock to a mobile repair facility are such good options is the fact the high surface strength of the deck of both. The pressure on the dock bed can be really high for certain types of vessels and this requires not only strong and stable dock block arrangements but also a strong deck surface. When converting a vessel that is equipped with such decks, no extra costs will be needed for the strengthening of the decks.

Jack-up configuration The Damen portfolio provides yet another type of design that might be altered for this cause. The DG Jack-up 14350P, seen in Appendix G is a jack-up vessel that fits the required dimensions and houses more than is requested for the operation of as a shiprepair platform. Possible alterations would be the dismantling of the large crane and replacing it with a much smaller one, including side walls, removing propulsion power and constructing workshops. The newbuilding price of such a facility would far exceed the range of the options mentioned above. The second hand market might bring a solution, because of the fact that many jack-up configurations are maintaining an idle status at the moment of writing. Finding a similar size vessel with the same lifting power can not be easily expected, especially since these type of vessels are currently the preferred ones for the construction of renewable energy sites offshore. As can be seen in previous years the size of for example offshore wind turbines is growing fast every year, resulting in larger and heavier construction vessels. The suitable size for our purpose might thus be available in coming years, when upgrading older vessels for the increase in offshore wind turbines is not profitable any more. Until then, smaller jack-up drill rigs and similar types are the ones that are currently laying idle and are waiting for either someone to buy them or to be re-instated. The price for the conversion of an old jack-up unit to a shiprepair facility would be hard to estimate at this point, but due to the experience of the Damen Trading team it has been made possible to estimate a range for the second hand price of a suitable unit of between 30 and 40 million Euro, given the fact that one would be for sale off course.

Range All viable options above give a range that should be used in the validation of the financial model by conducting the different case studies, as will be done in the next chapter. Because of the conceptual stage of the research, only a range will be given. When certain decisions are made regarding the best option for a particular case study, more detailed analysis can be executed into the initial investment needed to fund such a project. Working with a range for the initial investment gives the model a chance to check for the robustness of the case studies as well. Adjusting the input for the initial investment, either by making it higher or lower, checks for the result when unforeseen or overseen construction cost are taken into account. Resulting from the rough estimates made above, the range for the initial investment that will be used is between 25 million Euro and 35 million Euro, with steps of 2.5 million Euro. Important to notice is that these prices have been determined while keeping in mind the dimensions of the dock as has been determined in Section 3.1.2. The section below describes the method for financing the initial investment, regardless of the final price. Thought have been given to the range however, when the price will become much lower or higher, different financing methods might have to be used. The range for the prices might decrease or increase when data on vessels sailing in a specific area calls for a smaller or larger dock.

4.4.3. Financing

Such a large project needs proper financing. Firstly to start the entire project, but also to keep it going during the running years. Although Damen Shiprepair & Conversion, together with the Damen Shipyards Group, is a large organisation with a vast amount of liquidity to finance different projects, it is not wise to have the entire undertaking paid by the company itself. This would introduce an amount of risk that is too large. This means that a different kind of financing has to be found that can be combined with the own equity to fund the investments needed to start the project. A commercial bank loan (debt) has been chosen to supply the extra capital needed. Owners and other investors generally require high rates of return on their equity, while banks satisfy themselves with lower rates and are therefore favoured for the large bulk of the financial assets needed over private equity. Both the equity and the debt loan will be described individually below, considering a division between the two of respectively 30% and 70% of the total CAPEX.

Equity The equity, in this case own capital, comes from within the entire Damen Shiprepair & Conversion organisation and is not fuelled by any public offerings. The nature of this research does not allow for a fully detailed description about the difference between both, the only factor to examine is the Weigthed Average Cost of Capital (Hereinafter: WACC). Put simply, WACC is the minimum acceptable rate of return at which a company yields returns for its investors [Investopia, 2018e]. As will be seen later, this variable will be used for the long term feasibility of the proposed concept. A minor further explanation will be given here. The WACC can be used in two different ways, but is in both methods a percentage. Firstly, it can be used by financial analysts as an indicator of the health of an investment. The other method is to lock the WACC and using it as the discount rate for future cash flows. The second method will be used in this financial model and will be elaborated on more in Section 4.6. To give an image of where this factor comes from, the to calculate the WACC is given below. It will not be used, but knowing where it comes from helps in the understanding of the total operation. The 'E' in the equation stands for the market value of the equity involved and the 'D' stands for the debt. The sum of both is the 'V' used, and the percentage of equity and debt financing is depicted by the respectively first and the second fraction. The former is multiplied by the cost of equity, where the latter is multiplied by the cost of debt and the inverse of the corporate tax rate. Summing all together gives the weighted average cost of capital as a percentage

$$\mathrm{WACC} = \frac{E}{V} \cdot R_e + \frac{D}{V} \cdot R_d \cdot (1 - T_c) \tag{4.2}$$

Debt Several factors determine the results of the amount of debt taken from a commercial bank. It all starts with the total CAPEX of the project, of which 70% will be financed by taking a debt. As part of the negotiations that are done when taking the loan, the pay-off years will be determined. Depending on the type of the pay-back structure, an amount per year has got te be paid back. For this purpose, a linear scheme has been chosen. This comes down to the following formula for calculating the amount of money to pay back to the bank every year. If all goes according to plan, the total loan should be paid back to the bank at the end.

$$\text{Annual loan pay-back} = \frac{\text{CAPEX} \cdot 70\%}{\text{pay-off years}} \tag{4.3}$$

A commercial bank will never make a profit when the money they lend to clients will be simply paid back, which is why an interest has to be paid in pre-determined time frames. This expense will be seen on the balance sheet as an expense to pay before the final net income of the fiscal year can be determined. The interest rate has been discussed just as the pay-off years have been and a interest rate of 2.5% will be used in this matter. Above is has been settled that a linear pay-off scheme will be used, meaning that the interest expense will decrease in a linear fashion. The reason for this is that the interest to be paid is a percentage of only the amount of loan that is still left to pay. To calculate the total interest expense, the outstanding loan has to be multiplied by the interest rate. The outstanding loan can be calculated by the taking the average of the sum of the loan to be paid from the current and last year. This amount will naturally decrease, since the debt decreases annually.

4.5. Short term feasibility

The short term feasibility is not extremely useful for the final conclusion of this research. It however gives a proper image of how all financial items described above work together to generate the information needed to give an answer to the research question. The short term feasibility will be nothing more than the net income of one fiscal year. Where last chapter only described the financial picture up to the EBIT, all further expenses will be discussed here. To end with the net earnings, the interest and tax expenses have to be deducted from the EBIT. The interest expenses have been explained above and can be a major part of the deducting, especially in the maritime industry where the asset is generally the largest cost of an owner. Tax expenses are only deducted from the EBIT if it is a positive number and the percentage is determined by the country of registration of the company. The Dutch government recently proposed a deduction of the corporate tax to a rate of 20.5%, which is the number that will be used for the final calculation. The final numbers is the net income of that specific year. This value does not say much about the health of the company and needs to be seen together with the years to come. A starting company or venture is not expected to make money at the beginning of its running period, which can explain a negative income. When luck has been on the side of the company for one year, resulting in a (relatively) large positive number for the net income, it might as well be that the following years are disastrous for that same company. It is far more important to look at the long term feasibility, in this case represented by the Net Present Value.

The financial numbers of an example first year of the proposed concept can be seen below, this to provide an overview of the cost items that have been described individually above. It is extremely important to notice that this overview does not compete in any way in the development of recommendations on the total feasibility, it is merely to show the differences with the benchmarking from the previous chapter. What aids in the overview is the listing of the values that have been used for the variables that are the inputs for the financial model. These values have been chosen for the explanatory purpose of the overview and can be seen in Table 4.12.

Table 4.12: Variables as input for the financial model as the base for Figure 4.7 on the next page

Variables	Values
Initial investment	€32.500.00,-
Fuel price	€710,-
Day rate of client	€9.000,-
Nr. of days for refit	10
WACC	8%
Deviation days reduction	2
Case Study (local pricing level)	Caribbean Sea

	Total DS&C	MSRF Year one
Production value (PV)	**445,380,433**	**12,012,348**
Direct Labour	(84,824,353)	(2,212,500)
labour cost on sales	*-19%*	*-18%*
Work contracted out and materials	(239,788,947)	(2,326,579)
Third party cost on sales	*-54%*	*-19%*
Workforce Division	*2.83*	*0.13*
Contribution Margin	***120,767,132***	***7,473,269***
Percentage	*27%*	*62.21%*
Salaries and Wages Indirect Staff	(27,322,967)	(702,000)
Percentage on Sales	*-6.13%*	*-5.84%*
Percentage of Indirect Cost	*21.93%*	*16.59%*
Social Security & Pension Indir. staff	(7,402,230)	(175,500)
Percentage on Sales	*-1.66%*	*-1.46%*
Percentage of Indirect Cost	*5.94%*	*4.15%*
Indirect cost of direct staff (maintenance/idle)	(17,183,829)	-
Percentage on Sales	*-3.86%*	*0.00%*
Percentage of Indirect Cost	*13.79%*	*0.00%*
Depreciaton and amortization	(11,685,947)	(1,300,000)
Percentage on Sales	*-2.62%*	*-10.82%*
Percentage of Indirect Cost	*9.38%*	*30.73%*
Personell related expenses (excl staff on loan)	(6,976,647)	(90,655)
Percentage on Sales	*-1.57%*	*-0.75%*
Percentage of Indirect Cost	*5.60%*	*2.14%*
Housing cost	(17,364,271)	(520,756)
Percentage on Sales	*-3.90%*	*-4.34%*
Percentage of Indirect Cost	*13.94%*	*12.31%*
G&A	(11,787,467)	(279,707)
Percentage on Sales	*-2.65%*	*-2.33%*
Percentage of Indirect Cost	*9.46%*	*6.61%*
Machinery and installations	(7,401,511)	(307,412)
Percentage on Sales	*-1.66%*	*-2.56%*
Percentage of Indirect Cost	*5.94%*	*7.27%*
Travel expenses	(2,081,347)	(314,210)
Percentage on Sales	*-0.47%*	*-2.62%*
Percentage of Indirect Cost	*1.67%*	*7.43%*
Material cost	(13,274,343)	(436,173)
Percentage on Sales	*-2.98%*	*-5.93%*
Percentage of Indirect Cost	*10.65%*	*10.31%*
Sales expenses	(1,560,034)	(104,218)
Percentage on Sales	*-0.35%*	*-0.87%*
Percentage of Indirect Cost	*1.25%*	*2.46%*
Public relations	(550,182)	-
Percentage on Sales	*-0.12%*	*0.00%*
Percentage of Indirect Cost	*0.44%*	*0.00%*
Cost to be covered	***(124,590,774)***	***(4,230,632)***
Percentage	*27.97%*	*35.22%*
Result	**(3,823,641)**	**3,242,637**
Percentage	*-0.86%*	*26.99%*
Other operating income	3,932,947	
Financial income and expenses	(1,919,508)	(597,188)
Result before tax	**(1,654,271)**	**2,645,449**
Result / PV	**-0.37%**	**22.02%**

Figure 4.7: Financial numbers of an example of the first year of the MSRF project

4.6. Long term feasibility

Determining the long term feasibility of the proposed concept is the method for answering the research objective; "To make recommendations on the total feasibility of a Mobile Ship Repair Facility by gaining insights in the economic viability of the concept". For this purpose, several financial indicators and methods can be used, of which the Net Present Value (NPV) is the most widely used. The subsections below will describe how this method is used to give an answer to the overall objective of this research.

4.6.1. Net Present Value

The NPV method is an approach that is used often to analyse the profitability of a projected investment [Investopia, 2018d]. The net present value is the difference between the present value of cash in and outflows over a certain period of time. It uses the discounted cash flow method, which discounts the future projected cash flows to counter for the desired profit to be made from an investment. To illustrate, Equation 4.4 shows the calculation done for providing the Net Present Value of an investment. In this formula, 't' is the period in 'T', the total running time of the project. For this model, the time frame is in years. The WACC, described above, is being used as the discount rate 'r' and the initial investment costs and left-over value of that investment are depicted as respectively 'C_0 and C_T. The 'C_t stands for the net cash inflow, called the free cash flow, during period 't'. This value is being discounted by dividing it by a value that increases when the period increases as well and is a variable of the discount rate to result in the present value of that cash flow. Summing those value gives the sum of the present values over all periods.

$$NPV = \sum_{t=1}^{T} \frac{Ct}{(1+r)^t} - C_0 + C_T \quad (4.4)$$

The discount rate will be a number that is being determined by DS&C itself, to ensure an honest answer at the end of the analysis. Generally, when the proper WACC is being used, a positive net present value will be profitable and an investment that results in a negative NPV will result in a net loss. This is why this method is used to determine the long term feasibility of the proposed concept. The challenge in the calculation of the net present value is the determination of the future free cash flow. This is where the calculation of the short term feasibility comes in. The data for the free cash flow calculation results from the balance sheet and depicts the short term feasibility calculation for every running year of the project. The free cash flow consists of the after tax profit at the end of the fiscal year, the depreciation (since this is only a virtual cost item and the cash has only been reserved and is therefore available still) and amortization (if the latter is used) and the interest expenses [van der Berg et al., 2014]. These values can be taken from the balance sheet and be filled into the Equation 4.4. The three financial numbers that make up the free cash flow have been compiled from a number of different variables. When these are determined, the final judgement can be given about the feasibility of the entire project. Section 4.6.2 describes how the uncertainty of these variables, especially in the future, can be covered by applying a Monte Carlo Simulation.

Break-even moment A break-even analysis, to entail the calculation and examination of the margin of safety for an entity [Investopia, 2018a], is the next step. To determine the moment that this project results in a break-even moment, the net present value will be examined. The break-even moment has been determined as the moment at which the NPV passes the line between negative and positive, with the time period as output. The first year that the accumulated present value of the discounted cash flows (NPV at that moment in time) shows a positive result is seen as the final break-even moment, if this moment exists in the first place. The meaning if this value is the margin of safety for the total investment, which entails the moment at which the invested money can be retained and used for other projects. When presented as a result, the mean break-even year only counts for the runs for which the net present value is positive. Another way of exploring this viewpoint is by using the Internal Rate of Return (Hereinafter: IRR).

Internal Rate of Return The net present value presented above can be used for determining the internal rate of return as well. This measure describes the probability of the investment to earn money in a similar way the net present value does, but the difference with the pre-determined WACC gives the real result of the this analysis. This comes from the method of calculating the IRR, which is by setting the NPV to zero and solving for the WACC. The value found for the weighted average cost of capital that yields a net present value of zero is the internal rate of return. This can not be calculated analytically and must either be established by trial and error or by using a particular software as has been done in our case.

4.6.2. Monte Carlo Simulation

When assessing the long-term feasibility of a project, many decisions have to be taken with regards to the future. Many long-term projects, as with this one, have a running period of over 10 years in which the invested money needs to be earned back. As much research as possible can be done for estimating the future values of the variables needed to determine the feasibility, but there will always be room for uncertainty. Taking the price of fuel as an example, natural disasters, international affairs and many reasons more can lead to an unexpected turn in the price of oil, resulting in possible unforeseen outcomes of the return on investment. To check for the robustness of a project, multiple outcomes have to be simulated for different variables. This can be done for every variable individually, but simulating all possible outcomes together results in an overall picture. For this purpose, a Monte Carlo Simulation can be used. "By using this method, the distribution of all possible outcomes of an event is generated by analysing a model several times, each time using random input values selected from the probability distributions considered normal of the components that comprise the model" [Platon and Constantinescu, 2014]. The method algorithm is shown below. The financial parametric model has been the subject of this chapter, including the variables used as inputs to the model and the outputs used for answering the research objective. Table 4.13 summarizes the outputs of the Monte Carlo simulation, showing two that are yet unknown; The probability of Loss and the mean NPV. These outputs are only possible when the model is being run for a large number of times, as is the case in a Monte Carlo Simulation. Next chapter will discuss the evaluation methods in more detail, of which the results from a Monte Carlo simulation serve as an important parameter.

- step 1: Creating a parametric model, $y = f(x_1, x_2, ..., x_q)$;
- step 2: Generation of random input set of data, $x_{i1}, x_{i2}, ..., x_{iq}$;
- step 3: Effective calculations and memorizing results as y_i;
- step 4: Repeating step 2 and 3 for $i = 1$ to n ($n \geq 5000$);
- step 5: Analysing the results using histograms, confidence intervals and other statistical indicators resulting from the simulation, etc.

Probability of Loss Dividing the amount of times the output of the Monte Carlo Simulation gives a negative result by the total amount of runs gives the Probability of Loss (Hereinafter: PoL). Firstly, it has to be determined what classifies as a negative result. In this case, it is straight forward. When the net present value is zero or lower, it is being seen as a negative case. Other options for evaluating the loss of a project can be thought of as well. These examples will just be of the explanatory nature however, since a negative NPV is the only suitable one for this research. When an investor, either a company or a bank or private person, wants to have a pay-back period before the end of the running period of the loan, this can be taken as a positive case as well. Dividing the accounts where this does not happen over the total runs gives the same factor: probability of loss. It is therefore important to state that in this research, the PoL is defined as the negative outcomes in terms of the net present value divided by the total amount of runs. Inevitably, the lower the percentage of loss, the better the outlook for the proposed concept.

Mean NPV An output that relates greatly to the one explained above is the mean net present value of all runs done during the Monte Carlo simulation. This is because of the fact that a negative value at one output results in a negative value at the other as well. The differences in the measure of the outputs makes that together, they give a full image. Where the former is just a percentage and thus gives an outcome quickly, the latter shows a number that needs more thought. This is because it depends on multiple factors how fruitful the result is. The total amount of the investment, break-even moment and the interest chosen are just two examples, but many more can be thought off.

Table 4.13: Outputs of the Monte Carlo Simulation

Variables
Initial Rate of Return
Net income first year
Net income last year
Break-even year
Probability of Loss
mean Net Present Value
Minimal occupation rate

Applying a Monte Carlo simulation for this research can be done in two different ways. The difference between both is the number of variables used and especially the choice that has been made between them. The first option to consider is to treat every single variable as an uncertainty and use all in the simulation. This results in a scenario that depicts a totally uncertain future and can be used as a benchmark for the second method. By choosing 'case studies´, several variables can be locked into a value that is being decided as certain for the coming years. This is the second option that will be exploited by means of the Monte Carlo simulation. The case studies will be chosen based on several factors that are related to the capacities, advantages and limitations of the proposed concept. The bigger part of next chapter will cover these case studies and show the results of the Monte Carlo simulation after having conducted a mathematical sensitivity analysis of all variables to show the dependency of the individual variables. A combination of both yields the proper results to make recommendations on the total feasibility.

5 Evaluation of the proposed concept

This chapter will evaluate the proposed concept by means of two different sensitivity analysis. These analyses shall be done for two case studies. The particulars of the case studies will be described individually, making it possible to determine the values of the inputs to the financial model for the evaluation of the concept. One individual project at the mobile facility shall be analysed first, followed by the choice for the transportation method and the location of the facility itself.

5.1. Individual project

The previous chapter has depicted some cost items as fixed cost and some cost items as variable cost. The former are the costs that will be made independent of the amount of goods that are sold, in this case vessels that are being repaired. In the case of a mobile shiprepair facility, the direct labour and the indirect cost together make up the fixed cost and the cost for the contracted client specialists and the accompanying expenses can be seen as the variable cost. There are different methods for setting up the financial structure of a individual project and Chapter 2 has highlighted the trend of Damen Shiprepair & Conversion to decrease the fixed cost by utilising a higher percentage of hired labour instead of own labour. This trend will not be followed by the proposed concept as can be seen below.

5.1.1. Cost of the provided service

The hourly rate of the direct labour needs to be calculated to determine the fixed cost of an individual project. The rates have already been projected in Table 4.2 but the simple calculation behind them is explained here. For a project executed at an existing land-based facility, the cost of the direct labour is connected with the work that is to be done. An estimation is made of the amount of direct hours that are going to be needed to complete the planned work and that is the base of both the cost of those hours and the money that is asked to the client for the service those hours provide. In the case of the mobile shiprepair facility the calculation is different. The total amount of direct labour that is on board is fixed and the client will have to pay for all of them for the amount of time that its vessel spends at the yard. This seems severe, but it is expected that almost all workers will be put to work at all times due to a proper planning and the versatility of the workers. This means that the clients will rent the direct labour based on a price per day and based on the estimation time that is needed to complete the project. As will be seen later as well, a faster service means a lower price for the direct labour. If the amount of hours per level of responsibility is multiplied by the average hourly rate associated with it, a final cost per day for the direct labour can be determined, which results to €9.273,50. To validate this number, that is based on the amount of hours worker per day and thus per project, a comparison needs to be made, see Table 5.1. The expected amount of hours per project, based on an eight day project, on the MSRF is compared with the total (normalised) amount of hours of the example projects mentioned in the previous chapter. The total amount of hours is based on the cost calculations that are made after the execution of a project, which mostly display hours as well. When only the costs of certain services are known, that cost is divided by the hourly rate of that service to calculate the number of hours. Although all projects are based on the vessel coming in for an intermediate or special survey, not all projects are the same type in terms of revenue. To counter for this, the amount of hours have been normalised. The value in the second column is multiplied by the normalised project revenue. This is the average project revenue of the starred projects[1] divided by the individual project revenue. The result of this is the amount of hours that the project would need if it would be the right size, given the ratio between the original amount of hours and project revenue. The average of these normalised values gives the value that will be compared to the amount of hours the MSRF has available for an eight day project. It can be seen that the values match up correct. With a nine day project, the advantage will be that a buffer of personnel shall be available to cover for unforeseen events.

Table 5.1: Validation of the total amount of direct labour hours per project

Projects	Total hours	Project revenue	Normalised hours
Coolwater*	3360	€180.698,-	4399
Containership VIII*	3244	€262.000,-	2929
Union Fighter*	4689	€285.000,-	3892
Chem Amsterdam	1048	€69.661,-	3559
City of London*	3771	€218.582,-	4081
Jade	1348	€99.256,-	3213
Frisian River	857	€47.315,-	4283
Victor Hensen	1166	€64.072,-	4304
Amadeus Aquamarijn	1744	€100.831,-	4039
Average*	3766	**€236.570,-**	3825
Average	2358	€147.491,-	**3861**
MSRF			**3785**

The determination of the cost for work contracted out and materials is determined in a different way. Historical information on projects that have been executed at both DSCu and DSR have been examined for this purpose. The projects that are looked at have been picked because of the similarities in both the type of maintenance and the size and type of the to be serviced vessels. The main result from this analysis is the total amount of workers that is related to the executed work per day. The average of the total amount of hours that these workers have worked on the projects makes that, taking into account the differences in the amount of hours per shift, a total of 64 extra workers are needed per project. This comes on top of the 46 shifts per day that are being made by the direct labour from the facility itself and this work will thus have to be contracted out. Although the highest efforts can be taken to plan ahead, there will always be specialised and unexpected work, which in this case can be executed by the additional 64 workers. This means that a fixed price per project shall be calculated. The price per day per worker has been taken as €500,-, which corresponds to the medium level of responsibility as has been listed in Table 4.2. This means that a fixed cost of €32,000 per project is associated with work contracted out. Important to state is that the 'work contracted out´ in this case is different then in the status quo of the current shiprepair services offered by DS&C. The contracted workers in the case are client specialist, over which only a small percentage is taken as the yard itself. They are the workers that are not in the workforce of the yard. If, after having completed numerous projects, it become evident that some jobs that require client specialists occur often, it can be decided to take in that expertise in the the workforce of the yard as well.

Another conclusion of the comparison of the executed projects is the percentage of cost that is associated with the additional materials that need to be bought apart from the ones that are taken by the contracted workers. For the example projects, the percentage comes down to an average of roughly 2.5% on the total cost and roughly 6% on the total cost for work contracted out. The calculation of the materials cost for our purpose will be a percentage on the cost for work contracted out and will thus be a fixed value. Since it is assumed that the cost for additional materials will be more for a mobile facility due to the limitations in warehousing capacity, the percentage will be taken as twice the percentage from the example projects. The fixed cost per project are going to be around €4.000,-. This excludes the cost made for the transportation of the material, which will be the next subject.

Additional cost need to be taken into account for the transportation of the contracted workers and the additional material. Because of the fixed amount of workers and thus cost per project, it has been assumed that a

[1] The reason for these projects to be used is the fact that the size of the vessels, and thus the project revenue, compares to the expected projects that will be executed in the MSRF.

fixed amount of trips need to be made per project as well, which is set at four. Depending on the distance between the mobile facility and the service hub that is going to be used, the cost for the transportation is based on the cost of the fuel that is used. Either the indirect labour or the obsolete direct labour, if qualified, can captain the supply vessel and no additional cost will thus have to be taken into account for crewing. Because of the dependency on the distance that needs to be travelled per supply trip and the fuel price it is not possible to give a total cost at this moment. The travel price will be added to the total cost for the work contracted out and the materials.

The final costs that are made in order to provide the promised service are the cost of living. It has been mentioned before in Section 4.2.1 and accounts for both the cost of the energy needed and the cost for food, drinks and entertainment. Based on the amount of days the workers are on board, the total cost comprises of two parts. The cost made by the direct labour, which is variable depending on the amount of days per maintenance period, and the fixed cost for the contracted workers. The cost will be added to the corresponding type of labour because of the different margins that will be taken over the two types of labour. All different costs and the implication on the total project cost can be seen in Table 5.2.

Table 5.2: Justification of the project cost calculations[2]

Variables	Situation 1	Situation 2
Direct labour cost per day	€9.273,50-	€9.273,50-
Nr. of days per project	8	11
Distance to service hub [nautical miles]	200	100
Deviation days reduction [days]	1	3
Project costs		
Travel cost[3]	€16.417,50	€8.208,75
Direct labour cost	€79.144,-	€108.823,-
Client specialist cost	€49.277,-	41.068,50
Material cost	€3.895,50	€3.895,50

5.1.2. Margins and the price for the provided service

The example projects have been used for the establishing of the margins that result in the minimum price that needs to be asked for the to be provided services. Since the work contracted out (client specialists) and the materials are actually directly bought by the client and the shiprepair yard acts merely as a middle-man, the margin that is taken over these services is just 5%. This will not change when the same service is provided by a mobile facility and it has thus been chosen to use the same margin. The margin that needs to be charged on the direct labour is based on the required contribution margin. Using a trial and error method, where all inputs have been set on their mean values and the only variables to change is the margin on direct labour, it has been found that a margin of 100% suits best to cover the indirect cost that need to be made and leaves some room for a profit. This means that the price at which the direct labour is being sold is twice the cost. The margins will be taken over the total cost, meaning that the cost of travel and the cost of living is being taken into account as well. The first part of the earnings, which have been described as the 'normal income' before, is calculated by multiplying the amount of projects that can be executed per year by the total cost times the margins of one project. The normal income for both situations has been sketched in Table 5.3. This is the minimum price that needs to be asked to cover the cost of the service. Local pricing levels, that depend among others on the available competition or the local exchange rates, need to be added to the normal income. This will be done in the form of a percentage that is added to the minimum required income. This percentage can also cause the price to decrease, meaning that the local pricing level is not high enough to support the cost that need to be made.

[2]Many of the values have been either described in text or shown in tables in this or the previous chapter already and these tables can be used as reference.

[3]This calculation has been executed with a constant fuel price since the fuel price and the other variables are in no way correlated.

Table 5.3: Justification of the normal income calculations

Cost item	Total cost	Margin	Total selling price
Situation 1			
Direct labour	€79.144,-	100%	€158.288,-
Client specialists	€49.277,50	5%	€51.741,-
Material	€3.895,50	5%	€4.090,50
Total	€132.317,-	62%	€214.119,50
Situation 2			
Direct labour	€108.823,-	100%	€217.646,-
Client specialists	€41.391,-	5%	€43.460,50
Material	€3.895,50	5%	€4.090,50
Total	€154.109,50	72%	€265.197,-

To calculate the final price of an individual project and thus the total earnings per year, the added value needs to be determined per project. The method for the determination of the added value of the to be provided service has been given in Section 4.3.1. The days that are saved by both the efficiency of the facility and the reduction in deviation time is multiplied by the estimated daily earnings of the client to approximate the amount of the client's money that is being saved. To make it a win-win situation for all, 85% of that amount is counted as the added value and will be added to the total price of the to be provided services. The price of the provided services will therefore be value-based in stead of cost-based. This concludes the pricing of an individual project. Multiplying the selling price by the amount of projects that can be done (depending on the amount of days per project and the occupational rate) yields the total annual production value. Important to notice is the fact that the local pricing level, for which conclusions will be taken in the remaining of this chapter, have not yet been taken into account because they are case study sensitive. The differences between both sketched situations can be seen in the below Table.

Table 5.4: Justification of the annual revenue calculations

Variables	Situation 1	Situation 2
Maximum amount of projects per year	43	31
Added value per project	€31.875,-	€25.500,-
Normal income per project	€214.119,50	€265.197,-
Annual production value (occupational rate is 1.0)	€10.577.770,-	€9.011.607,-
Annual production value (occupational rate is 0.85)	€9.101.802	€7.848.820,50

A final validation needs to be made. The method of calculating the cost of a project for both the yard and the client is slightly different than usual. To check that this method is valid, the following comparison is made. The financial model has been run using case study 1 and a distance to the service hub of 100 nautical miles (more information on this will follow in this chapter). The difference between both situations is the amount of project revenue. In the general case this is €300.000,- for every project. This number has been determined to be a base values by expert consultation. In the MSRF case, the method described above has been used. The number of projects per year is the same in both cases, varying in every run of the Monte Carlo simulation due to the varying number of days one project takes. To be able to see the difference in different situations, the occupational rate (a fixed value in the simulation) has been changed between simulations. The results can be seen in Table 5.5. Both methods produce similar outcomes, especially when the scale of the calculation is kept in mind. THe calculation is done of the project's lifetime (20 years) and every simulation is 5000 runs. The above mentioned method can thus be taken as valid.

Table 5.5: Validation of project calculations

Occupational rate	General method	MSRF method
100%	€13.656.547,-	€13.792.546,-
95%	€6.781.793,-	€5.005.524,-
93%	€1.602.410,-	€1.638.852,-
90%	€–3.493.103,-	€–3.493.724,-

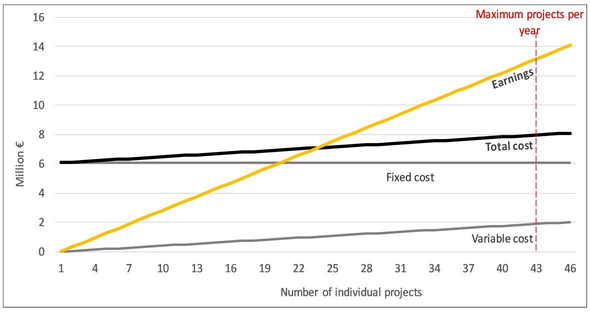
5.1.3. Cost graphs

One of the most iconic methods for displaying the cost structure of a project is the way that can be seen in Figures 5.1 & 5.2. All the parameters have been described above and they include the variable cost and fixed cost that together make up the total cost and the earnings, all for one year. The x-axis depicts the number of projects that are executed in that year. Both the x-axis and the y-axis have been fixed at certain values for readability purposes, which does not mean that the same amount of projects can be executed in every situation. To show the maximum amount of projects that can be executed in one year based on the number of days one maintenance project takes, a dotted vertical line has been added to all graphs. Two inputs to the financial model have been varied to get an insight in the cost structures and the influence of both. These variables have been chosen because they are the source of the added value of the concept. The top six rows in Table 5.6 list the values that have been used as fixed variables and the bottom two rows list the fixed value for the changeable variable if the other one is varied. To give an example, the deviation days reduction is kept at two if the number of days per project is varied.

Table 5.6: Variables as input for the cost structure graphs

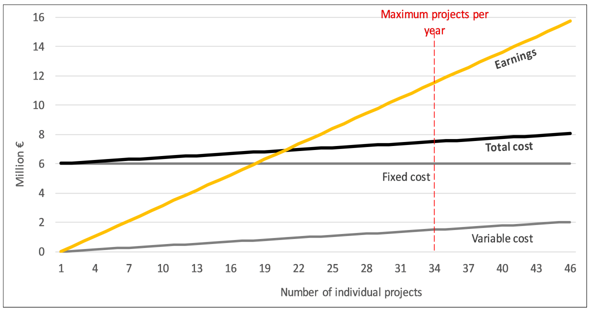
Variables	Values
Initial investment	€25.000.00,-
Fuel price	€550,-
Day rate of client	€9.000,-
WACC	8%
Occupational Rate	1.0
Local pricing level	West-Africa
Deviation days reduction	2
Nr. days per project	9

The first variable that is varied is the number of days that it takes to complete one maintenance period. It is planned that this will be less than the average number of days for a land-based yard and this will produce a part of the added value of the proposed concept. Figure 5.1 shows the cost structure graphs for four different situations which differ by the amount of days one project takes. Two conclusions will be drawn from these figures, of which the first one is quite obvious. When the efficiency is higher, meaning that one project takes fewer days, the maximum amount of projects that can be executed in one year is higher as well. It can be seen that the line showing the yearly earnings becomes steeper when the number of days for one project increases. This means that the price that is asked to a client for the provided services becomes larger with a decrease in efficiency. The added value of the higher efficiency is lower than the price for the daily rent of the direct labour, meaning that it is beneficial for the client if the number of days needed for one project is as low as possible. The revenue that can be earned for one project will thus be smaller if the projects takes fewer days, even when the added value is taken into account. Looking at Figure 5.1 concludes that this is only an advantage for the financial results of the proposed concept. Although the earnings line is flatter when the efficiency is high, the maximum amount that can be made is more. This can be seen by the different sizes of the area that is generated between the total cost line, the earnings line and the virtual line showing the maximum amount of projects that can be executed per year. This is the main conclusion from varying the number of days needed per project.

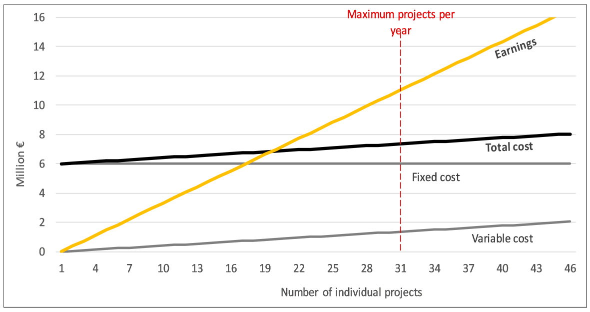


(a) Nr. of days per project is 8 days

(b) Nr. of days per project is 9 days



(c) Nr. of days per project is 10 days



(d) Nr. of days per project is 11 days

Figure 5.1: Dependency on the number of days per maintenance project

When the deviation days reduction is being varied, a different picture is to be seen. Figure 5.2 displays the situation in which the number of days for one project is fixed at nine and the reduction of deviation days is set at 0, 1 ,2 and 5 days. The reason for displaying zero reduction as well is that that is the situation where one of the added value parts is being eliminated. It can be seen that the virtual line showing the maximum amount of projects per year does not move and is similar to one of the graphs in the figure above, the reason for this is the fixed value for the amount of days that are needed to complete one project. The lines for the variable cost, fixed cost and thus total cost do not change as well since no variables are changed that have any influence on them. The only line that shifts in the earnings, which becomes steeper when the amount of reduced days go up. This leaves more space for a potential profit, depicted by the area between the earnings line, the total cost line and the maximum projects per year, and is exactly as can be expected. A last conclusion from this section can be taken when comparing the actual profit when the variables are being varied, which will be done next.

What is extremely important to keep in mind when assessing these graphs is the difference between the short-term feasibility and the long-term feasibility of the entire running time of the concept. When enough projects will be done for the earnings to surpass the total cost, this depicts sure viability on the short run only. Long-term viability builds enough free cash flow to pay off both the depth to the bank and the weighted average cost of capital. For this reason, the cost graph alone is not enough to yield reliable results on the total financial feasibility of the proposed concept. The graphs have solely been produced for the better understanding of the cost structures of the concept and the influence the total amount of projects per year and the deviation day reduction have. The sensitivity analyses will tell more about their influence on the long-term viability.

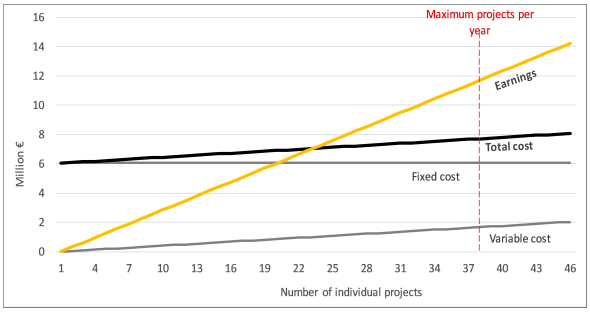
Table 5.7: Variables as input for the financial model

(a) Deviation days reduction is fixed at 2

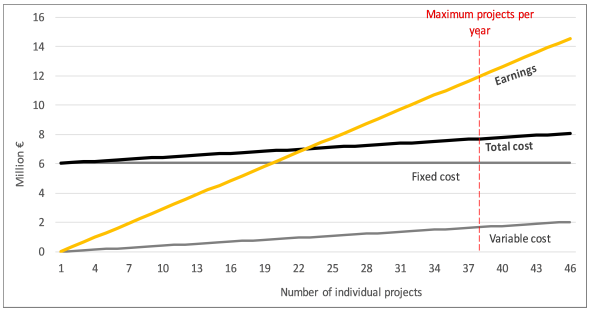
Nr. of days per project	Profit
7	€2,818,480,-
8	€1.971.680,-
9	€1.395.267,-
10	€929.506,-
11	€610.965,-
12	€219.064,-

(b) Number of days per project is fixed at 9

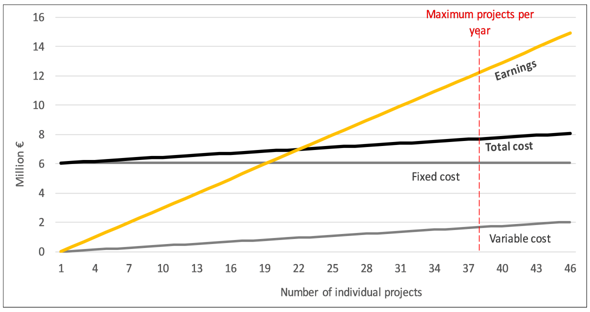
Deviation day reduction	Profit
5	€2.267.367,-
4	€1.976.667,-
3	€1.685.967,-
2	€1.395.267,-
1	€1.104.567,-
0	€813.867,-,-



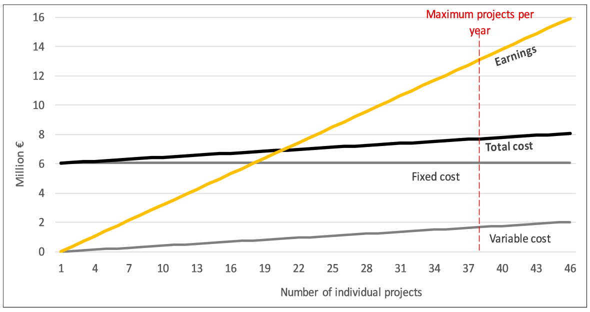
(a) Deviation days reduction of 0 days



(b) Deviation days reduction of 1 day



(c) Deviation days reduction of 2 days



(d) Deviation days reduction of 5 days

Figure 5.2: Dependency on the reduction of deviation days

The actual profit is hard to see on the above graphs, which is why Table 5.7a and 5.7b list them for all given situations and more. What can be seen is that the influence of the number of days needed per project is larger than that of the reduction in deviation days. This can be seen by the difference between the profits per situation, which is bigger for the left table. The main conclusion of this section is that the financial success of the proposed concept is more dependant on the increase in efficiency than the amount of deviation days it reduces for its clients.

5.2. Transportation method

Before this section it has not yet been determined which form of transportation will be used for the moving of the facility itself. There are two choices, being own engine power or a (partly) dependency on third parties with a tug boat service. Both options will be discussed briefly, after which they will be compared to each other in terms of both the cost per hour of sailing and the total cost of the transport.

Own engine power The cost of supplying own propulsion power for the transportation of the facility comes in two fold. Firstly, the operational expenses of running the engines to move the facility need to be calculated and the capital expenses that are related to installing such engines in a vessel are the second part. For the determination of the total amount of power that is needed to transport the facility at a relatively normal speed of 15 knots it has been chosen to compare vessels of a similar size and shape. Most of these have been mentioned in Section 4.4 already and consist of the vessels that might be converted into a mobile shiprepair facility. Keeping in mind that the facility will most probably not have any vessels in its dock when on the move, the required installed power will be less than the compared heavy transport vessels. When the facility needs to move with a vessel in its dock, it will only be to transport the facility to a sheltered location to perform the maintenance and a slower speed can thus be maintained. When comparing similar vessels and their propulsion power, keeping in mind the above mentioned considerations, a total installed power of 7000 (seven thousand) kW would be sufficient. Another factor that has been kept in mind when assessing the required installed power is the fact that the power that is needed to supply the repair services can be used for propulsion. This can however only be so when a diesel-electric type of energy generation is used. The consequences of this can be seen below in the second part of this section. The same type of calculations used in Section 4.2.5 and 5.1.1 for the determination of the cost of sailing per hour can be used for this purpose. The final operational cost of sailing one hour with own propulsion is dependant on the fuel price, but an example can be given. When a fuel price of € 550,- per ton is used, the cost of sailing one hour is roughly € 740,- with a speed of 13 knots. A more detailed calculation would require a more detailed design to estimate the resistance that is linked to the required propulsion power, which is not part of the conceptual phase, but of a later study.

The second part of the cost of transporting the facility with own propulsion power is the capital expenditure related to the installed engines. These cost will be different when an older vessel is converted to a repair facility than when the facility is being newly build. Because most vessels that are on the second hand market still have their engines installed, a conversion to diesel-electric propulsion will be the main expenditure in such cases. Also, when it is decided not to equip the facility with its own propulsion, the installed engines might be sold on a second hand market, but not much revenue can be expected from this. When the facility will be newly build, the price for new engines and propulsion equipment needs to taken into account. The maintenance of the added installed power is going to increase the indirect cost item for machinery & installations as well. When all installed power is new, this increase will be less than for a converted option. It has been assumed that an extra 2.5 million Euro needs to be take into account when assessing a conversion and an extra 4.0 million Euro needs to be added to the CAPEX when the facility will be newly build.

Tug boat service The second option for the transportation of the facility is the use of a tug boat service. An advantage of this choice is the fact that one of the additional vessels that comes with the facility is a tug boat, which can help in the towing of the facility. To determine the cost of using a tug service for the transportation of the facility, the required bollard pull (BP) needs to be calculated first. This is a measure of the pulling power of a tug, as has been described before in Section 4.4.1. Again, a detailed version of this calculation can only be part of a later stage of this study. For this, detailed information on the forces resulting from wind, waves and current acting on the facility need to be know. This is not possible at this moment due to a lack of resources, meaning that an empirical formula will be used in this case. This formula is used by port authorities as a guidance for calculating the required bollard pull of a barge and can be seen below. Since a dry dock, or a vessel that houses own, has similarities with a barge in terms of its two-dimensional shape, this formula can be used at the conceptual stage of the feasibility study. Some terms in the formula require additional explanation. The Δ is the displacement of the facility, that itself is a variable that is only to be calculated accurately in a later design stage. At this moment, an estimation is used based on the comparison vessels and preliminary dimensions of the facility. The 'v' in the formula stands for the required speed of the tow and has in this case been chosen as eight knots. The 'B' stands for the breadth of the facility and the 'D_1 is the depth of the exposed transverse section of the towed vessel. The final variable is the condition factor 'K', which can be differed between 0.5 and 3.0 and is related to the expected weather conditions during the tow. For exposed tows, which is generally the case if the tow occurs on the open ocean, this factor is chosen between 1.0 and 3.0. To ensure a safe transit, this factor will be taken as 2.0 for the calculation. Using this formula, the required bollard pull can be calculated. Subtracting the bollard pull from the additional vessel yields the required bollard pull that needs to be hired.

$$\text{BP (ton)} = ((\Delta^{2/3} \cdot \frac{v^3}{7200}) + (0.06 \cdot B \cdot D_1)) \cdot K \tag{5.1}$$

The cost of a tug boat service has been estimated by adding up the cost of the fuel for the Stan tug that is part of the facility and the cost of hire of an additional tug boat and its service. The fuel cost are calculated using the already mentioned methods and the cost of hiring a tug boat is estimated by looking at the cost of fuel and safe manning of such a vessel. It has been tried to reach out to market experts to determine the cost of hiring a tug boat of various bollard pulls, but these attempts have failed. During the calculation of the cost of hire, it has been taken into account that the market for such vessels (OSV's and PSV's) is low and thus minimum prices can be considered. When a speed of eight knots is required and the preliminary dimensions for the West-Africa case study are used, the required bollard pull is 163 tons which leaves a required bollard pull for hire of 93 tons when the Stan tug 3011 (with a bollard pull of 70 tons) is the own vessel. This adds up to a cost per hour of roughly € 1.000,- for the tug boat service option.

Cost and revenue To evaluate both options, the cost of the transportation of the facility as well as the possible added value of this type of project need to be determined. The cost of the extra service, which is the transportation of the dock and its facilities to the client, comes in two fold as well. Firstly, the cost of the actual transport is calculated, of which the two options to do so have been described above. Secondly, the missed earnings when the facility is on the move need to be taken into account. The cost of lost earnings is related to a 'normal' individual project as has been described in the section above and will be different for the two case studies. The case study, and all other variables, used for the evaluation of the best transportation methods are the same as for the section above and can thus be seen in Table 5.6. The only variable that is new for this analysis is the distance to travel, which has been taken as 500 nautical miles. To yield the best possible insight, the number of transportations per year is varied between one, two and three. The own engine power option has been split into two because of the different cost for the conversion or new building options. The results for all three for the cost per mile, cost for one transportation and the cost for the project life time can be seen in Table 5.8. The first column, the total cost for one transportation of the facility, is calculated by adding up the cost of transport and the cost of unavailability and counts for one time sailing the distance of 500 miles. To calculate the cost per mile of sailing, one more factor has be taken into account apart from dividing the total cost by the distance. For the own engine power option, the capital expenditure per mile of sailing needs to be calculated. Although this is a rough way of estimating cost, it is a useful way of displaying the impact of additional capital expenditure instead of performing a sensitivity analysis. The additional cost per mile for installing propulsion engines, either for the conversion or new building option, can be found by simply dividing the total cost by the miles that are sailed for the entire lifetime of the project. Adding this to the cost per mile for the fuel cost and unavailability cost yields both the total cost per mile and the total cost for the entire project life time.

Table 5.8: Cost per mile of different transportation methods

Option	Total cost of one transportation	Total cost per mile of sailing	Total cost for project lifetime
Nr. of transportations per year = 1			
Tug boat service	€ 175.512,-	€ 351.02	€ 3.510.235,-
Own engine power (Conversion)	€ 102.034,-	€ 454,07	€ 4.540.683,-
Own engine power (New build)	€ 102.034,-	€ 604,07	€ 6.040.683,-
Nr. of transportations per year = 2			
Tug boat service	€ 175.512,-	€ 351.02	€ 7.020.470,-
Own engine power (Conversion)	€ 102.034,-	€ 329,07	€ 6.581.366,-
Own engine power (New build)	€ 102.034,-	€ 404,07	€ 8.081.366,-
Nr. of transportations per year = 3			
Tug boat service	€ 175.512,-	€ 351.02	€ 10.530.706,-
Own engine power (Conversion)	€ 102.034,-	€ 287,40	€ 8.622.049,-
Own engine power (New build)	€ 102.034,-	€ 337,40	€ 10.122.049,-

The added value of this type of project results mainly from the fact that the client is able to keep working on the days that it would normally spent sailing to a repair yard. This only depends on the distance to the yard and thus does not differ for the transportation option that is chosen for the facility itself. The revenue will thus be taken out of the analysis.

Conclusion The most important column to base a conclusion on is the last one displaying the total cost for the project's lifetime. For two of the three variations, the winner option seems to be the converted own propulsion power option because the total cost for every column is the lowest of all three options. Based on two facts, this option will not be chosen however. Firstly, the additional cost that need to be made for the additional maintenance required when the facility houses propulsion engines have not been taken into account. These cost are extremely hard to forecast, but expert consultation has yielded that these cost will be higher than the difference between the tug boat service and converted own propulsion option when the amount of transportations per year is equal to two. This means that the tug boat service option 'wins' in two out of the three situation. Secondly, based on the conclusion from the previous section that the deviation days reduction will be less influential than the efficiency of the service, it is expected that the facility will move less than twice a year. In this situation, the tug boat service has a lower total cost. This concludes that the best option for the transportation of the facility itself will be a (partly) dependency on third party tug boat services.

5.3. Offshore vs. Near shore

Factors that can limit the workability of the operations on board of the proposed concept need to be examined to evaluate the option of conducting the proposed services offshore in stead of in a (sheltered) near shore location. Having the option to work offshore increases the type of projects that can be executed and might give the chance to escape from certain (national) regulations. As has been shown, the efficiency of the operation is more valuable than the reduction of deviation days of the client. This means that it should be avoided that the efficiency is jeopardised when operating offshore. To evaluate this, the following points will be described:

- (maximum) Ships motions during loading/unloading
- (maximum) Ships motions during the maintenance project
- Added value of offshore operations

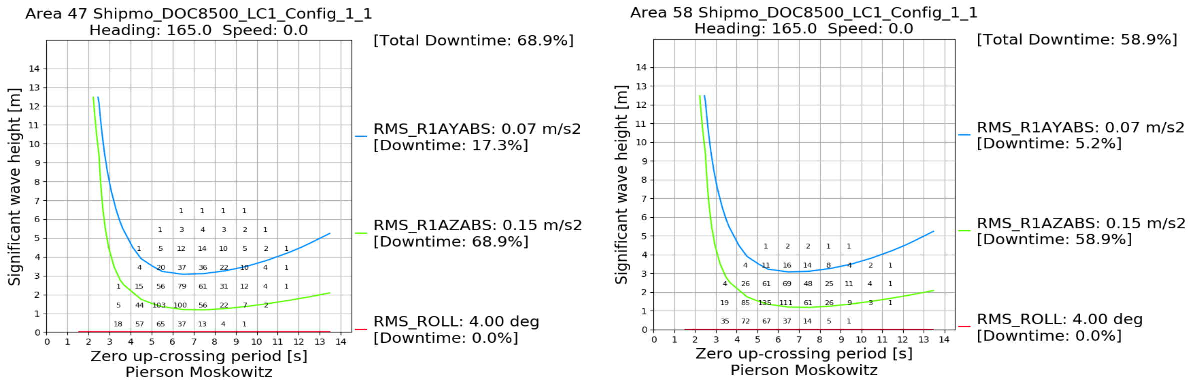
Loading/Unloading One of the most critical operations in the total maintenance project is the loading and unloading of the vessel into the dock. Due to the vertical, horizontal and roll motion of two vessels and the relative motions between them, this operation is extremely high in complexity. These operations are tried to be carrier out in sheltered waters where the influences of the weather are as minimal as possible. Loading/unloading in sheltered waters and towing to the offshore location is an often executed procedure for lifting operations using a semi-submersible unit. Multiple conversations, both within Damen and with Arthur Hellinga, author of a Master thesis that investigated the Dockwise Vanguard as a dry-docking options for FPSO's [Hellinga, 2013], have yielded that a typical limitation of the significant wave height for such operations is 0.5 meter. For the loading/unloading of a vessel in the proposed concept, this means that a weather window for these conditions of at least one working shift needs to be available. It can be stated that waiting for these weather windows might heavily reduce the efficiency of the proposed concept and thus the feasibility of the entire project.

Ship motions during the maintenance project To asses the workability and the reduction of the operational efficiency due to ship motions, the criteria for accelerations and roll will be used. Ship motions are a result of weather conditions such as the wave height, swell direction and wave period. Table 5.9 lists the maximum vertical and lateral acceleration and maximum roll angle for different types of work on board of a vessel. The work that is being executed on the proposed concept is categorised as light and heavy manual labour. Because heavy manual work has the lowest acceptable limits, these values will be chosen as maximum allowable. To evaluate the consequences on the efficiency, the ship motions as a result of different wave heights and period need to be examined. Detailed studies into this can only be made when a detailed design is present and it is not possible at this moment to produce one. This means that an example vessel, that might be used for the conversion to the proposed concept, shall be used. The Damen Offshore Carrier 8500 has been used as example vessel. This vessel is smaller than the proposed concept as well, but the dimension ratios will be very similar. Since these ratios determine a large part of the stability of a vessel, its response amplitude operators (Hereinafter: RAO) can used for this research. This can only be done because the current state of the research is conceptual.

Table 5.9: Maximum accelerations and roll angles for different activities
Source: Table made by author, taken from [Journée and Massie, 2001]

Type of work	Max. vertical acceleration	Max. lateral acceleration	Maximum roll angle
Light manual work	0.20 g	0.10 g	6.0°
Heavy manual work	0.15 g	0.07 g	4.0°
Intellectual work	0.10 g	0.05 g	4.0°
Transit passengers	0.05 g	0.04 g	2.5°
Cruise liner	0.02 g	0.03 g	2.0°

The RAO's for the example vessel are calculated for a location on the main deck of the vessel, which corresponds to the position on the proposed concept where the maintenance work shall be conducted. These values are then put into a software program called 'Operability Viewer', build by the MARIN institute. To check for the workability, the maximum values for heavy manual work taken from the table above have been put in as criteria. To display the most information in one image, a heading of 165° has been chosen. The reason for this is that a heading of 180°, meaning that waves comes exactly from the front, leaves out the lateral accelerations. Any angle further away from head waves would not simulate a real-life example, since it will almost be tried to position the vessel in head waves. The speed is kept at zero knots, since the facility will not be moving while working. The software has build in wave data for several area on the world map. The two areas that are examined are area 58 (West-Africa) and area 47 (Caribbean Sea). These areas are chosen from the Global Wave Statistics from the database of DNV-GL. The Pierson-Moskowitz spectrum is used for representing a big fetch sea area. For both areas, the criteria are the same. The most important result that can be taken from the figures below is the total downtime percentage. This number represents the percentage of time that it is not possible to perform the promised services because of the response of the facility to the waves that are coming in. For the Caribbean Sea this number is 68.9% and for West-Africa it is 58.9%. The scatter diagrams for the area are the average of the entire area, site specific data will be used later in this chapter. It can be seen the vertical acceleration yields the biggest downtime. The numbers on itself do not say much since the RAO's come from an example vessel, but the numbers are that big that the conclusion can be made that working offshore is probably not possible. Site specific, for both case studies, will either support or not support this conclusion.



(a) Operability restrictions for area 47, Caribbean Sea

(b) Operability restrictions for area 58, West-Africa

Figure 5.3: RAO's from example vessel tested against heavy manual labour criteria

Added value of offshore operations The option to load/unload and/or maintain a client's vessel offshore can have the added value that more locations can be categorised as suitable for the deployment of the proposed concept. This means that more (types of) projects can be excepted and more work can be done. The project can however only be done if the ship motions offshore fit in the above mentioned window, related to the local sea states of that location. Another added value of the offshore option is the possibility to escape from certain national laws that might limit the efficiency of a maintenance project. These rules and regulations relate to, among others, the environmental duties, labour laws and quality standards. Escaping these does not mean that no attention whatsoever shall be given to these aspects. Damen is a company that demands high standards in all given aspects in all the projects they do. This means that the own values can and will not be forgotten. The quantification of both added values is hard to execute. For the total evaluation between the offshore and the near-shore option, this factor shall be taken as a motivation to examine whether or not it is possible to work offshore without reducing the efficiency of a maintenance project.

5.4. Evaluation methods

For the determination of the methods for evaluating the proposed concept using the financial model that has been introduced in the previous chapter, multiple sources have been used. All three sources have summarized different sensitivity analysis methods, either as the final goal of their research or as an introduction and benchmark for their own method. Their analysis can be used for the determination of the most suitable methods for this research. Both [Hamby, 1994] and [Frey and Patil, 2002] make a distinction between two different analysis methods. Where the former uses the terms 'Differential sensitivity analysis' and 'Parameter sensitivity analysis', the latter applies 'Mathematical methods' and 'Statistical methods' for the same purpose. The first methods do not address the variance in the output due to the variance in the inputs, but they can assess the impact of the range of variation in the input values on the output [Frey and Patil, 2002]. Only single variables can be used for this analysis, but it can be helpful in screening for the most important, read influential, inputs. To include the sensitivity of certain variables on other variables as well, a parameter, or as [Frey and Patil, 2002] calls it 'statistical', sensitivity analysis is needed. Not only will it be possible to include multiple variables including their dependency on each other in the analysis, by using a large array of randomly selected input parameter values and calculating the output values it will be possible to test for the robustness of both the model and the business case of the proposed concept. These models involve simulations where the inputs are varied by assigning probability distributions to them and the model is run numerous times to cover all possible situations. They are so called 'Monte Carlo Simulations'. Both have been mentioned in the end of the previous chapter and below will be stated how they will be used in the final evaluation of the business case.

These methods need a particular real-life example to be put to their best use, which will be done in the form of two case studies that each simulate one of the possible ways of exploiting the Mobile Shiprepair Facility. These case studies have been explicitly chosen for the ability to show the influence of different parameters and the answering of the initial research objective. Both sensitivity analysis methods described above will be used for all case studies in the following way. Due to the nature of the choice of case studies, some variables will be set at a fixed value and thus treated as a constant. These choices will be substantiated by certain conditions that define the case study and show by itself certain dependency of variables already. The remaining variables are being fed into the mathematical analysis method firstly, after which particular distributions will be chosen for determining the feasibility and robustness of the concept using the Monte Carlo simulations.

The choice of case studies will depend on multiple factors that will be elaborated on when the individual studies are being explained below, but one general decision factor will be given here. One of the most eminent ingredients in determining a suitable location for the a shiprepair yard is the abundance of vessels. Without floating objects, no clients are around to fill the proposed docking facilities. One way of illustrating the location of a large part of all vessels sailing around the world is by graphing them using a density map. Density maps take known quantities of some phenomenon, in this case traceable vessels, and spreads them across the landscape based on the quantity that is measured at each location and the spatial relationship of the locations of the measured quantities. Dr Lin Wu [Wu et al., 2016] has written an article about the mapping of global shipping density from AIS data using density maps. She has collaborated in this research by sharing some data from her findings. This data has been used for the production of density maps showing the shipping density in 2014 at a resolution of 1° by 1°. The result can be seen in Figure 5.4, where the darker parts depict the areas which have been visited most by the worlds fleet. A number of remarks need to be made to fully understand the image. First of all, no use have been made of any coastal lines when producing the image. The shape of the continents, including the major rivers and lakes, results solely from the routes that vessels take to reach their destination, no border mapping have been done. This tells something about the importance of the global shipping itself, but that is a discussion on its own, it also (partly) outlines the correctness of the data. Equation 5.2 shows the method for calculating the density of vessels for one month in a certain grid. The numerator is the sum of the time stayed by all the ships in the particular gird in that month, while the denominator defines the relative value to acquire a nominated result. For the purpose of the current state of the research, the image that has been created will only be used to identify possible regions for the exploitation. Locations of other shiprepair facilities ultimately determine together with the shipping routes which is the best location to deploy the proposed concept. This mapping can be seen in Figure 5.5. The reason that both information sets are not plotted in the same figure is the fact that the vessel density does not include mapped country outlines and that the coasts of this method might differ from the actual coastal borders, causing for a distraction in the mapping of shiprepair yard locations. Detailed images will be presented in the individual case studies. As will be visible in the remainder of this research, the choice of the exact location might become extremely important for the feasibility of the concept. Further research will be needed for this, where the acquired data can be of great help. More reading on this can be found in Section 7.3.

$$\text{Shipping density}_i^m = \frac{\sum_{s=1}^{\text{s=Ship count}} \cdot \text{Time}_i^s}{\text{Time}_{\text{month m}} \cdot \text{Area}_{\text{grid i}}} \tag{5.2}$$

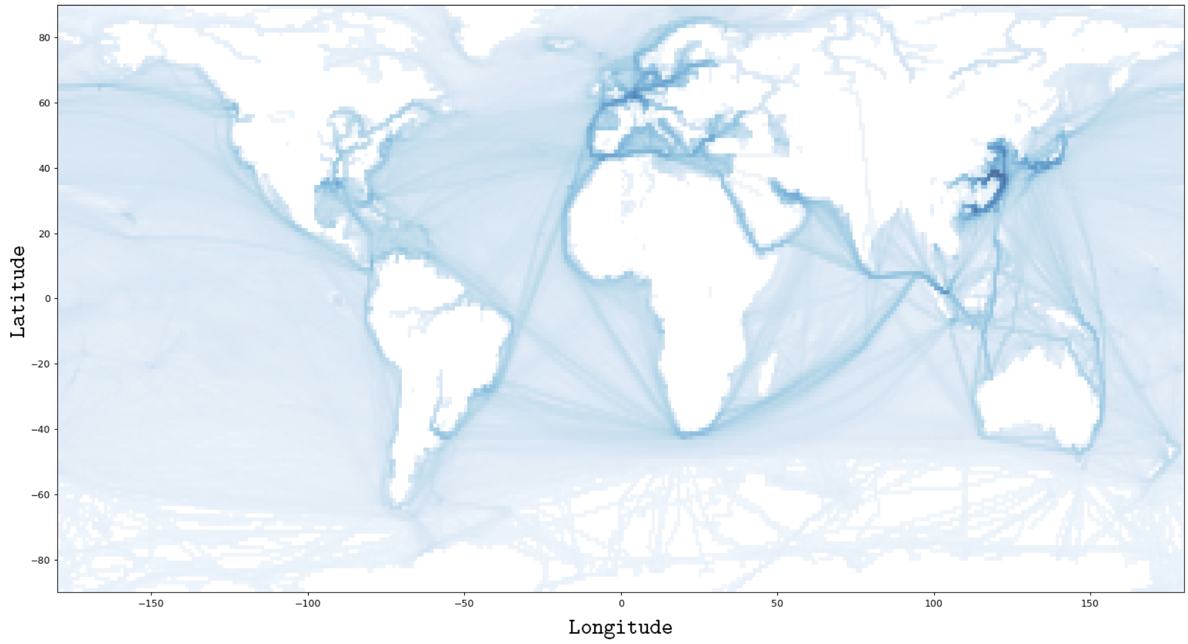


Figure 5.4: Global vessel density, 2014
Source: Graph made by author, data gathered from a contribution with [Wu et al., 2016]

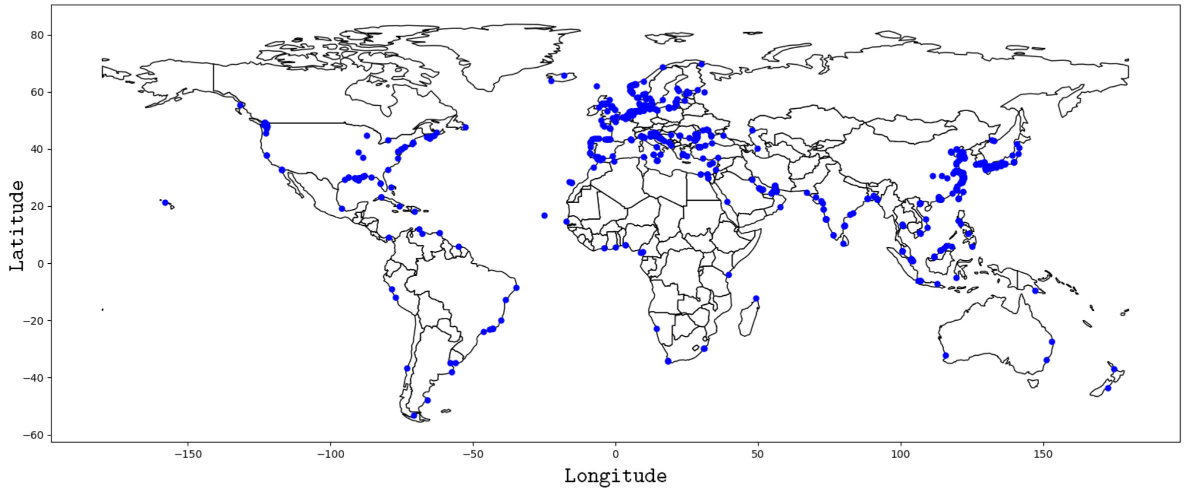


Figure 5.5: Global shiprepair yard locations
Source: Graph made by author, data gathered from a contribution with www.trusteddocks.com

To evaluate the proposed concept, two case studies have been chosen. The first study involves the Caribbean sea and the second study relates to the west-coast of Africa. Both cases will be examined on multiple factors. Firstly, the characteristics of the case studies shall be given and secondly the evaluation methods described above will be used to yield conclusion that result in recommendations on the total feasibility.

5.5. Case study 1; Caribbean sea

By far the biggest trend that controls the changes in the maritime developments in the Caribbean is the recent expansion of the locks of the Panama channel to accommodate larger and wider vessels than before. This results in the transport of larger vessels through the channel, which causes the coastal route along the east-coast of South America to loose a part of its vessels. With bigger ships come stronger and larger tugboats as well, together with investments in port transshipment hubs to make their infrastructure ready for the increase in the dimensions of the vessel that are now able to cross the new channel. Activity in the dredging market is increasing due to the investments in port infrastructure. A more recent trend is the trade war between the United States and among others China, strengthened by the protectionism that has been mentioned in Section 1.1. Container shipment will decrease, but the size of this decrease is not yet known. The possibilities and opportunities for other South-Asian countries can rise, where the countries surrounding the United States might benefit from this trend as well. With the proximity of offshore oil fields in Venezuela (although this market is going through some trouble at the moment of writing), Colombia, Brazil and Mexico, the Caribbean has its share in this repair market as well. Several possible competitors, Table 5.10, focus specifically on this market. With the high oil price of this moment, chances on the rehabilitation of the oil and gas market and thus the refurbishment of laid-up supply vessels are possible. Another event that determine many moves in the market is the bespoken IMO decision to lower the maximum allowed emissions for certain particles. Figure 1.4a shows both the current and future ECA zones, of which (part of) the Caribbean is going to be part of. This opens opportunities for the conversion of propulsion systems on board or the installation of after treatment systems. Although the shiprepair yard on the island of Curacao is one of the best running yards in the area, the productivity of the personnel does not reflect is. This is partly due to a deficit in the dock planning and the available personnel, but it can also be attributed to the cultural influences of the area. The area is notorious for the lack of productivity and assertiveness maintained by the local labour. Where the high temperatures and dry climate can be a cause for this, it means that by working with productive crews can already give an added value to the mobile docking service. To be able to determine which variables can be fixed and what the distribution is of those that are left, a market study have been done similar to the one above. All the market information is taken from recent issues of the Caribbean Maritime, the official journal of the Caribbean Shipping Association [CM3, 2018a], [CM3, 2018b] and [CM3, 2018c].

5.5.1. Market study

The market study consists of two parts. Firstly the current shiprepair facilities will be examined to asses the possible future competition when the concept is to be exploited here. Different data on the vessels that sail in the area shall be analysed afterwards. The combination of the two leads to a conclusion on the size of the shiprepair facility itself and an estimation on the potential for extra docking capacity to serve (future) demand.

Competition The same method as above has been used for the determination of the amount and quality of the possible competition that can be found around the Caribbean Sea. The current repair yards can be seen in Figure 5.6 and the particulars of most of all have been summarised in Table 5.10. The locations and facilities are listed, together with the targeted market of the yards. The final column depicts that rating that judges the quality of the service that these yards supply. This rating has been concluded by the author as a result of personal conversations with both sales managers from Damen Shipyards and Damen Shiprepair & Conversion. It is based on the facilities, the markets that they are targeting and especially the quality and willingness from clients to go there in stead of to the proposed concept. It can be seen that the size of the docks is considerably larger than the yards on the west-coast of Africa have. The size differences will be mentioned in more detail later, together with other differences between the two areas. The yard that is not in the table but is a large portion of the repair service in the area is Damen Shiprepair & Conversion, spoken of a lot in the previous chapters. Since the mobile shiprepair facility will be part of the entire DS&C service it will not be seen as competition. Of course, caution should be taken that an additional (mobile) dock does not harm the clients of DSCu. The docks will be incorporated in the estimation of the docking potential later in this section. The figures showing the repair yards in the area leaves open quite some spots where a repair yard would be expected, especially when looking into the vessel density seen in Figure 5.4. This has been acknowledged by Damen by shipping two new dry docks to the Caribbean Sea that are planned to go into service in the end of 2018. The value of adding dry docks to an existing shipyard is the fact that the difficulty in supplying materials and personnel to the yards is one of the issues that face shiprepair yards.

This is causing a supply gap in the region, which can be exploited when the supply chain management is on target. Possible competition in the larger class vessels will primarily come from the Bahamas and the yard in Bilbao, Panama, the oil and gas market is serviced for a large part by the yards in the Dominican Republic and Trinidad & Tobago and the yards in Cartagena service many of the smaller vessels that sail the area. Many of the larger vessels that are build to the dimensions of the Panama Canal and makes use of this canal sail on the routes that connect Asia with the Caribbean Sea. This means that many of the owners of these vessels decide to perform their mandatory survey work in yards situated there because of the lower labour cost. Even when the charter rate for a back haul voyage to Asia is far lower than the front haul, it can still pay off. Next, vessels that have been calling into certain ports in the year 2016 have been analysed.

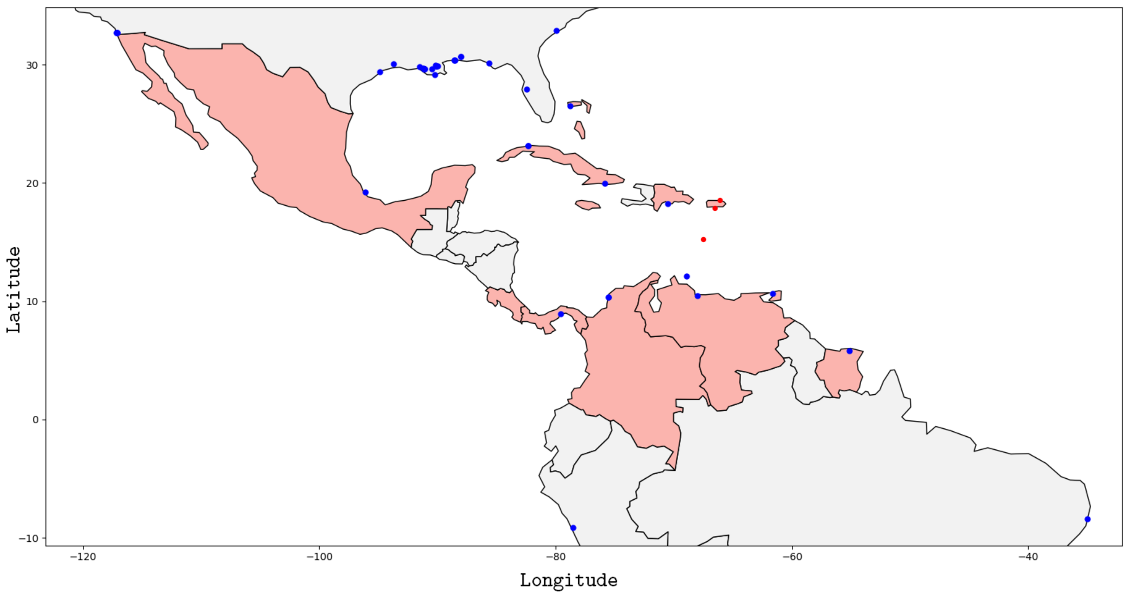
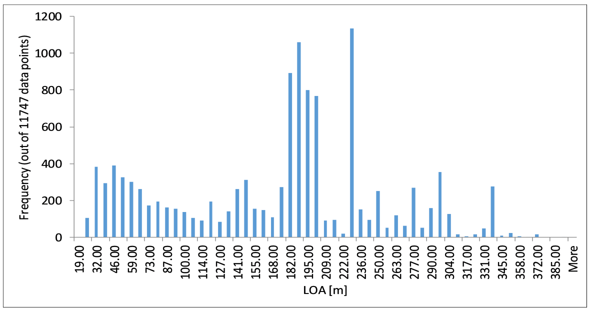


Figure 5.6: Repair yard (blue dots) and buoy locations (red dots) in the Caribbean Sea

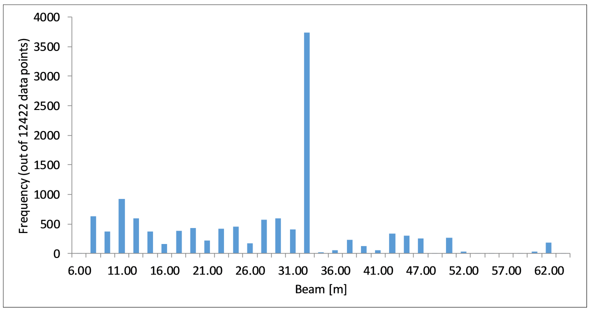
Table 5.10: Listing of possible competition in the Caribbean
Source: Company websites

Name	Country, city	Docking facilities	Market	Rating
Grand Bahama's Shipyards	Bahamas, Freeport	Floating dock: 310 m x 54 m Floating dock: 300 m x 59 m Floating dock: 278 m x 34 m	Cruise, container and tanker vessels mostly	3 stars
MEC Panama	Panama, Balbao	Graving dock: 318 m x 39 m Graving dock: 130 m x 30 m Graving dock: 70 m x 18 m	Dry docking and repairs of many types of vessels	2 stars
CL Marine	Trinidad & Tobago	Graving dock: 230 m x 39 m	Mostly offshore market	2 stars
Ciramar	Dominican Republic	Floating dock: 150 m x 25 m Floating dock: 60 m x 13 m	Dry docking and repairs of many types of vessels	1 star
Cotecmar	Cartagena, Colobmia	Synchrolift: 120 m x 22 m Slipway: 67 m x 14 m	Newbuilding and dry docking of both commercial and navy vessels	1 stars
Astivik	Cartagena, Colombia	Graving dock: 110 m x 21 m Graving dock: 70 m x 27 m Graving dock: 73 m x 19 m Graving dock: 63 m x 20 m	Tugs, cargo, fishing and dredging vessels	1 stars
SDS&C	Suriname	Floating dock: 50 m x 22 m Floating dock: 30 m x 14 m	Small vessels, but agent for Damen	1 star

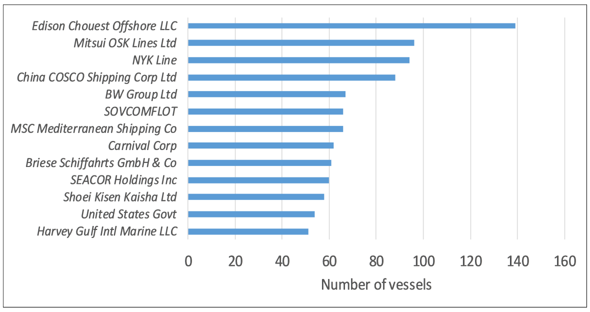
Vessel data As can be seen in Figure 5.6 some countries have been coloured. These countries are the countries of which ports are taken into account for the vessel data analysed. Not all ports in some countries have used because of their dimensions and the limits they impose for the size and type of the vessels visiting them. The full list of ports can be seen in Appendix H. The histogram for the beam of the tracked vessels shows one large peak around 32 meter. This peak coincides with the maximum beam allowed to pass the old Panama canal. The new locks can accommodate larger beams, but since this data is from 2016 this has not yet taken into account. The possibility that more recent data shows a small change in the beam histogram should be kept in mind thereafter. The handymax type bulk carriers can be found in the Caribbean Sea resulting from



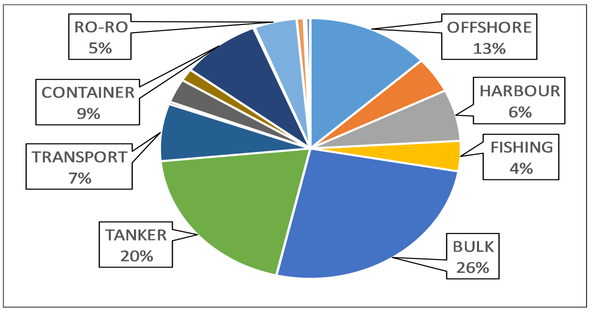
(a) LOA histogram



(b) Beam histogram



(c) Information on shipping owners



(d) Ship type division

Figure 5.7: Information on vessel characteristics in the Caribbean sea
Source: Graphs made by author, data gathered from IHS Markit Maritime Portal

the peak in the graph showing the length overall around the 180 meter, but a bigger peak can be seen. This is the maximum length for the old dock of the Panama canal. It can be seen that the Panama canal determines the size of the vessels when looked at the data in the current way.

The oil and gas market is a large chunk of the pie chart that shows the division of the ship types of the tracked vessels. A slightly different method for characterising the ship types has been used as for the west-coast of Africa, one that allows for a smaller number of types, which is the reason for a slightly different image when comparing the two. It can be seen that there is more activity in the tanker and dry bulk market, seen also in the length and breadth histograms. With the offshore market being 13% of the total, a similar image as for the west-coast of Africa can be concluded. The ports in the gulf of Mexico have not been taken into account, but if they would have this number will most probably be even bigger. The reason for not taking into account those ports is the fact that there is a sufficient amount of shiprepair services on the coast of the United States (which can also be seen in Figure 5.6)that is connected to the gulf, serving the local demand within their own strict rules & regulations. Looking into the owner profile of the vessels sailing in the area gives a slightly different image. The biggest contributor is an American company that operates in the offshore market, but the ones underneath are all Asian owners that mostly own vessels that are used for either dry or liquid transport.

Docking estimation The next piece of valuable information that can be subtracted from the online information is the expected (special) survey data of the tracked vessels. The last survey data and the building year and month of the vessel are used to estimate when a vessels needs to visit a (dry) dock for their mandatory surveys. By analysing this data, it will be possible to estimate the total number of docks that are required in the area to serve all the demand. To do this, the estimated survey data have been divided into yearly quarters. The minimum, maximum and average have been taken to determine a pessimistic, optimistic and probabilistic scenario as can be seen in Figure 5.8. The figure shows that the Caribbean basin would allow for 21, 40 or 29 docks for respectively the pessimistic, optimistic or probabilistic scenario. Historical data has been analysed for determining an expected percentage of vessels actually docking in the Caribbean, which comes down to roughly 43%. The number of vessels calling into port in Willemstad and Amsterdam that were due for a special survey has been compared to the number of actual dockings at DSCu (more precisely the former CDM) and both yards in Amsterdam to get to this percentage. The other half of the vessels most probably divert to a cheaper area, take China or South-Korea for example, to conduct their maintenance. One of the reasons that this is lower than for the west-coast of Africa is the slight difference in the type and dimension of the vessels that have been tracked. The division into different beam or length categories has not been made due to the lack of useful information for this, but thoughts on this can be given when multiple figures in this market study are being analysed. It seems that for the bigger size docks there is the biggest potential, but with a large dock comes large (financial) risk as well. The offshore market and the complementary vessels are being housed by a sufficient amount of docking capacity, leaving the widest peak in the length histogram as a best pick for the docking potential.

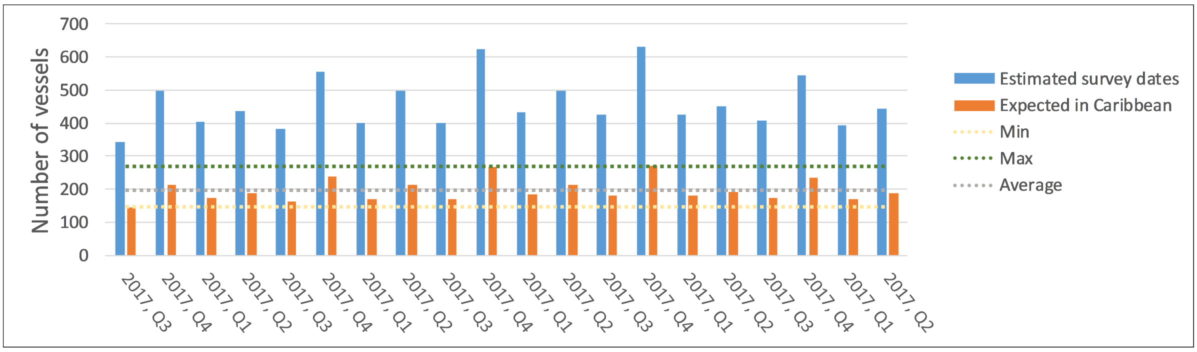


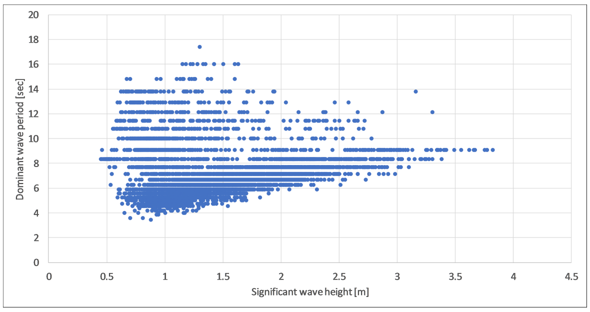
Figure 5.8: Docks estimation on tracked vessels in the Caribbean in 2016

Meteorological study The last part of the the market study is a look into the meteorological data that is available from the area to get an insight in the possible areas of operations within the Caribbean Sea. To achieve this, data on the wave climate on three different spots within the Caribbean Sea have been analysed. The National Data Buoy Center (Hereinafter: NDBC) of the government of the United States provides publicly available data on this, gathered by weather buoys. Several types of data are gathered in different times intervals that tell much about not only the wave climate, but also about the wind, air and water that surrounds the buoy. For this research, two data sets are important in particular; The significant wave height (in meters) and the dominant wave period (in seconds). The reason for this is that the most common way of displaying the wave climate is by the wave spectrum diagram based on these two parameters. Many conclusions can be taken from this diagram, together with the scatter plot that comes with it, that help this research into deciding what (type of) locations will be best for a safe and efficient operation. The three buoys that have been chosen are 42059, 42083 and 41053. They are located around 180 nautical miles south-south-west of Ponce, Puerto Rico, of the south-coast of Puerto Rico near Ponce and on the north-coast of Puerto Rica near its capital San-Juan respectively. The red dots in Figure 5.6 show the location of the buoys. There are two main reasons for the choice of these buoys. The first one relates to the availability of data within the possible resources, where only publicly available data can be used and the NDBC provides the needed information for these buoys. Secondly, analysing these three buoys and their differences gives an proper insight in the wave spectra for different locations within the Caribbean. All buoys will be discussed individually and a conclusion will be drown finally. But first, the reason for displaying both the significant wave height and the dominant wave period shall be given.

The significant wave height is the average of the highest one-third of the waves as measured from the trough to the crest of the waves. A different calculation, which can also be converted to determine the wave spectrum in the end, is that the significant wave height is 4 times the average of m_o, which is the variance of the wave displacement times series. It is often used as a measure of the height of ocean waves and was originally intended to mathematically express the height estimated by a trained observer. The dominant wave period is the period corresponding to the frequency band with the maximum value of spectral density in the non-directional wave spectrum. This means that this is the period of the waves with the highest energy, corresponding with the waves that are used to measure the significant wave height. An approximate representation of the wave climate is given by a bivariate histogram of the significant wave height and the zero-crossing wave period, which is the scientific name for the dominant wave period. This histogram, also called a scatter diagram, represents the distribution of sea state conditions during the period when wave records have been produced [Capito and Burrows, 1995].

The first buoy to analyse is buoy number 42059, which is situated in the middle of the Caribbean Sea about 180 nautical miles south-south-west of the south-coast of Puerto Rico. The NDBC describes the location as 'Eastern Caribbean Sea' and the data gathered from this buoy can be seen in Figure 5.9 below. This buoy serves mainly to see whether or not it will be possible to operate in the middle of the Caribbean Sea. Although not many work is expected at this location, it is a good benchmark for possibilities that might occur further than 12 miles from the coast due to the advantages taken from reduced legal obligations.

It is a general opinion that a low wave height and a long wave period is desired when stability is required, as is the case for having a vessel on dock blocks in a dry dock. When a scatter plot is made from the data on both parameters, it is desired to have most of the points in the top left corner of the plot if the significant wave height is shown on the x-axis and the dominant wave period is shown on the y-axis. Figure 5.9a depicts such a plot for buoy 42059 and the results are not good. Although the wave height is not that large, the period of the waves is rather short. Both can be explained by the fact that the Caribbean Sea is enclosed by land and the waves can therefore not build up in height and length. The probability density diagram, seen in Figure 5.9b, shows the same. The numbers indicate the total amount of measurements that have been recorded for that particular combination of wave height and period. To give an example, the most dominant combination are the measurements for a wave height between 1.5 and 2 meters and a wave period between 6 and 8 seconds. Again, low but very short waves.



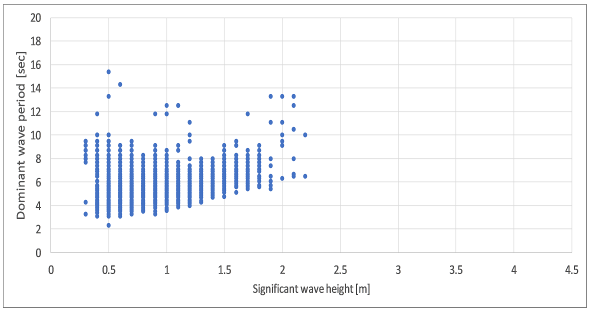
(a) Scatter plot of buoy 42059

Buoy 42059		Dominant wave period [sec]											
Significant wave height [m]		0	2	4	6	8	10	12	14	16	18	20	sum
	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.5	0	0	0	0	0	7	0	0	0	0	0	7
	1	0	0	6	527	216	258	158	115	4	4	0	1288
	1.5	0	0	0	1588	1593	138	128	74	11	22	0	3554
	2	0	0	0	266	2284	64	46	24	1	4	0	2689
	2.5	0	0	0	2	727	139	33	6	0	0	0	907
	3	0	0	0	0	69	115	13	4	0	0	0	201
	3.5	0	0	0	0	3	39	0	2	0	0	0	44
	4	0	0	0	0	0	9	0	0	0	0	0	9
	4.5	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0
	sum	0	0	6	2383	4892	769	378	225	16	30	0	**8699**

(b) Wave spectrum diagram of buoy 42059

Figure 5.9: Graphical information on meteorological data from 2017 of buoy 42059 situated in the Caribbean Sea
Source: Graphs made by author, using data gathered from the National Data Buoy Center historical database

Buoy 42083 is located on the south-coast of Puerto Rico, just of the harbour city of Ponce. Closer to shore, it is expected that the conditions would be more favourable for dry docking operations. Indeed, when looking at Figure 5.10, the wave height decreases slightly, but so does the wave period. These conditions are still relatively tricky for the dry docking of a vessel and the work that follows.



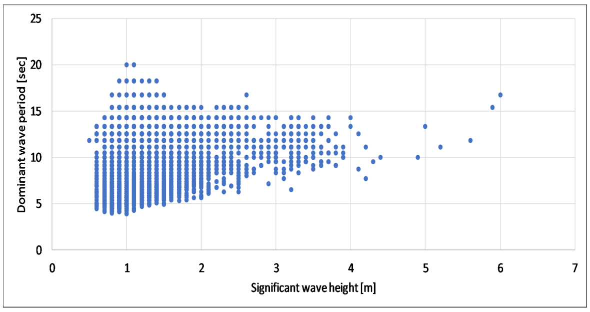
(a) Scatter plot of buoy 42083

Buoy 42085		Dominant wave period [sec]											
Significant wave height [m]		0	2	4	6	8	10	12	14	16	18	20	sum
	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.5	0	0	10	43	28	59	3	0	0	0	0	143
	1	0	0	53	921	364	83	4	1	2	2	0	1430
	1.5	0	0	5	594	890	22	4	4	0	0	0	1519
	2	0	0	0	35	254	43	2	1	0	0	0	335
	2.5	0	0	0	0	4	4	5	4	0	0	0	17
	3	0	0	0	0	0	0	0	0	0	0	0	0
	3.5	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0
	4.5	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0
	sum	0	0	68	1593	1540	211	18	10	2	2	0	**3444**

(b) Wave spectrum diagram of buoy 42083

Figure 5.10: Graphical information on meteorological data from 2017 of buoy 42083 situated on the south-coast of Puerto Rico
Source: Graphs made by author, using data gathered from the National Data Buoy Center historical database

The last two buoys are situated in the Caribbean sea, which causes the particulars that have been described above. By analysing the information gathered from a buoy that is not situated in the Caribbean sea, but still in the same area, it will be possible to conclude on a most fitting location and on the feasibility of doing business offshore. The buoy that delivered the information that is graphed in Figure 5.11 is situated on the north-coast of Puerto Rico, which makes that it is lying the the Atlantic Ocean. A totally different wave picture can thus be expected. The wave scatter diagram in Figure 5.11b proves this hypothesis, where it can be seen that the wave height is larger than the height measured by the first two buoys and the wave period is longer as well. The waves have more time and space to develop and the wave picture confirms this. Although the period of the wave is longer, which causes a more gradual slope of the waves, the height of the waves would make it more difficult to work offshore on this part of the northern islands that enclose the Caribbean Sea.



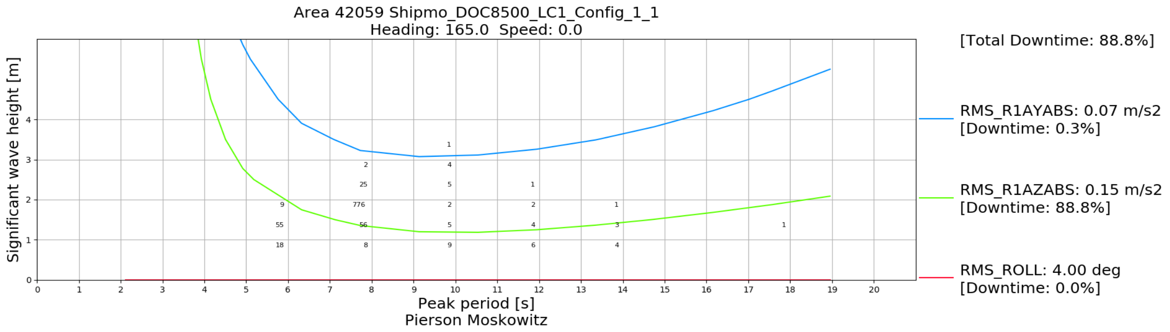
(a) Scatter plot of buoy 41053

Buoy 41053		Dominant wave period [sec]											
		0	2	4	6	8	10	12	14	16	18	20	sum
Significant wave height [m]	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.5	0	0	0	0	0	0	0	0	0	0	0	0
	1	0	0	0	474	420	508	293	162	50	53	2	1962
	1.5	0	0	1	677	1221	1279	902	268	143	163	15	4669
	2	0	0	0	39	376	318	407	129	60	64	0	1393
	2.5	0	0	0	3	34	83	54	86	39	39	0	338
	3	0	0	0	0	7	27	47	16	12	13	0	122
	3.5	0	0	0	0	2	19	44	23	8	8	0	104
	4	0	0	0	0	0	11	22	10	2	2	0	47
	4.5	0	0	0	0	1	2	2	2	1	1	0	9
	5	0	0	0	0	0	0	1	0	0	0	0	1
	sum	0	0	1	1193	2061	2247	1772	696	315	343	17	**8645**

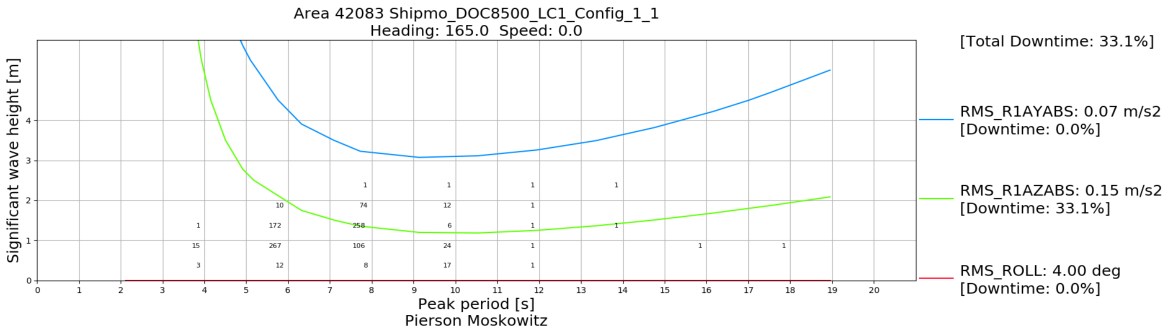
(b) Wave spectrum diagram of buoy 41053

Figure 5.11: Graphical information on meteorological data from 2017 of buoy 41053 situated on the North-coast of Puerto Rico
Source: Graphs made by author, using data gathered from the National Data Buoy Center historical database

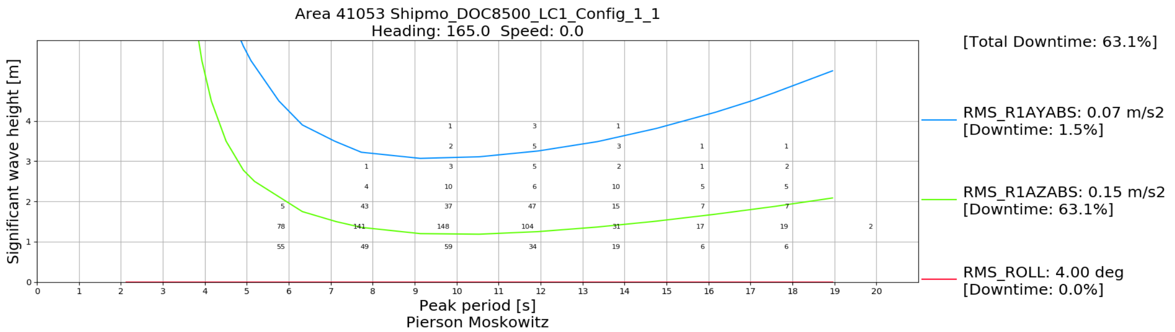
Every site, represented by the wave data gathered by the above mentioned buoys, will be put to the test. The 'Operability Viewer' software from the MARIN institute shall be used just as in the beginning of this chapter. The wave spectrum diagrams that are shown in the figures above have been put into the software to be tested against the same heavy manual labour criteria as before. The results of all three sites can be seen in Figure 5.12. Buoy 42085, close to the south-west coast of Puerto Rico, results in the smallest downtime. This is however one-third of the time, which is too high to be able to work offshore or outside of the (natural) protection from waves and swell.



(a) Operability restrictions for bouy 420595



(b) Operability restrictions for bouy 42085



(c) Operability restrictions for bouy 41053

Figure 5.12: RAO's from example vessel tested against heavy manual labour criteria for case study 1

Local pricing level The minimum price that needs to be asked for one individual project has been determined before in Section 5.1. This paragraph serves to determine firstly whether it is possible to ask this price for the provided service in the area, and secondly to find out if a higher price can be asked due to the local pricing level of competitor yards. The typical price for servicing the same type and size of vessels at the yard in Rotterdam is around €300.00,-. This, together with local pricing level in the Caribbean area, results from two sources. Firstly, example projects have been examined which are similar to the ones that will be executed in the proposed concept. Conversations with sales managers from DS&C, of both the Caribbean and the west-European area, have confirmed the findings. Both sources yielded that the local pricing level in the Caribbean is higher than the level in Rotterdam and Amsterdam. A percentage increase of 30% is a rule of thumb that can be used for this conceptual study. This means that when assessing the feasibility of the Caribbean case study, the price asked for the proposed service is the calculated minimal price multiplied by the local pricing factor of 1.3 This factor only relates to the 'normal' income and not the quantification of the added value.

Conclusion To yield inputs for both the sensitivity analysis and the Monte Carlo simulation, the market study and all its components need to be concluded in the form of recommendations on the size and type of vessels to service and the requirements of the location at which this will be done. The wide peak for vessels that have the dimensions that fall into the range of Handymax/Supramax vessels, with a width that fits the Panamax dimension, will have to fit into the dock of the facility. This means that the many bulk and tanker vessels of that size will be able to visit the facility for their planned maintenance service[4]. With a dock that large, it will be possible to fit all the vessels that supply the oil and gas market and the local bulk material market as well. With a proper dock planning, accommodating multiple vessels of that kind at the same time would be an option as well. Cranes, workshops and tools that shall be needed for such maintenance work needs to be taken into account when a more detailed design of the facility is made. The big workshop, dimension ratio of the dock and crane capacity call for either a conversion or new-building of a semi-submersible heavy lift type of platform. This platform fits the versatile nature of the entire concept. Their should be an abundance of dock block arrangements to house the larger vessels. Work that will be conducted shall mainly concern planned mandatory maintenance work, where the higher efficiency and mobile nature help the client in reducing the amount of time that is needed for the maintenance of their vessels.

The possibility to execute this work offshore, meaning outside of the Exclusive Economic Zone of a country, will only be possible in extreme favourable weather conditions and can not be counted on. Picking up clients and hauling them out of the water would be possible, also referring to [Peters et al., 2012], but the maintenance work needs to be done in a sheltered area. This also follows from comparing the above found sea states with the maximum allowable values found in Section 5.3. Because of the mobile independent nature of the facility, the location to execute the work does not have to be in a well facilitated harbour and can be in a bay or cove as well. The exact location depends on the market demand, but the selection of fitting spots can be increased by using a 4-point mooring system in stead of a standard anchor. This also means that the facility should comply with the national rules of that country. The labour rules, that are part of the national regulations, can however be interpreted different. Because all personnel is part of the ship's crew, the rules of the flag state and the owner of the facility can be maintained. The law should always be complied to, as well as the international labour conventions, but a more free method for the interpretation of the national regulations can be maintained.

5.5.2. Sensitivity Analysis

As has been mentioned above, the first evaluation method concerns the mathematical sensitivity study. By varying the inputs of the financial model one by one, while keeping the other inputs on their base value, gives a proper insight in the influence of the different variables. Table 5.11 summarises the values that have been used as base values as well as the initial investment that has been chosen, specifically for this case study. The variation in the input variables has been taken as percentages of the base value. Working with 15% and 30% difference, both above and below the base value, should give enough insight in the changes in the output that accompany these differences. The net present value has been taken as the output to compare, since this is chosen as a comparison for the financial feasibility of the concept. Figure 5.13 shows the percentage changes in the base value on the horizontal axis and the net present value on the vertical axis.

Table 5.11: Base level of chosen variables for the sensitivity analysis

Variable	Value	Slope
Initial investment	€32.500.000,-	
Distance to service hub [nm]	100	
Fuel price (MGO)	€550,-	–3.82
Day rate of client	€9000,-	8.68
Nr. of days for one project	9	–45.30
Deviation days reduction	1	2.17

Initial investment The second highest value in the range established in Section 4.4 is chosen as the initial investment for the Caribbean Sea case study. The reason for this is the size of the to be serviced vessels, which

[4]These type of vessels, that carry cargo, dock when they are empty. When eventually chosing a location for the facility, this will be taken into account.

results from the vessel data described above. The ultimate dimensions that are planned to be taken into the dry dock are the dimensions from the smaller Supramax class vessels. These vessels are primarily bulk carriers, but the type of class has only been taken as an example for descriptive purposes. A tanker, multi-purpose vessel or any other type of vessel that is not larger than the given dimensions will not be rejected.Vessels with these type of dimensions comprise of around 35% of the total worlds fleet and should therefore be of enough abundance. Due to their size, with lengths between 160 and 190 meter, the facility needs to be of a certain size. With that size comes large investment costs.

Fuel price The fuel price in the Port of Spain, Trinidad & Tobago at the moment of writing has been taken as the base value. The same goes for this case study as for the second one, where the absolute value is not of major importance due to the nature of the sensitivity analysis.

Day rate of client The day rate at the moment of writing of a Supramax vessel is chosen as the base value, based on the information taken from the Hudson Shipping lines information [Hudson]. This data represents the average time charter rate, which is a measure for the amount of money it costs to hire such a vessel for one day. The data is shown in dollars and has been converted to Euro with the exchange rate of the day that has been chosen as base value. Again, this analysis serves as a sensitivity analysis and the absolute value is not of major importance.

Nr. of days for one project The base level value for the amount of days one maintenance project takes is chosen as nine. This means that, with the percentage variations, the maximum value for this analysis does not exceed the average of 12 days that have been taken as benchmark value. The reason for this high degree of efficiency is the fact that the Netherlands, and Damen itself, have good relationships with countries, cities and companies in the area. This results in easier handling of the supply chain logistics that might become a challenge for the proposed concept. Also, considering the high initial investment, the facility will be large enough to house a decent workshop and warehouse. This means that the efficiency of the facility will not find any obstructions due to the in-efficiency of the workshops.

Deviation days reduction Due to the fact that the Caribbean Sea is not that big and the size of the dock compares with repair areas located in the Caribbean Sea as well, the amount of deviation time of clients that can be reduced is not big. The base level is taken as 1 day, which corresponds to roughly 360 nautical miles if the speed of the client is 15 knots. The result is that the variations in the input, which are based on percentages of the base level, are not big either. This suits the situation.

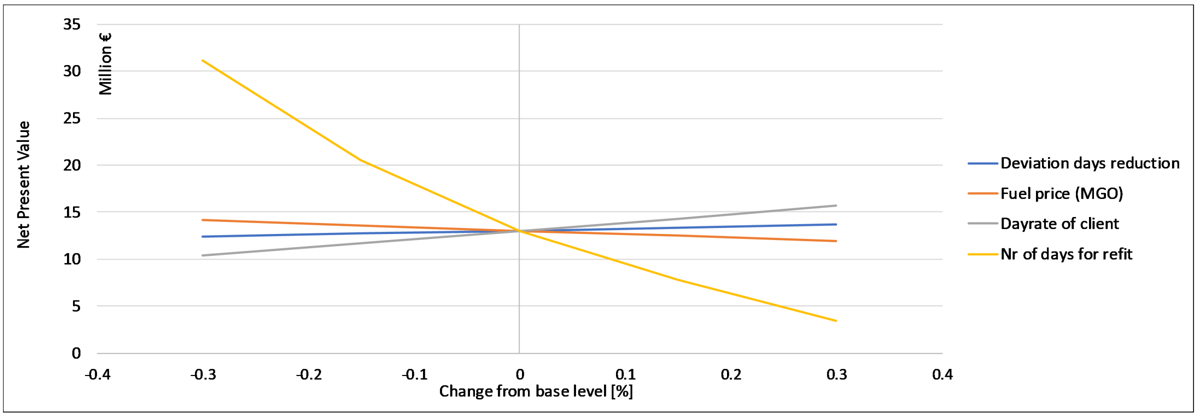


Figure 5.13: Sensitivity analysis for the Caribbean Sea

Slope To be able to compare the variables and their influence to each other, the slope of the lines in Figure 5.13 can be seen in the most right column in Table 5.11. The differences between several variables can easily be taken from the graph, but the slope serves as an extra. When the slope is positive, a positive correlations exists between the variable and the net present value, and vice versa. The slope is calculated with Equation 5.3.

$$\text{Slope} = \frac{(y_{30\%} - y_{-30\%})}{(x_{30\%} - x_{-30\%}) \cdot 1.000.000} \tag{5.3}$$

Conclusion Figure 5.13 yields several interesting conclusions. First of all, one of the variables stands out as the variable with the highest influence on the outcome of the study. The net present value of the entire project is mainly influenced by the number of days it takes to complete one maintenance project. This determines the amount of projects that can be executed at the facility and therefore has a large influence on the total revenue. This image is familiar for a project of which the fixed cost are substantial and the variable cost are lower. The, somewhat surprising, least influential variable is the reduction of deviation days of the client. One of the factors that causes this result is the small variation in the input. To support this, if the base value for the deviation days reduction is chosen as two, this variable is not the least influential variable any more. The difference in the slope between the deviation days reduction and the fuel price is however still minimal. This means that the deviation time reduction, which is one of the added values of the proposed concept, is of very little influence. The biggest win can be achieved by increasing the efficiency of the service as much as possible.

5.5.3. Monte Carlo Simulation

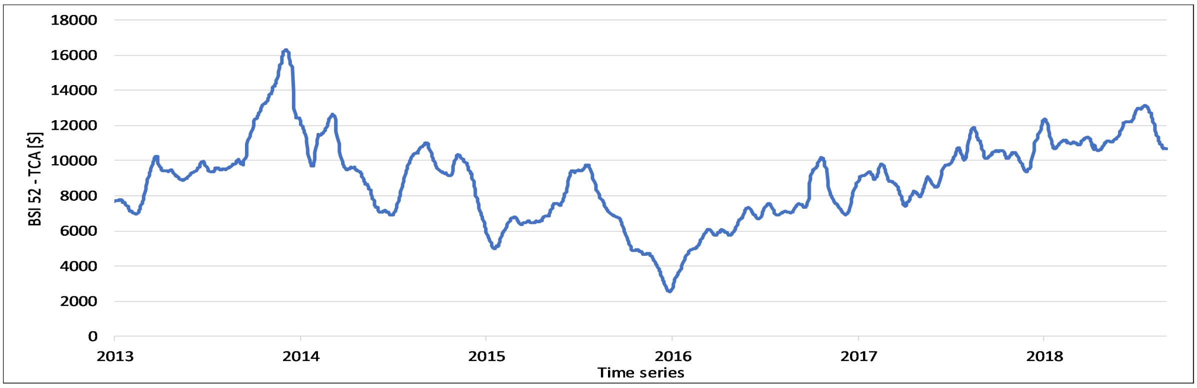
The second evaluation method to check for the financial feasibility of the proposed concept is the Monte Carlo simulation. Because the values for the input of the model for the years in the far future (at the end of the running period of 20 years of the project) are extremely hard to predict, they have to be estimated based on certain values. The proposed concept needs to be able to cope with fluctuations in the inputs for the variables and the financial model needs to be checked for this. This is done by running the model for a large number of times, while randomly changing the input within the given distributions. All inputs will be described individually.

Day rate of clients using Baltic Supramax Index The Baltic Exchange has collaborated in this research by supplying the times series for the past five years for the Baltic Supramax Index (Hereinafter: BSI) and the accompanying Time Charter Equivalent (Hereinafter: TCE). The former is a result of the latter and it is a sub-index of the Baltic Dry Index that has been mentioned in 1.1 already. The value of the TCE depicts the average amount of money (in Dollars) that it costs to hire a Supramax vessel for one day in a time charter fashion, taken over six different routes that each have different portions in that average. A standard 'Tess 52' type vessel is used, which has roughly the dimensions that are taken as the maximum for the facility for this specific case study. This time series can be used extremely well for the establishment of a method for the estimation of the future day rates of possible clients. To do this, a method similar to that of Section 3.1.1 will be used. The method involves several steps;

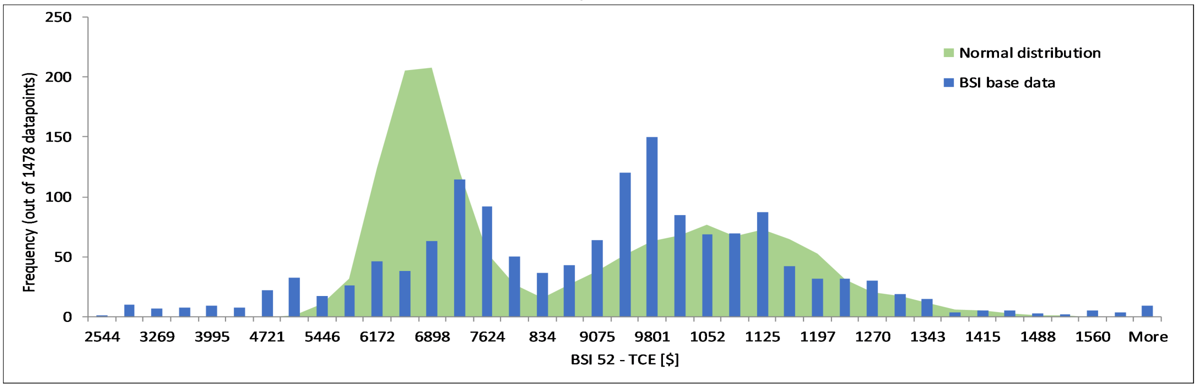
- step 1: Obtaining of data;
- step 2: Graphing the data as a line chart;
- step 3: Graphing the distribution of the original data using a histogram;
- step 4: Establishing the required data for the calculation of the equivalent (inverse) normal distribution;
- step 5: Graphing an example of the (inverse) normal distribution to check for similarities

Step one has already been accomplished by the Business Development department of The Baltic Exchange, for which I am really grateful. After several cleaning and organising proceedings, the data can be graphed as is needed in step two. Figure 5.14a shows the line chart of the average TCE in Dollars on the y-axis. It can be seen that the value fluctuates quite dramatically, which will later show to cause a difficulty in the establishing of a fitting distribution. Step three helps in this, by graphing the data in the form of a histogram. This type of graphing has been mentioned before and the result can be seen by means of the blue bars in Figure 5.14b. Clearly seen are the two peaks that correspond to a lower and a higher range of the value for the TCE. Where the former is slightly less skewed, the latter seems to have a wider base. These last three steps have just resulted in the establishing of a proper picture of the historical data and the right parameters need to be picked out now to complete step five. To counter for the two peaks, the histogram will be split into two where $8500 has been used as the split value. For both divisions, the mean and the standard deviation of the data is then found. These serve as the input for the inverse normal distribution. Where the normal distribution itself supplies the probability of a value to fit into the distribution with a given mean and standard deviation, the inverse does it the other way around. This also means that it is possible to randomise the input to generate an output that can be used for a Monte Carlo simulation. Given the mean and standard deviation found by splitting the TCE data and supplying a random probability, the inverse normal distribution results in the value that fits the probability. The value would in this case be the amount of Dollars for a day of hire estimated in the future, based on the given data. This method fits the purpose of supplying input to the Monte Carlo simulation perfectly, but will most probably not be used for any other purpose because of the fact that many (external) factors are not being taken into account. The only step left is to merge both inverse normal distribution based on the split histogram. This has been done by generating a random number, which can only be either one of zero, and by applying the formula 5.4. In the formula, rand() stands for the random number that is either one of zero, $Norm_{low}$ stands for the inverse normal distribution of the lower division and $Norm_{high}$ stands for the other division. The final value to use as the estimated randomised future TCE is $Norm_{final}$. The final value is therefore either the inverse of the lower or the higher division and the histogram, in the form of the area underneath, can be seen by the light-red are in Figure 5.14b. Because the input is partly random, the graphs shows an example of the calculated distribution. Running the randomised calculation again will result in a slightly different figure, but the differences will be minor and decrease with the amount of runs per simulation.

$$Norm_{final} = Norm_{low} \cdot rand() + (1 - rand()) \cdot Norm_{high} \tag{5.4}$$



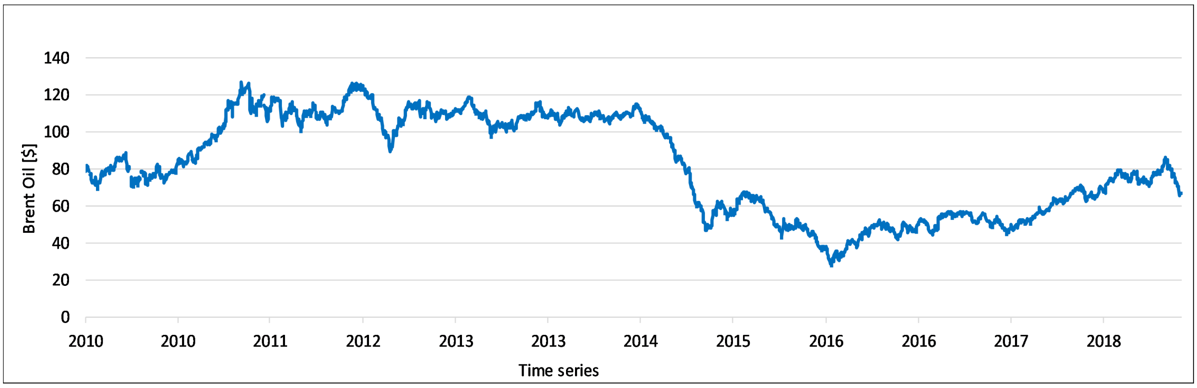
(a) Line chart of the original data for the BSI 52 TCE



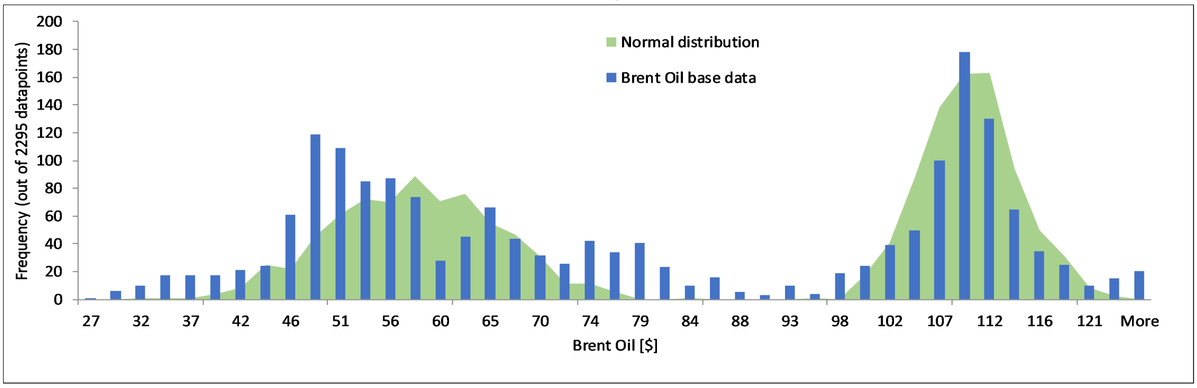
(b) Distribution used for the estimation of future client earnings

Figure 5.14: Graphical information on the fitting of a normal distribution for future BSI estimation
Source: Graphs made by author, using data gathered from a collaboration with the Baltic Exchange

Fuel cost based on Brent Oil The same method as for the estimation of the future earnings of Supramax vessels has been used to establish a distribution that depicts an input for the fuel price in the Monte Carlo simulation. The data that is being used as the base data is the value of Brent oil and the several conversions to find the MGO price at different locations around the world, similar as has been done to establish the inputs for the sensitivity analyses. An online article written by DNL-GL ([DNV-GL, 2018]) on the current developments in the oil and gas market is used for both the validation of using Brent Oil data and the method for establishing the MGO price for the Brent Oil data. One of the graphs in the article[5] shows several line graphs in one figure, including the price of MGO 0,1% sulphur and Crude Brent Oil. Dating back to 1991, both graphs show a dramatic similarity. This fuels the motivation to use the data on Brent Oil for the estimation of future MGO prices. Step one of the method described above has been done by downloading a time series on Brent Oil futures for an open-source established website [Exchange, 2018]. The raw data for the data set has been taken from the Intercontinental Exchange, the online futures market that trades the Brent Oil futures. Step two of the process can be seen in Figure 5.15a, where the time series goes back to the beginning of 2010 and the y-axis shows the price (Dollars) of one barrel of Brent Crude Oil. The name comes from the Brent oilfield in the North-Sea and the value of its oil is still being used as a benchmark for the pricing of oil all around the world. The distribution of this data can be seen to have two different peaks as well (Figure 5.15b), although they differ more than the distribution of the Supramax day rates. The same method for establishing the inverse normal distribution that serves as the input for the Monte Carlo simulation is used as for the Supramax day rates, that of splitting the distribution of the base data in two. The result of this, step five in the process, seen in Figure 5.15b as the light-green area under the distribution. Said again, this is an example of the final result due to the randomised input. It can be seen that the found distribution fits the base data well and can therefore be used for the estimation of MGO price for the Monte Carlo simulation.



(a) Line chart of the original Brent Oil data



(b) Distribution used for the estimation of future MGO fuel price

Figure 5.15: Graphical information on the fitting of a normal distribution for MGO fuel price estimation
Source: Graphs made by author, using data gathered from the Quandl online database

[5]The graph can unfortunately not be shows in the report due to the lack of resources to work around the copyright.

Deviation day reduction To simulate the reduction of deviation days of clients, a discrete frequency distribution is used. Every value of this reduction, with a step of one day, is given a probability. The values for the probability is determined based on the knowledge gained during the entire research and coincides with statements that have been made in the sensitivity analysis section; the deviation days reduction is not the main factor in the Caribbean case study due to the smaller distances between ports and repair yards. The frequency distribution that is used can be seen in Table 5.12 and needs some explanation. The method for finding a value for the deviation days reduction to use in the Monte Carlo simulation is by randomly selecting a lookup value (left most column of the table) based on the probability given in the right most column of the table.

Table 5.12: Probabilities of the discrete frequency distribution for the Caribbean Sea case study for the deviation days reduction

Lookup value	Deviation days reduction	Probability
0.0	0	35%
0.35	1	30%
0.65	2	20%
0.85	3	10%
0.95	4	5%
1.0	5	0%

Number of days for one maintenance project An uniform distribution is used for the simulation of the length of one maintenance project. This distribution is based on minimum and maximum values that are used for the sensitivity analysis as well. No better can be done at this stage of the research into this concept. The values used can be seen in Table 5.11. The distribution of all the inputs to the model are summarised in Table 5.13, together with their particulars.

Table 5.13: Distribution particulars as input for the Monte Carlo Simulation

Values	Deviation days reduction	Nr. days for one project	Fuel price (MGO)	Day rate of client
Mean	1.2	9.0	€741,-	€8.605,-
Maximum	4.0	11.7	€1.087,-	€15.585,-
Minimum	0.0	6.3	€251,-	€5.106,-
Standard deviation	0.7	0.5	€87,-	€1.745,-
Type of distribution	Discrete	Uniform	Normal	Normal

5.5.4. Results of case study 1

Running the financial model with the given distributions and fixed values for 5000 (five thousand) times yields a Monte Carlo simulation. To evaluate the results, a histogram has been made and the outputs mentioned in Chapter 4 are given. Both can be seen below. The simulation has been run with an occupational rate of 100%.

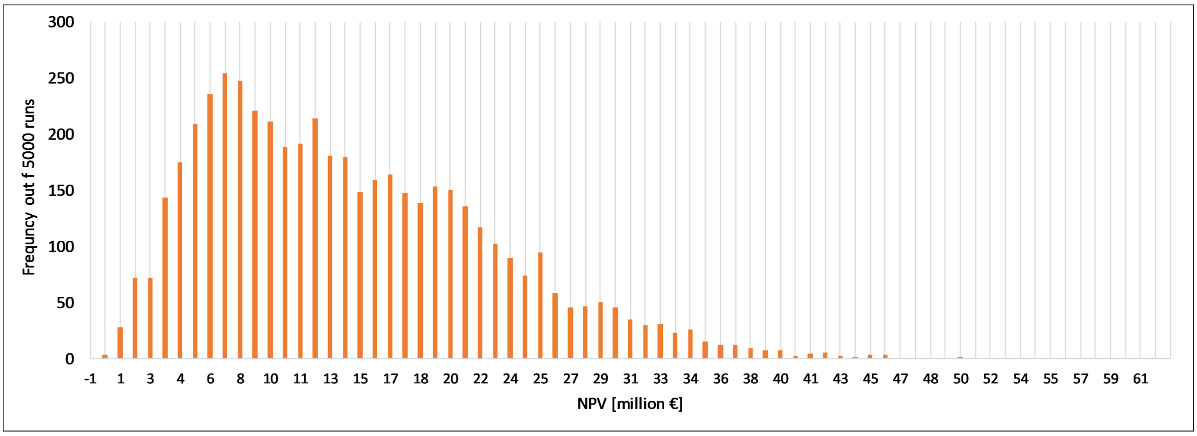


Figure 5.16: Histogram displaying the results from the Monte Carlo simulation of the Caribbean Sea case study

Table 5.14: End results, case study 1

Output	Value
Mean Net Present Value	€13.965.721,-
Probability of Loss	0.12%
Mean break-even year (out of 20)	11.23
Mean IRR	11.02%

Discussion The result that jumps out is a probability of loss of below 1%. This would mean that there is close to zero percent chance that the project would fail, a near perfect result. The project would result in a profit of nearly 14 million Euro. This almost seems to good to be true, and it is. For the above outcome, the occupational rate has been kept at 100% within the total amount of days that can be spent on servicing vessels[6]. Changing the occupational rate changes the amount of projects that are executed in one year. Because the length of one project, and thus the amount of projects in one year, is highly influential on the outcome, it is expected that the occupational rate will be highly influential on the outcome as well. Table 5.15 shows the expected. A negative chance in the occupational rate means a sharp decrease in the results. A realistic occupational rate (when the time needed to maintain the facility itself is already taken off and the option of berthing the vessel alongside the facility both before and after the docking taken into account) is between the 80% and 90%. This would mean that the concept will not be profitable, given the values that have been taken for analysis.

Table 5.15: Discussion analysis of a varying occupational rate, case study 1

Occupational rate	Mean NPV	Probability of Loss
100%	€13.965.721,-	0.12%
95%	€5.205.517,-	29.42%
93%	€1.756.698,-	47.54%
90%	€–3.174.622,-	71.00%

Interesting to see is whether is it possible to be profitable with a realistic occupational rate if certain fixed values or variables change favourable. The two that will be discussed here are the capital expenditure and the day rate of future clients. The former is chosen because of the fact that it is at this stage extremely hard to

[6] In Chapter 4, this amount has been set on 350 days in one full year

predict the resources required for the building of a new facility or converting an old vessel into the proposed concept. If a chance comes to buy a donor vessel at a very low price, the capital expenditure might end up lower than expected. A varying CAPEX has been investigated for an occupational rate of 80% and 90%. Also, a high capital expenditure has been simulated with an occupational rate of 100% to check for an upper limit. The results of this discussion analysis can be seen in Table 5.16. A capital expenditure of 15 million, which is extremely low for such a concept, is not even low enough to be a profitable facility when the occupational rate is 80%. Being the lowest value in the range of realistic occupational rates, not all hope is lost. Sales sells the first project and the production teams sell the next three, meaning that both need to work really hard to maintain an occupational rate of 90%. With this rate, the concept becomes profitable if the capital expenditure can be kept below 27,5 million euro. It will still be a major risk, because a rate of 90% is the highest value in the realistic range.

Table 5.16: Discussion analysis of a change in the capital expenditure, case study 1

Occupational rate	Capital expenditure	Mean NPV	Probability of Loss
80%	€32.500.000,-	€–18.587.234,-	99.74%
80%	€25.000.000,-	€–13.252.223,-	98.22%
80%	€15.000.000,-	€–5.914.619,-	85.98%
90%	€30.000.000,-	€–1.633.832,-	63.94%
90%	€27.500.000,-	€238.351,-	55.28%
90%	€20.000.000,-	€5.625.516,-	23.12%
100%	€50.000.000,-	€1.440.603,-	50.24%

The last discussion analysis that is interesting to conduct for this case study is to vary the day rate of the possible clients, while keeping the capital expenditure at the value that has been determined before. This will change the added value that can be produced per project and might result in increasing profitability. When the market is really healthy, as it was before the last major global financial crisis, the time charter equivalent day rates are healthy as well. To simulate this, the day rate has been doubled and tripled and the results for the low and high values in the range of realistic occupational rates are shown in Table 5.17. The same image can be sketched as in the first discussion analysis. An occupational rate of 80% is just too low to be profitable. When a rate of 90% can be achieved, a very healthy market (it takes many favourable factors to double the amount of money a vessel can earn in one day) can make the concept profitable.

Table 5.17: Discussion analysis of a change in the day rate of possible clients, case study 1

Day rate of client	Occupational rate	Mean NPV	Probability of Loss
x2	80%	€–12.541.034,-	89.94%
x3	80%	€–6.164.285,-	71.76%
x2	90%	€4.635.741,-	42.20%
x3	90%	€12.084.182,-	27.90%

5.6. Case study 2; African West Coast

One quick glance at the locations of global shiprepair facilities displays multiple areas that show minor coverage. One of these areas is the African continent, where the east coast is even less densely populated than the west-coast. These findings become valuable only when comparing the locations of repair facilities with the shipping density of those areas, which is needed to graph both the supply and the demand. Figure 5.5 displays both and gives the opportunity to choose the west-coast of the African continent as a viable option to assess the feasibility of a Mobile Shiprepair Facility. It can be seen that the area between the Cape Verde's and South Africa only includes ten shiprepair facilities, including both countries. Comparing it to the density seen in Figure 5.4 that number seems to be limited, especially when the marine activity in that area and the resulting opportunities are known. Both the gulf of Guinea and the sea to the west of Senegal and Mauritania houses a vast quantity of oil and gas exploration, which is accompanied by decent marine activity. Both in the form of vessels that supply support to that industry (offshore supply vessels, anchor handling tugs and research vessels) and (chemical) tankers to transport the produced oil and gas. Many of the repair facilities in the area focus on these markets, in particular those that surround the gulf of Guinea. A market study has been conducted to conclude the introduction of this case study, after which certain variables can be fixed and the distribution of others can be determined. The remaining variables will undergo the sensitivity analyses described above and used in the Monte Carlo simulation to asses the feasibility of a mobile shiprepair platform on the west coast of the African Continent.

5.6.1. Market study

The market study consists of two parts. Firstly the current shiprepair facilities will be examined to asses the possible future competition in the area. Information on the vessels that sail in the area shall be analysed afterwards. The combination of the two leads to a conclusion on the size of the shiprepair facility itself and an estimation on the potential for extra docking capacity to serve (future) demand.

Competition Part of a regular market study is the judgement of future competition. This determines the strategy for that specific market by finding a niche market where the concept can be exploited the best. For a shiprepair yard, the location and facilities of the yards in that area are most important, followed by the quality of their services and the willingness of possible clients to visit those yards for the maintenance of their vessels. Zooming in on the worldwide locations shown in Figure 5.5 yields a more detailed map of shiprepair facilities along the west coast of the African continent (Figure 5.17). It can clearly be seen that two spots have a number of yards, which are both driven by the oil & gas market in particular. Both in front of Senegal and in the Gulf of Guinea can shiprepair yards be found, which has been summarized in Table 5.18. All columns have been described in the first case study already, only the insightful facts shall be mentioned. Comparing the vessel density map from Figure 5.4 and the competition seen in the figure below, there seems to be room for the proposed concept. Before this can be determined as a final decision, two additional things need to be done. By looking at the vessels that sail in the area and their particulars, possible scenarios can be sketched for the need of dry docks in the area. Secondly, the port calls in the area can be analysed for finding the best suited size of a competing dock in combination with the existing facilities.

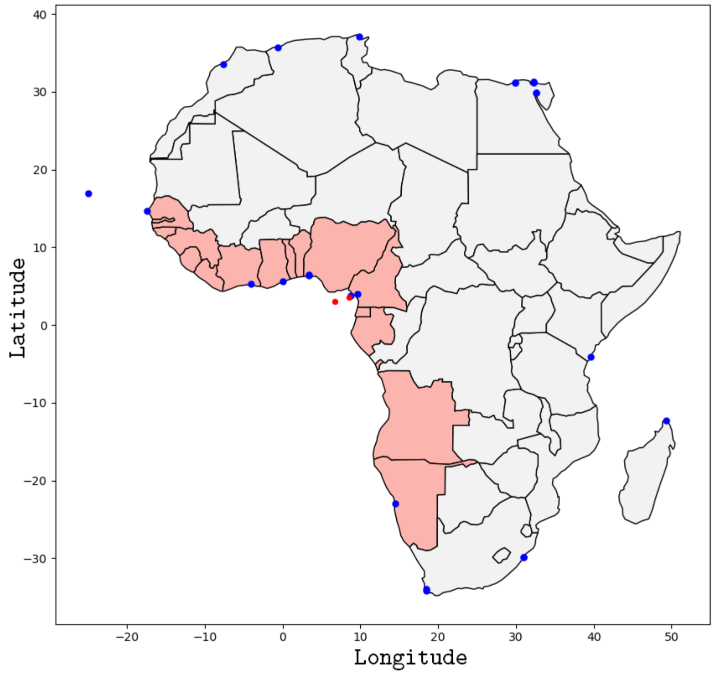
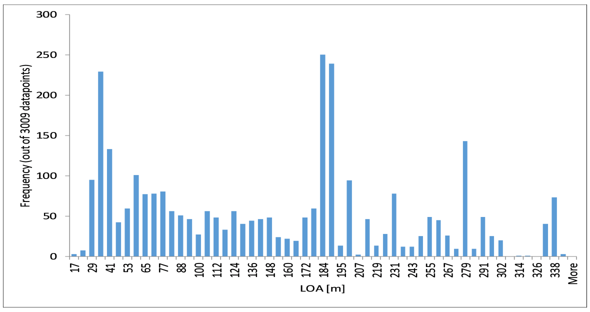


Figure 5.17: Repair yard locations African continent

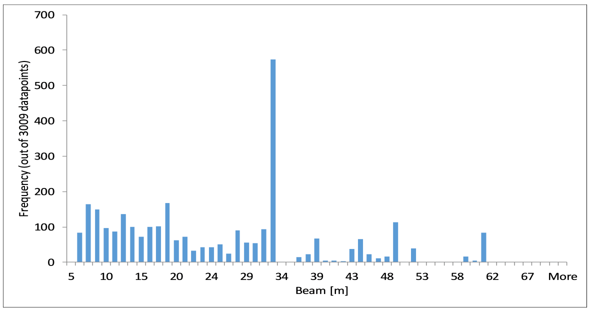
Table 5.18: Listing of possible competition on the coast of West-Africa
Source: Company websites

Name	Country, city	Docking facilities	Market	Rating
Dakarnave	Senegal, Dakar	Graving Dock: 235 m x 29 m Floating dock: 110 m x 14 m	Dry docking and common repairs mostly for the oil & gas	3 stars
EBH Namibia	Namibia, Walvis Bay	Floating Dock: 195 m x 35 m Floating dock: 140 m x 25 m Floating dock: 140 m x 25 m	Dry docking and repairs of many types of vessels	3 stars
Cabnave	Cape Verde, St. Vicente	Slipway (6x): 110 m x 18 m	Dry docking and common repairs	2 stars
Nigerdock	Nigeria, Lagos	Graving Dock: 25000 DWT Floating dock: 5000 DWT	Marine construction work as well	2 stars
Cameroon Shipyards	Cameroon, Douala	Floating Dock: 172 m x 33 m Floating dock: 90 m x 26 m Floating dock: 60 m x 14 m Floating dock: 42 m x 14 m	Dry docking and repairs	2 stars
Carena Ship Repair	Ivory Coast, Abidjan	Floating Dock: 140 m x 32 m Floating dock: 80 m x 16 m	Dry docking of offshore vessels	2 stars
PSC Tema	Ghana, Tema	Graving Dock: 277 m x 45.7 m Graving dock: 107 m x 14 m	Offshore market and transit vessels	1 stars
Asaba	Equatorial Guinea, Malabo	Floating dock: 210 m x 36 m Floating dock: 105 m x 23 m	Mostly offshore market	1 star

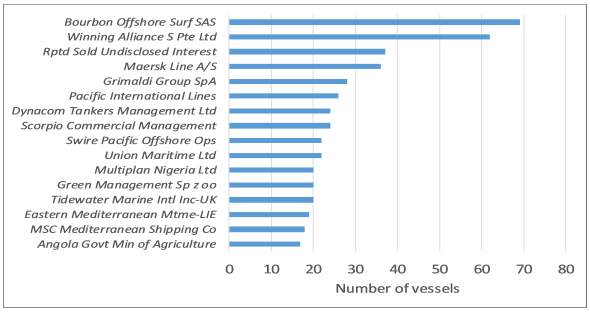
Vessel data Data on vessels and their particulars that sail in the targeted area can be helpful in a number of ways. The dimensions and type of the vessels determine the size of dock that is needed to service them and the owners and technical managers have a lot to say about the decisions surrounding the docking of their vessels. To gather the needed data, port calls in the countries on the west coast of the African continent have been analysed in the period starting on the 31^{st} of July 2018 and ending on 31^{st} of October 2018. The Cape Verde island are the starting point and Namibia is the ending of the list of countries. The countries that have been used are coloured in the map that shows the locations of rival repair yards. The choice for the time period has been limited by the limit on output data from the source of the data, which is the vessel movement tool from IHS Markit, an online platform that offers a combination of analytics and information on many different markets including the shipping industry. It has been assumed that the data of those three months pictures the entire year because of the fact that the markets on the west coast of Africa do not depend much on the seasons. This is because the oil & gas market makes up most of the activity and this market operates all year long.



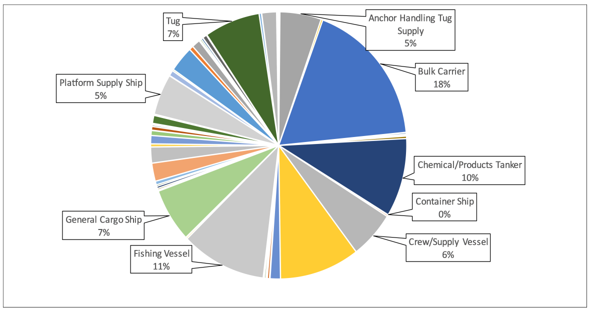
(a) LOA histogram



(b) Beam histogram



(c) Information on shipping owners



(d) Ship type division

Figure 5.18: Information on vessel characteristics on the west-coast of the African Continent
Source: Graphs made by author, data gathered from IHS Markit Maritime Portal

Both histograms show several peaks that need explanation. The peak with a length around 180 meter can be attributed to the Handymax/Supramax type bulk carriers that sail the area. These vessels can be accommodated in most of the ports on the west-coast of the African continent. Where they used to be geared (having loading cranes on board of the vessel) because of the lack of unloading facilities in the ports, the current developments cause for an increase in the length of the vessels and a decrease in the dependency on their own cranes. The histogram on the top left displays two additional peaks; One between 29 and 41 meter and the other one around 280 meter. The former are vessels that lend their services to the oil and gas market vessels and those that are used for ship handling in the ports. The latter fits the dimension of the Panamax class and are in this case mostly large tanker vessels. It can be seen that only one peak exists in the histogram showing the distribution of the breadth of the vessels, between 32 and 34 meter. This fits the maximum allowed beam to transit the Panama-canal and that is most probably also the reason for the peak. A small peak is seen at the Neopanamax width and even wider vessels are offshore structures that have an IMO number but are not vessel like shaped and will not be future clients of a mobile repair facility. Many of the smaller vessels are actually a vessel out of one of the Damen standard designs (FCS 3307 and different tug designs). This can be seen as a major advantage for this case study, since this will simplify the supply chain logistics as has been explained in Section 4.2.4. Being one of the oldest ways of making money from the sea, fishery vessels are also a large part of the smaller vessels that sail the area. Patrol vessels from the authorities, both for the protection of the agriculture and private parties, make use of the smaller and faster vessels as well. It can be seen that the west-coast of Africa imports more than it exports, but the route from the far-east to west-Africa is one of the fastest growing international trade route [UN, 2017]. This will most probably result in different type of vessels, but only if the required facilities grow alongside.

The dependency on the oil and gas market can be seen in the ship type division as well. The vessels that supply all kinds of services to the oil and gas market contribute to 15% on the total amount of vessels sailing on the west-coast of Africa. That is bound to grow even more, since new oil and gas fields have been found. The ship type division figure connects very well with the other three graphs;. The bulk carrier peaks explain the large percentage of bulk carriers sailing the area and the fact that Bourbon Offshore (a company that provide assisting services on the oil and gas market globally) owns the highest amount of vessels coincides with the large percentage of supply vessels to the oil and gas industry.

Docking potentials When it is being estimated that shipyards service 27 vessels in their average potential annually (leaving room for maintenance on their facilities and based on the average time for one survey on a land-based yard) and the number of docks in the area add up to 17 (Table 5.18), it is possible to calculate the docking potential that is left in the market. Multiplying 27 dockings per year by 17 dry docks in the area results in 459 open slots annually. Looking at the graph, it can be seen that the estimated average for the dockings expected in west-Africa is around the four hundred. This number is based on the fact that it has been estimated that around two thirds (66.7%) of the vessels sailing in the area need a docking on the west-coast. This number results from expert consultation both within Damen and with the vessels owners seen in 5.18c. The other one third are mostly the larger vessels that sail long routes and that can fit a visit to the far east into their schedule to plan a docking at a yard there to benefit from the cheaper labour prices. Another factor to keep in mind is that some oil and gas related vessels do not enter ports for some time to be of service for at sea. This thought might increase the total number of potential dockings. This analysis does not say anything about the different sizes of the docks and an estimation based on that, but the results of the calculation that has been done combined with the competitor overview generate an insight enough to build conclusions on. The fact that the oil and gas market is expanding in the area, the low ratings earned by the current shipyards and the information gathered from conversations with representatives from owners of vessels sailing in the area together give enough evidence to believe that there is enough market potential for an additional shipyard in the area.

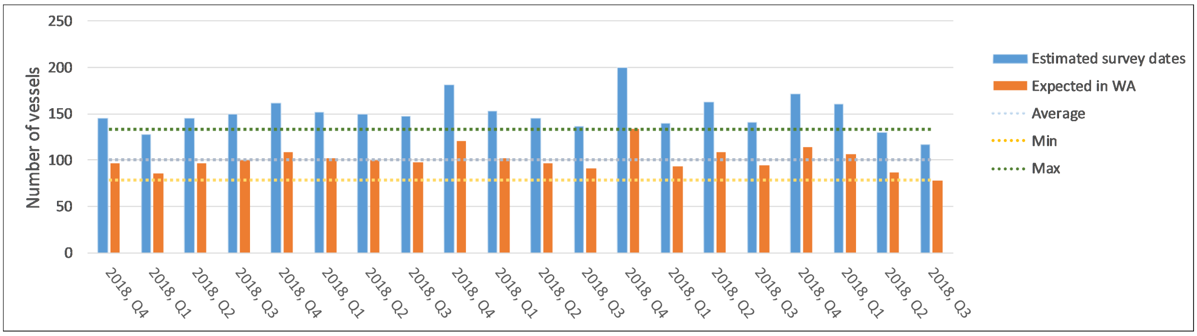


Figure 5.19: Docks estimation based on port calls from 31-July 2018 to 31-October 2018

Meteorological study The last step of the market study is an analysis of the meteorological data of a part of the west-coast of Africa. No measurement information has been available within the resources, which means that hindcast data that can be openly found on the internet has been used. In oceanography and meteorology, a hindcast is a way of testing a numerical model. The model is tested by comparing the output of the model with a know real life situation with the purpose of optimising the prediction of future outputs. The hindcast database that is used for this study has been generated by MetOcean Solutions, a division of a New Zealand state owned enterprise. Two locations have been chosen that lay relatively close to each other in the Gulf of Guinea. One of them is the location of the Egina FPSO and the other one is just of the west-coast of the Island of Bioko, part of Equatorial Guinea, both have been graphed in Figure 5.17 with the red dots. The reason for the choice of these locations comes in two fold. The coast of west-Africa is extremely long and analysing the entire length of the coast would be a waste of resources. Because the swell comes from roughly the same direction all year for the entire analysed area, analysing only one part would be sufficient. By choosing the Island of Bioko, roughly the centre of the coast has been taken. Secondly, by choosing these two different locations, both the offshore option can be checked as well as the near-shore option. The location of the Egina FPSO, 3.0 degrees North and 6.7 degrees East, is chosen due to the fact that this FPSO has only recently been build and deployed at the site. It is a recently discovered site and can be taken as example for the future locations of the activity in the oil and gas market in the Gulf of Guinea. Possible offshore work can thus be discussed by analysing this site. The next location, at 3.6 degrees North and 8.5 degrees East, is just of the west-coast of Bioko Island in the bay of San Carlos. This can be considered as a close to shore location that falls within the Exclusive Economic Zone of Equatorial Guinea. Both locations will be discussed individually.

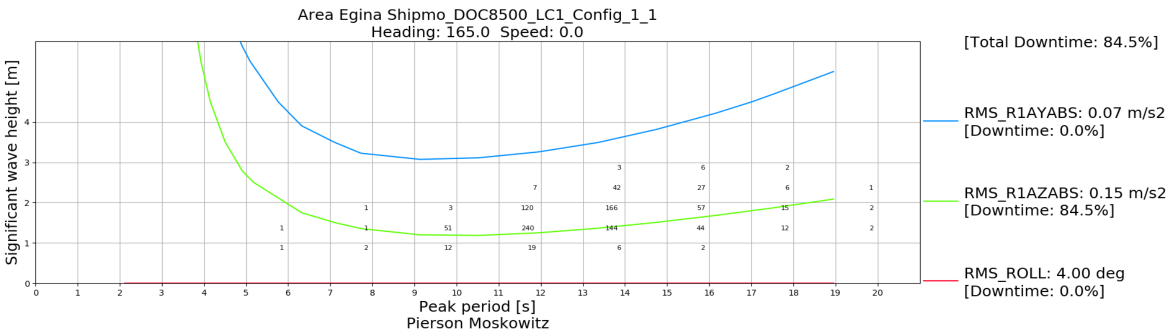
Egina		Dominant wave period [sec]											
		0	2	4	6	8	10	12	14	16	18	20	sum
Significant wave height [m]	0	0	0	0	0	0	0	0	0	0	0	0	*0*
	0.5	0	0	2	13	0	0	0	0	0	0	0	*15*
	1	0	0	20	127	238	1281	1991	630	183	30	5	*4505*
	1.5	0	0	0	149	112	5290	24816	14898	4591	1242	212	*51310*
	2	0	0	0	42	53	260	12397	17185	5905	1593	225	*37660*
	2.5	0	0	0	0	3	0	735	4357	2802	651	72	*8620*
	3	0	0	0	0	0	0	4	310	629	167	10	*1120*
	3.5	0	0	0	0	0	0	0	0	32	21	0	*53*
	4	0	0	0	0	0	0	0	0	0	0	0	*0*
	4.5	0	0	0	0	0	0	0	0	0	0	0	*0*
	5	0	0	0	0	0	0	0	0	0	0	0	*0*
	sum	*0*	*0*	*22*	*331*	*406*	*6831*	*39943*	*37380*	*14142*	*3704*	*524*	**103283**

(a) Operability restrictions for Egina site

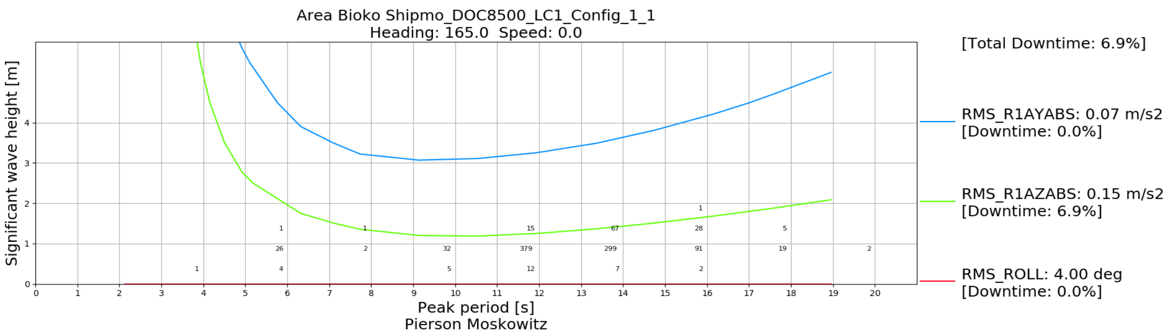
Bioko		Dominant wave period [sec]											
		0	2	4	6	8	10	12	14	16	18	20	sum
Significant wave height [m]	0	0	0	0	0	0	0	0	0	0	0	0	*0*
	0.5	0	0	70	391	25	542	1203	680	194	27	3	*3135*
	1	0	0	37	2705	186	3310	39127	30867	9403	2007	237	*87879*
	1.5	0	0	0	114	89	3	1599	6893	2891	542	30	*12161*
	2	0	0	0	1	2	0	0	5	90	10	0	*108*
	2.5	0	0	0	0	0	0	0	0	0	0	0	*0*
	3	0	0	0	0	0	0	0	0	0	0	0	*0*
	3.5	0	0	0	0	0	0	0	0	0	0	0	*0*
	4	0	0	0	0	0	0	0	0	0	0	0	*0*
	4.5	0	0	0	0	0	0	0	0	0	0	0	*0*
	5	0	0	0	0	0	0	0	0	0	0	0	*0*
	sum	*0*	*0*	*107*	*3211*	*302*	*3855*	*41929*	*38445*	*12578*	*2586*	*270*	**103283**

(b) Operability restrictions for Bioko site

Figure 5.20: RAO's from example vessel tested against heavy manual labour criteria for case study 2



(a) Line chart of the original Brent Oil data



(b) Distribution used for the estimation of future MGO fuel price

Figure 5.21: Graphical information on the fitting of a normal distribution for MGO fuel price estimation
Source: Graphs made by author, using data gathered from the Quandl online database

The hindcast data has been supplied in such form that it is not possible to make a scatter plot of the significant wave height and the dominant wave period, for both locations. The probability density diagrams can be made however and both are seen in Figure 5.20. They produce a different image than those of the first case study, especially in terms of the wave period. Longer waves can be seen, as expected due to the large amount of space in the Southern Atlantic ocean, and the images for both locations are roughly the same only for one parameter. The biggest difference between both is the significant wave height, which is smaller for near-shore location than for the offshore location. This is caused by both the difference in water depth and the slight shelter the near-shore location enjoys. The wave period is similar for both sites, as would be expected, since the same ocean swell produces both statistics.

Both the Egina and the Bioko site are tested against the heavy manual labour criteria as well, as can be seen in Figure 5.21. The difference between the downtime of both is large, but expected. The wave scatter diagrams show the large differences as well. The total downtime is almost 7%, which makes the option of working on that site fairly possible. The results further in this chapter will show if a downtime of 7% is acceptable.

Local pricing level When assessing the financial feasibility of this case study, the minimum price that can be asked for the provided services to make the desired contribution margin coincided with the local pricing level of this area. With the lower quality of the service of the competition come lower prices as well. This causes that no extra factor can be taken on the 'normal' income and only the added value of the concept can be used to outsmart the competition and potentially yield a profit.

Conclusion Taking into account all the considerations that result from the market study that has been done, a conclusion can be drawn that results in the input for both the sensitivity analysis and the Monte Carlo simulation. Both a decision is made on the type and size of the clients and the location that will be used as a base for the operation. The first decision is based on the information that is gathered from the port calls of the entire coast. It has been seen that the emerging market in this area of the world is the oil and gas market, responsible for around 15% of the port calls. Local coasters, primarily tankers and small bulk vessels, are also abundant in the area. This results in the need for a facility that has a dock that can accommodate both the vessels that are used to support the offshore oil and gas market and the smaller (liquid) cargo vessels. A high dock (block) loading, for the accommodation of OSV's and PSV's, and a long enough dock, for the accommodation of coasters, can be considered as required characteristics. The best option for the construction of the facility should be a semi-submersible platform. Either a conversion or new-build, this type of platform fits all particulars best. The primary work that will be conducted is the maintenance related to the mandatory surveys demanded by the classification societies that not involve the jobs that have been listed in Table 4.6.

Comparing the wave scatter data from above with the maximum allowable ship motions, it would be best to use the bay of San Carlos, next to the island of Bioko, as the base location. This bay forms a natural shelter to the sea swell and is perfectly located to suite the offshore oil and gas market that surrounds the island. Because of the rapid decline in water depth at that point, it is recommended to make use of a 4-point mooring system to give the facility a steady location. The same goes as for the first case study, that the required sheltered location is always situated within the national (economic) borders of a country. Where national regulations apply, they can be interpreted more freely due to the fact that the labour laws should comply to the flag state rules of the facility itself.

5.6.2. Sensitivity analysis

As has been mentioned above, the first evaluation method concerns the mathematical sensitivity study. By varying the inputs of the financial model one by one, while keeping the other inputs on their base value, gives a proper insight in the influence of the different variables. Table 5.19 summarises the values that have been used as base values as well as the initial investment that has been chosen, specifically for this case study. The variation in the input variables has been taken as percentages of the base value. Working with 15% and 30% difference, both above and below the base value, should give enough insight in the changes in the output that accompany these differences. The net present value has been taken as the output to compare, since this has been chosen as a comparison for the financial feasibility of the concept. Figure 5.22 shows the percentage changes in the base value on the horizontal axis and the net present value on the vertical axis.

Table 5.19: Base value of chosen variables for the sensitivity analysis

Variable	Value	Slope
Initial investment	€25.000.000,-	
Distance to service hub [nm]	100	
Fuel price (MGO)	€550,-	–4.20
Day rate of client	€5000,-	5.23
Nr. of days for refit	10.5	–26.19
Deviation days reduction	3.5	3.66

Initial investment The initial investment has been taken as the lowest value of the range determined in Section 4.4 in the previous chapter. This has been done since it is chosen to focus on the oil & gas market that prevailing on the west-coast of the African continent and the (smaller) size of the dock that it requires. The deck of the dock needs to be strong enough to support the Offshore Supply vessels and the Platform Supply Vessels that are predicted to come to the yard and that focus a large percentage of their weight in a relatively small area of their keel.

Fuel price The fuel price for MGO in the port of Lagos, Nigeria at the time of writing has been taken as the base value. The price of oil is dependent on multiple macro and micro factors, which makes it hard to pick one price as base value. Since this type of analysis only serves to show the dependency on specific inputs, the exact base value does not make such a difference. The changes in the oil price are of much more importance for the Monte Carlo simulation in the next section, for which more research has been done.

Day rate Since the focus lays on the oil & gas and the offshore market, the day rate of the vessels that come to the yard have been chosen as €5000,-. This value has been obtained by conversations with persons both within and outside of Damen that serve or have served in this market. Also, the value of this variables has been gathered from sources within Bourbon Offshore, one of the largest operators in the offshore oil and gas market in that area.

Nr. of days for one project The amount of days necessary for the completion of one maintenance project is more than for the first case study. This is due to two factors. Firstly, the size of the facility, which is smaller than for the one to be deployed in the Caribbean Sea, results is a smaller workshop. This means that the needed efficiency (increase) of the workshop is harder to reach and this has results for the entire efficiency of the project. Also, the supply chain logistics in this area of the world will cause more problems than in the Caribbean. Local governmental problems, border controls and a lack of quality suppliers are examples of events and factors that can limit the possibilities to increase the efficiency of the projects executed at the yard. The maximum value of this variable in the analysis exceeds the average of the benchmark, which indicates that the problems might as well cause a smaller efficiency than the benchmark.

Deviation days reduction The distances between shipyards on the west-coast of Africa is relatively large compared to the Caribbean Sea and especially the dense area's of West-Europa and south-east Asia. This causes that the reduction of deviation time of clients can be increased as well. The targeted vessels often have slower sailing speeds than the one in the first case study, which is also one of the reason for the large value for this variable. To give an example; The vessels of the subsea division of Bourbon that are located around the city of Luanda, Angola, need to sail five days to dock at the repair yard in Walvisbaai, Namibia. This substantiates the higher values for the deviation day reduction.

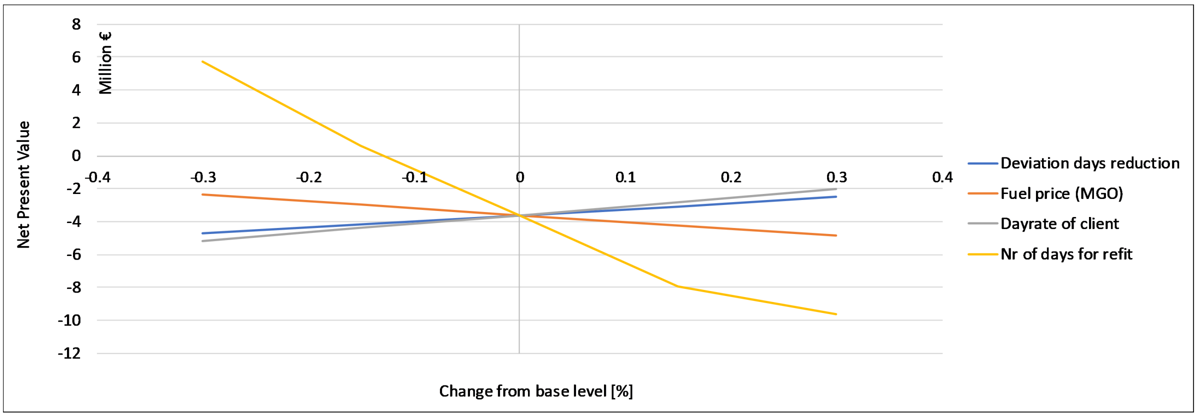


Figure 5.22: Sensitivity analysis for the African West-Coast

Slope The same method shall be used for the calculation of the slope of the lines in the above figure as for the first case study. The values for the slope serve as an extra for the comparison of all variables and their influences. The equation is repeated below.

$$\text{Slope} = \frac{(y_{30\%} - y_{-30\%})}{(x_{30\%} - x_{-30\%}) \cdot 1.000.000} \tag{5.5}$$

Conclusion The amount of days necessary for one project is again the variable with the highest influence on the output. In the situation sketched in this analysis, two out of the five variations in this variable are the only ones that yield a positive net present value. Also, even with a higher value as base value, the deviation day reduction variable is the least influential with a slope of 3.66. This, again, displays that this variable is much less influential than has been expected. It is probably also the reason that the net present value at the base level of all variables is negative. The added value that is the focus in West-Africa is not as big as expected and the results of this can be seen. Next section will discuss if the this results is only true for the scenario sketched in this analysis, or if the robustness of the concept in this part of the world is not big enough as well.

5.6.3. Monte Carlo Simulation

The same method for determining the robustness of the proposed concept is used for the deployment of the concept in West-Africa case. All variables and their distributions shall be described individually.

Day rate of clients Different than for the first case study, the distribution used in for the West-Africa case is more simple. No historical data could be gathered, meaning that a nominal value needs to be used within a simple normal distribution. The values (mean and standard deviation) used in this distribution are the same as the values that have been used in the sensitivity analysis.

Fuel price The Monte Carlo simulation of the previous case study includes a description of the normal distribution and its values that has been used to simulate the future fuel price. The same distribution will be used for this case study. This coincides with the fact that the same fuel price has been used in the sensitivity analyses and that the sensitivity of the fuel price is very little.

Deviation days reduction The same methodology as for the first case study is maintained for the simulation of the deviation days reduction in the West-Africa case study. The lookup values and the probabilities related to the discrete frequency distribution can be seen in Table 5.20. Because the distances are bigger and the quality of the competition is less than is the case in the Caribbean case study, a larger reduction can be seen in the deviation time of clients.

Table 5.20: Probabilities of the discrete frequency distribution for the West-Africa case study for the deviation days reduction

Lookup value	Deviation days reduction	Probability
0.0	0	15%
0.15	1	15%
0.30	2	30%
0.60	3	20%
0.80	4	10%
0.95	5	10%
1.0	6	0%

Number of days for one maintenance project An uniform distribution is used for the simulation of the length of one maintenance project. This distribution is based on minimum and maximum values that are used for the sensitivity analysis as well, which are higher than for the first case study. No better can be done at this stage of the research into this concept. The values used can be seen in Table 5.19. The distribution of all the inputs to the model are summarised in Table 5.21, together with their particulars.

Table 5.21: Distribution particulars as input for the Monte Carlo Simulation

Values	Deviation days reduction	Nr. days for one project	Fuel price (MGO)	Day rate of client
Mean	1.75	10.50	€741,-	€5.000,-
Maximum	5.0	13.65	€1.087,-	€6.500,-
Minimum	0.0	7.35	€251,-	€3.500,-
Standard deviation	0.56	0.5	€87,-	€375,-
Type of distribution	Discrete	Uniform	Normal	Normal

5.6.4. Results of case study 2

Running the financial model with the given distributions and fixed values for 5000 (five thousand) times yields a Monte Carlo simulation. To evaluate the results, a histogram has been made and the outputs mentioned in Chapter 4 are given. For an occupational rate of 100%, both can be seen below.

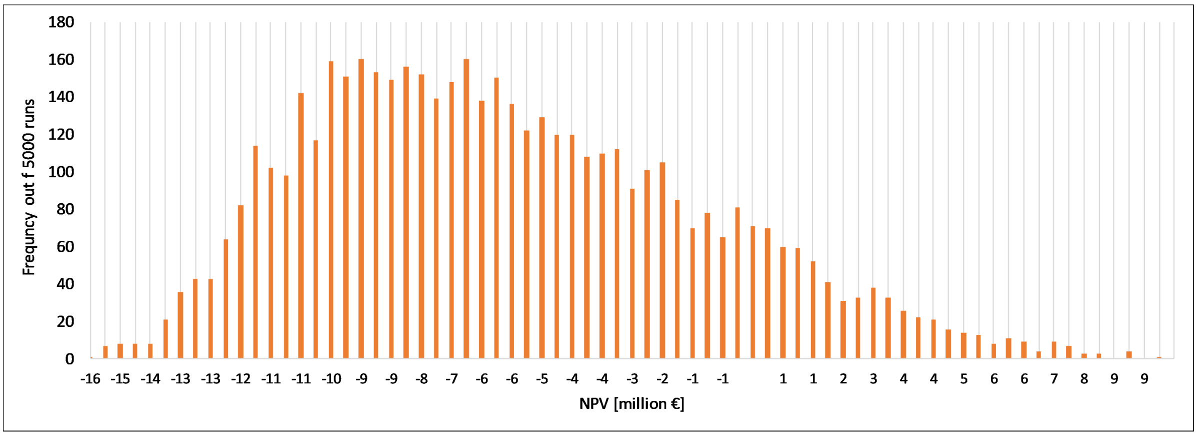


Figure 5.23: Histogram displaying the results from the Monte Carlo simulation of the Caribbean Sea case study

Table 5.22: End results, case study 2

Output	Value
Mean Net Present Value	€–5.950.855,-
Probability of Loss	88.28%
Mean break-even year (out of 20)	16.71
IRR	2.86%

Discussion The results do not look good. A probability of loss of almost 90% will scare of every financial involvement. The mean break-even year has been calculated only for the runs that results in a positive net present value. Having a mean break-even year of sooner than 20 years does therefore not mean that the results are positive. At first glance, deploying the proposed concept in the this area is not recommended. The required increase in efficiency can not be reached, meaning the the needed added value is not achieved. The amount of projects that can be executed per year is therefore just not high enough. Two different scenarios will be tested. Firstly, the direct labour cost will be varied and secondly the day rate of the clients shall be increased.

The west-African area makes it possible to look at the results when the direct labour cost are decreased. It might be possible to hire local labour for a smaller price than anticipated. Table 5.23 displays the results when the hourly rate of the direct labour is lowered. It is really important to keep in mind that the occupational rate in this analysis has been kept as 100%, which is not a realistic number. Therefore, this discussion analysis just serves to show the potential of decreasing the hourly rates of the direct labour.

Table 5.23: Discussion analysis of a change in the direct labour cost, case study 2

Direct labour cost decrease	Mean NPV	Probability of Loss
10%	€–4.126.086,-	79.90%
25%	€–1.439.327,-	65.08%
40%	€1.158.564,-	45.83%
50%	€3.066.875,-	30.24%

This case study has been chosen because of the expansion of the activity in the offshore oil and gas market. When the potential turns out to be bigger than is currently expected, the day rate of future clients might increase as well. The same type of discussion analysis as for case study one has been conduction for the west-African market. Two different occupational rates will be taken into account, where a rate of 80% has been left out since the potential to be profitable in that case is too low in this area. The day rates have been doubled and tripled again. The results can be seen in Table 5.24. The only scenario in this analysis that turns a profit is where the occupational rate is 100% and the day rates have been tripled. The reason that an increase in the day rate of future clients does not have a drastic affect on the results compared to the first case study is that less projects can be executed on an annual basis. This is mainly due to the smaller increase in efficiency, which has been proven to be an essential variable before.

Table 5.24: Discussion analysis of a change in the day rate of possible clients, case study 2

Day rate of client	Occupational rate	Mean NPV	Probability of Loss
x2	100%	€–1.651.703,-	62.12%
x3	100%	€2.608.730,-	46.98%
x2	90%	€–14.667.048,-	98.24%
x3	90%	€–11.997.110,-	90.52%

6 Conclusions

This chapter includes the overall conclusion as an answer to the research objective. The conclusions made in every chapter of this report are used to result in an overall conclusion. At the end of the chapter, an artist impression of the proposed concept on which the conclusions are based is given.

The goal of this research has been determined in Chapter 1 and is as follows.

"To make recommendations on the total feasibility of a Mobile Ship Repair Facility by gaining insights in the economic viability of the concept using a comparison between the added value and the expected costs of the to be provided services."

Recalling the research framework, this research has been divided into three parts; 'Research Perspective', 'Research Object' and 'Evaluation'. All three have been concluded in this research and their conclusions will be re mentioned in this chapter to be able to answer the research objective. The first two parts are used to construct the financial model that combines everything and the last part consists of the results that follow from running the model.

6.1. Conclusions made during the development of the financial model

The concept that is investigated in this research is that of a Mobile Shiprepair Facility. A sea-going facility that houses both workshops and a dry dock that can maintain and repair vessels all over the world. The first added value of the concept is the fact that (re)deployment of the facility requires less resources (of which time and money are the most substantial) than the setting up and/or breaking down of a land-based yard. Secondly, it is expected that the overall time of maintaining a vessel (the deviation time to a suitable dock and the actual time in the dock) can be decreased, which can be extremely beneficial for clients. Further details on the design and characteristics of the concept follow from conclusions of the individual chapters.

Research Perspective: The expected cost of the proposed concept have been calculated firstly. The relative differences between a land-based shipyard and the proposed concept are used to determine new cost structures. The base case in this comparison is a study into the background of all cost items that appear on the budgets of all yards in the Damen Shiprepair & Conversion group. The biggest differences between a standard repair yard and the proposed concept are the direct labour cost, M&I cost, housing cost and the travel expenses. Due to the fact that the MSRF uses direct labour that is part of the ship's crew, the hourly rates are lower. The reliance on this direct labour is bigger however, meaning that the percentage of direct labour cost on sales is higher. The labour will however be flexible in what they are capable of doing and this should result in a higher efficiency and a much lower dependency on third parties. Especially this last fact means that the percentage of direct cost on the total sales results to be almost half of that of a land-based shipyard. Because of the fact that most of the work will be executed by own labour, the cost of machinery and installations will be higher as well. All the needed equipment needs to be on board of the vessel since transporting equipment to be serviced outside of the facility is extremely costly. Another cost item that turns out to be relatively high is the housing cost of the MSRF. Both the fact that energy demand needs to be supplied by a fossil fuel powered engine and the large amount of travelling (where the price of the travel depends mainly on the distance between the facility and the service hub) cause an increase in the housing and travelling cost.

Research Object: The costs of the concept have to be covered by revenue earned by the supplying of ship maintenance and repair services on the facility. The calculation of income that can be generated on one shiprepair project has been divided into two parts; The normal income of providing ship repair services and quantification of the added value of the concept. The former is not much different than for a standard land-based yard and consists of margins taken over the direct cost of the provided services. Young vessels that do not require much steel repairs and projects that focus around the mandatory intermediate and special surveys shall be the target for the sales department to bring to the facility. The added value of the concept, reducing the time a clients needs to maintain its vessel by increasing the efficiency and reducing deviation time, needs to be quantified to be able to sell that service for the right price. It has been used that the total reduction time compared to the current standard multiplied by the time charter equivalent daily income of the client is the added value of the facility per project. To make it a win-win situation for everyone, 85% of this value is added to the normal income of one project to result in the price asked for maintaining a vessel on the facility. The total annual revenue depends on the amount of projects executed in that year, which is limited by the efficiency, time needed to maintain the facility itself and the occupational rate.

Comparing the research perspective and research object requires case studies. In this research, the Caribbean Sea and the coast of West-Africa have been chosen as case studies. The vessels in the Caribbean that are expected to be maintained are those that fit the Supramax/Handymax size because they should yield the highest demand. The capital expenditure has been adjusted to the size of these vessels and the resulting required size of the facility itself. Due to the potential size of the workshop, the dry climate and the large existing DS&C shiprepair yard on the island of Curacao, it is expected that the efficiency can be largely increased. The reduction of deviation days shall be small however. The last characteristic of this case study is the expected day rate of future clients based on historic data gathered from the Baltic Exchange.
The offshore oil and gas market is the target market in case study two, more specifically the vessels that support this market. A smaller initial investment than case study one results, as well as a lower expected day rate of future clients. The amount of deviation days that can be reduced is bigger, but the increase in efficiency is lower due to a smaller workshop and the larger distances in the area between ports. For both case studies, a semi-submersible non-propelled platform that requires a sheltered bay to perform its work has been concluded as the best option.

6.2. Recommendations on the total feasibility of the MSRF concept

The findings that are related to both the costs and revenue streams have been put into a financial model. The model can then calculate results that can be used to develop recommendations on the total feasibility of the concept. Firstly, for the main variables, a sensitivity analysis has been executed. The variables that are chosen for this analysis are the day rate of clients, fuel price, number of days per maintenance project and deviation days reduction. It has been found that the number of days one maintenance project takes has the biggest slope and thus the biggest influence on the outcome. The reason for this is that the amount of days it takes to complete one project determines the amount of projects that can be executed per year. Since the direct labour force is large and they stay on board of the vessel at all times, keeping them busy and selling them a large amount of times is very relevant in making a profit. Being efficient in supplying shiprepair services helps in this.

The second analysis that can be conducted with the financial model is a Monte Carlo simulation. The four variables that are investigated in the sensitivity analysis are given distributions and the model is then run for a large amount of times while varying the variables according to their distribution. This makes it possible to simulate the unknown and make recommendations on a project with a long lifetime such as this one. Certain fixed variables (in this Monte Carlo simulation at least), such as capital expenditure and occupational rate, are changed manually before every simulation. Both case studies require different base values and distributions for all variables, resulting in different outcomes. The outcomes that are the most important and on which recommendations can be made are the mean net present value of all simulation runs and the possibility of loss.

Evaluation It is recommended not to deploy the proposed concept on the West-African coast. Despite the large potential in the growing offshore oil and gas market, the required efficiency can not be achieved to earn a profit. Even when the day rate of future clients is increased dramatically, which might be the case if the supply vessel market for the offshore grows larger than expected, only with an occupational rate of 100% will it be possible to be profitable. This scenario is so unrealistic that no potential is seen in this case study.

The potential of the Caribbean Sea case study is a bit more positive. There are a few chances if the occupational rate can be kept at 90%, with is the highest value of a realistic scenario. If the capital expenditure turns out to be lower than anticipated in this research and the Supramax/Handymax market is healthy causing day rates of future clients to rise, the concept will be profitable in this area. Because of the fact that to be able to result in a profitable case, this scenario needs to be maintained for the full extend of the projects lifetime and because of the unlikeness of this, it is not recommended to deploy a mobile shiprepair facility in this area as well. This makes that the recommendations on the total feasibility of the MSRF concept is negative.

The entire research and report have been conducted with a concept in mind. Since the current state of the research is conceptual, no hard design can be given. However, an artist impression of the proposed concept at this stage of the research can be seen below. Figure 6.1 displays the proposed platform with a vessel in its dock and one at its berth. The negative conclusions in terms of feasibility of the concept have been based on the concept that can be seen in this artist impression.

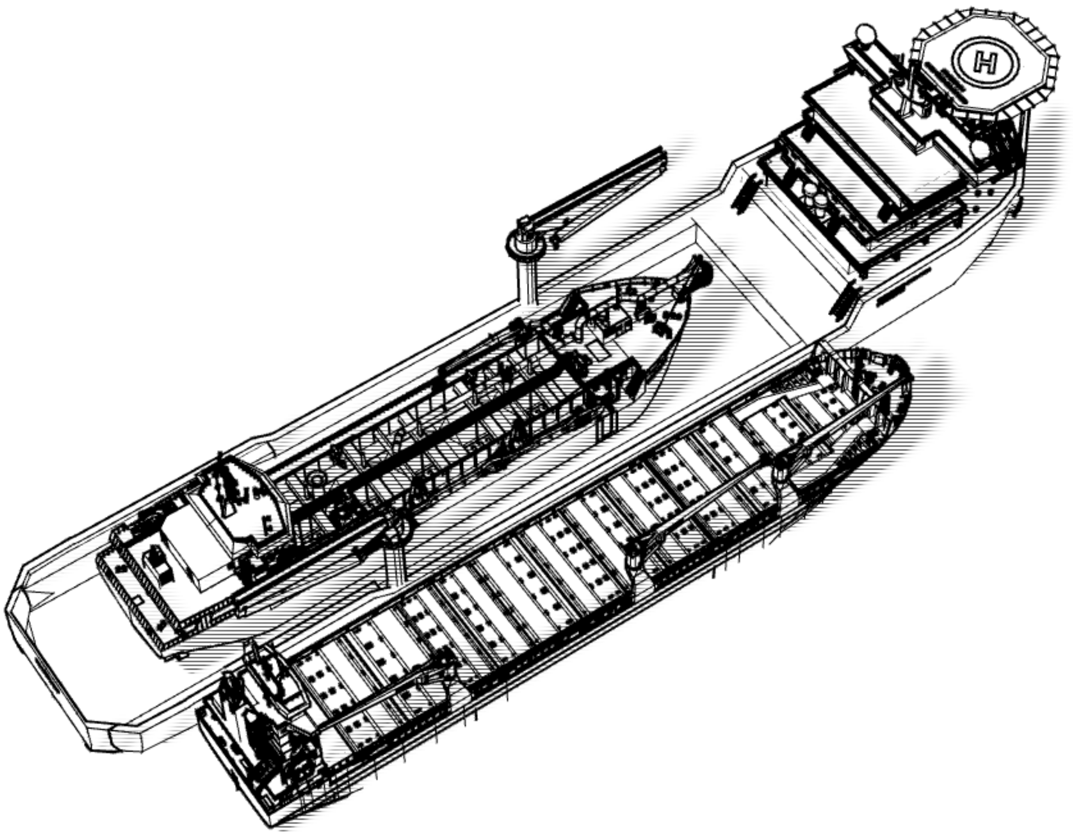


Figure 6.1: Artist impression of the Mobile Ship Repair Facility

7

Recommendations

This chapter includes recommendations for possible future researches. These can either be executed when the decision is made to continue with the production of a mobile shiprepair facility, or when additional research needs to be done to asses whether the concept is going to be profitable. Firstly, the design criteria that follow from this research are given. After that, two methods for potentially increasing the chances on profit are given; The prospect of remote surveys and the design of a tool to maximize the reduction in deviation time.

7.1. Design criteria

It has been shown that there is a slight potential for deploying the proposed concept in the Caribbean Sea, in the unlikely situation that the occupational rate can be kept near 100%. If a further design study shall be conducted for this concept, the following design criteria should be used.

- *Workshop:* One of the biggest factors that influences the efficiency of the total service is the efficiency of the workshop. The amount of work that needs to be done by the workshops depends on the scope for a specific project. However, the workshop, that serves as the warehouse as well, needs to house all specific equipment and machinery. Much attention should be paid in the design of the proposed concept to make the workshop as large as possible without giving in on the size of the dock.
- *Accommodation:* There should be enough accommodation for at least 90 persons. The types of accommodation, related to the space and privacy of a cabin, should differ. Different levels of responsibility within both the direct and indirect crew call for different types of accommodation and the third parties and the clients crew need to be housed decently as well.
- *Cranes:* The cranes on board of the facility need to be able to reach not only every part of the vessel in the dock, they should be able to take in supplies as well. No large lifting capacity is needed, but a large reach is recommended.
- *Generator power:* Enough generator power should be installed on board, together with fuel tanks that support the mobile nature of the concept. Not only does the generator power needs to support the daily usage, it should be able to provide peak power at certain times during a maintenance project. This does not only incorporate the voltage that come out of the generators. The current needed to for example run a crane should be made possible as well. Coming from the generators, but also from the connections on the work floor.
- *Deck strength:* The strength of the floor of the proposed dry dock should be strong enough to support the vessels that come in. Not all vessels can therefore be easily converted to the proposed concept. Also, when small ship motions occur, the strength and stability of the dock floor becomes even more critical.
- *Mooring system:* A solid mooring system should be used to be able to ensure a steady base for providing the proposed services. When it is not possible to use a quay as to moor the facility, it should be able to use its own system. A 4-point mooring system would in this case be sufficient, given the fact that work will be executed in sheltered bays.

- *Critical paths of individual jobs:* The increase in the efficiency of the to be provided services comes mainly from the fact that more hours can be made on one day. This means that the relatively easy jobs that are to be performed at the proposed concept will be done quicker. An additional study should be done to find out the critical paths of the individual jobs to find out which path, or which combination of paths, might jeopardise this increase in efficiency. The (additional) machinery & installations that are required for the fastening up of the individual jobs are part of this study.
- *Side walls:* Several factors make side walls for the dock mandatory. To start, it prevents water and other environmental elements from coming in to the dock, both during transit and bad weather while conducting maintenance work. All floating dry docks have these features as well. One of the biggest reasons for side walls on the dock is the prevention of hazardous (for humans, other animals and the environment) particles exiting the dock. Grid material from cleaning the outer hull, paint particles, lubricants and oils are several examples. The flag state of the facility, local and international authorities and the company's own values require a certain maximum impact on the surroundings of the facility, which is easier to reach when side walls are included in the design.

The criteria listed above are individual elements of the conceptual design of the facility. Although this research does not have a ship design nature, listed the elements can not be done without involving the design spiral as presented by Evans [1959]. This design method is still used today and involved the most detrimental elements of a ship design. In this research, several have been discussed. The bigger part of the research involved the vessel/clients objectives, which is the most important factor in a feasibility study. Conclusions have been made on the stability and hydrostatics, although used for a different purpose than for real ship design. The Monte Carlo simulation has shown that the maximum initial investment to fit all the design criteria is 45 million Euro, and only in the unlikely situation that the desired occupational rate can be achieved in the Caribbean case study. A preliminary design study should be conducted to analyse if this is possible, where the conversion from an existing semi-submersible heavy lift vessel has the highest potential. Since only part of one spiral turn, the concept design phase, has been touched in this research, the total design spiral needs to be gone trough for further design research if wanted. Certain elements from this research can then be used in the first spiral turn to go through the spiral in a faster pace.

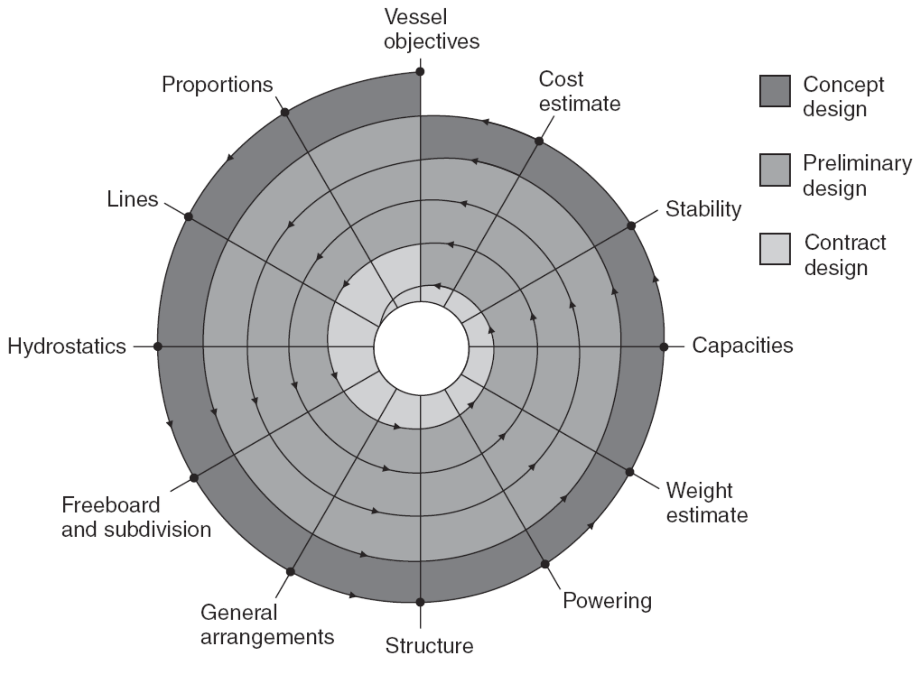


Figure 7.1: Ship design spiral as presented by Evans [1959].

Two additional methods for the maximization of the added value of the concept are given that might increase the chances of feasibility of the proposed concept. Firstly, two interviews have been conducted with representatives from two different classification societies to investigate the possibility of decreasing the cost for bringing in third parties in terms of conducting the special survey inspections from a remote location. Secondly, the thought process for the fabrication of a tool that maximizes the reduction in deviation time of future clients will be laid out.

7.2. Remote survey prospect

To minimize the direct cost of a project done at the MSRF, one of the options is to minimize the bringing in of third parties. Many (third) parties are absolutely necessary for the quality of the completion of a project, but trends are currently showing that work is being done to change the dependency on the physical presence of these parties. As seen in the working out of the different case studies in the previous chapters, the classification societies and the flag states play an important role in the event of the dry docking of a vessel required for the class renewal. The physical presence of a representative of at least one of these organizations is mandatory to execute a special survey. Because not all ships sail under the same flag state and/or the rules of the same classification society, it can occur that a new/different surveyor needs to be brought in on every individual project, causing for quite some extra cost. Remote survey work is the way to control these extra cost and to be able to sell a better service to future clients. Because this trend is currently far from actually being workable, it is included in this chapter. To discuss this trend and the possibility for it to replace current procedures, two people from inside the industry have been interviewed for a better understanding (see Table 7.1). The idea of remote surveys and the approach invented to propel this concept further will be described first, after which the answers from the experts will be given.

Table 7.1: Expert consultation for the understanding of remote surveys

Name	Function	Company
Richard Beckett	Survey Regulations & Procedures Manager	Lloyd's Register
Tore Torvbråten	Director of Class Development	DNV GL

Today, a surveyor employed by a class society needs to be on site to guide the renewal of a vessel's papers. Certain measurements, visual or physical depending on the age and status of the vessel, have to be carried out with the physical presence of these men or women. Without their approval, a vessel is not fit to legally sail the globe's oceans and rivers. The trend that is being seen under classification societies is that they are exploring the use of so called 'control rooms' where the class renewal events can be (partly) monitored from a remote location. This trend is fuelled by the advancing of the quality of the connectivity of vessels, the improvements in the usage of drones for all kinds of tasks and the taking over of the younger, more data/software driven, generation. Multiple classification societies are testing out different methods for taking over the general tasks that are involved in the class renewal event, and both Lloyd's Register and DNV GL are the leaders in this, explaining the choice for expert consultation. The approach invented that would exploit the improvements in the field of remote surveys for the increasing of the feasibility of the overall MSRF concept is to have one person on the facility licensed to do the survey work required while being in constant connection with a surveyor from the assigned classification society that works from the control room and is not present on the facility. This prevents the dependency on third party surveyors that need to be brought in while not giving in on the scope of work that can be executed in the dock. The answers of the experts on the following questions will be discussed next:

1. *What is the current state of remote classification work?*

2. *What is needed to exclude the physical presence of a class surveyor at the yard? And how long will it take to achieve this?*

3. *Will it be possible to have one dedicated person available at the yard to work with multiple classification societies?*

4. *What is the role of the flag states in this approach?*

The current state of remote survey work by classification societies is still in the early days. It is trailing remote work done by engine manufacturers for example, who are more and more operating from a control room outside of the vessel itself. Their physical presence is less needed and this is an example that we should follow [Torvbråten, 2018]. Class societies are actively engaged in exploring the use of remote inspection techniques, such as drones, to perform the survey of ship's structure. This not only includes a visual inspection but also thickness measurements, in spaces such as cargo tanks, where data is fed live to the operator or stored for analysis afterwards. For this and the entire class renewal process, the physical presence of the surveyor is still needed however.

The second question can be answered in two fold. The first step is to have the hardware and software ready to do the job. The technology exists to undertake remote surveys however classification societies recognise that a key requirement is to assess the capability of remote inspection equipment to confirm that it is capable of accessing all required survey areas and is capable of finding the specified defect types. To do this some classification societies are developing test standards against which equipment can be tested and certified. This will be an essential step towards gaining acceptance of remote survey by the regulatory authorities, which is the second step [Beckett, 2018]. The technology and the software needed is not still far from being able to confidentially executing thickness measurements. The current way of doing things is by building a scaffold inside the cargo tanks and manually operating the measurement systems. Doing it such it is possible to check hard to reach places for the thickness of the steel, this is something that a drone is currently not yet able to do. Since the technology is advancing in a rapid pace, the future will probably show that a drone can reach certain places when the development is in place. Even when this is possible, the connection to the operator, or in the perfect situation the surveyor that is in a control room, should be proper enough as well. Apart from the hardware needed, this depends on the location of the vessel as well. Due to the fact that by using a drone to do such work decreases, eliminates in the perfect future, the risk for surveyors, the developments in the fields of connectivity, ability to reach all places and the capability of detecting cracks will keep going [Beckett, 2018]. Secondly, and preferably alongside the first step, is the developments of regulations that approve such new techniques [Torvbråten, 2018]. This all starts with the acceptance of the industry and the International Maritime Organization, where the latter has the final saying. Proofing the ability of remote surveys to be as good or even better as the current standard should engage a movement inside regulatory organizations to work out new rules that accept these future techniques. A chance in the regulations can off course only happen when the technology improves enough. A start can be made with the class renewals of younger vessels, since the thickness measurements on these ships is less extensive than for their older sisters [Beckett, 2018].

When all the above is realized, the next step would be to license a dedicated person on board for the communication with the surveyor of the specific class society managing the vessel in dock. Even when for example a drone is accepted as a proper tool for testing, having one person licensed to do the work for all class societies will be a harsh next step. Not only because it is highly specialized work, also the entire industry will be turned around in such a way. If cost can be cut for the clients, safety of all people can be improved and the quality of the surveys will not be harmed, there might be a chance of success. It will however take some years and a consistent development to realize.

Classification societies do their work on behalf of flag states as recognized organisations. Under the rules and regulations set by the International Maritime Organization, the flag states have the final saying. The opinion of the flag states will have to chance as well. They should be involved from the very beginning to get this plan to success [Torvbråten, 2018].

To conclude, the trend of remote surveys is one that should be kept. When the technology and regulations are both in place, it could change the way the survey industry will work. Because such cost are mostly directly charged to the clients without any role for the shipyard, an advantage can be taken if the mobile facility is the first to participate in this new venture. The skipping of the cost will not directly be seen in the cost picture of a project, but it can be an advantage when the client makes up the total budget for the needed repairs and maintenance.

7.3. Maximization of deviation days reduction

For the purpose of clarity, both figures (Vessel density map and global shiprepair yard locations) from the beginning of the previous chapter will be repeated below. The text accompanying the figures refers to further research that can be done for the establishing of the best location for the deployment of the proposed concept. Due to the limitations in both time and scope, this research will not be part of this report. Recommendations can however be given that would increase the possibility of the feasibility of a Mobile Shiprepair Facility. The data that provides the vessel density map seen in Figure 7.2 can together with data on the location and facilities of the global shiprepair facilities be used supply vital information on the most profitable area and location for deployment. How this can be done will be described here. The vessel density data is provided in the amount of vessels that have been counted in a specific area of the world. The size of this area has been determined by Professor Lin Wu and is owned by her in an even smaller resolution than can be seen in the figure below. The type of vessels that have been counted is available as well, aiding in the possibilities. With the knowledge of the periodicity of the mandatory surveys that need to be conducted, the demand for dry docking services per area can be determined. This alone can already provide extremely useful information, but the combination with shiprepair yard data makes is even better. Many websites (of which www.shiptoyard.com is the most suitable, especially their online database) store information of yards, including the dimension of their docks, lifting capacity, services and location. This information can be seen as the supply of repair services that wants to serve the above mentioned demand. Because one of the business cases of the MSRF is the reduction of deviation days for possible clients, the best location for deployment would then be there where the reduction in deviation days is maximum. These calculations would require the use of a software package that is capable of performing this, because every location should be checked for the demand, supply and ultimately the reduction in deviation days.

Although the results from the research have shown that the amount of reduced deviation days does not have an extremely large influence on the added value of the concept, it is believed that this investigation will cause a shift in the amount of money that can be made. This means that the minimal occupational rate becomes lower and the probability to earn grows. If done correct, all small changes might bring the end verdict around.

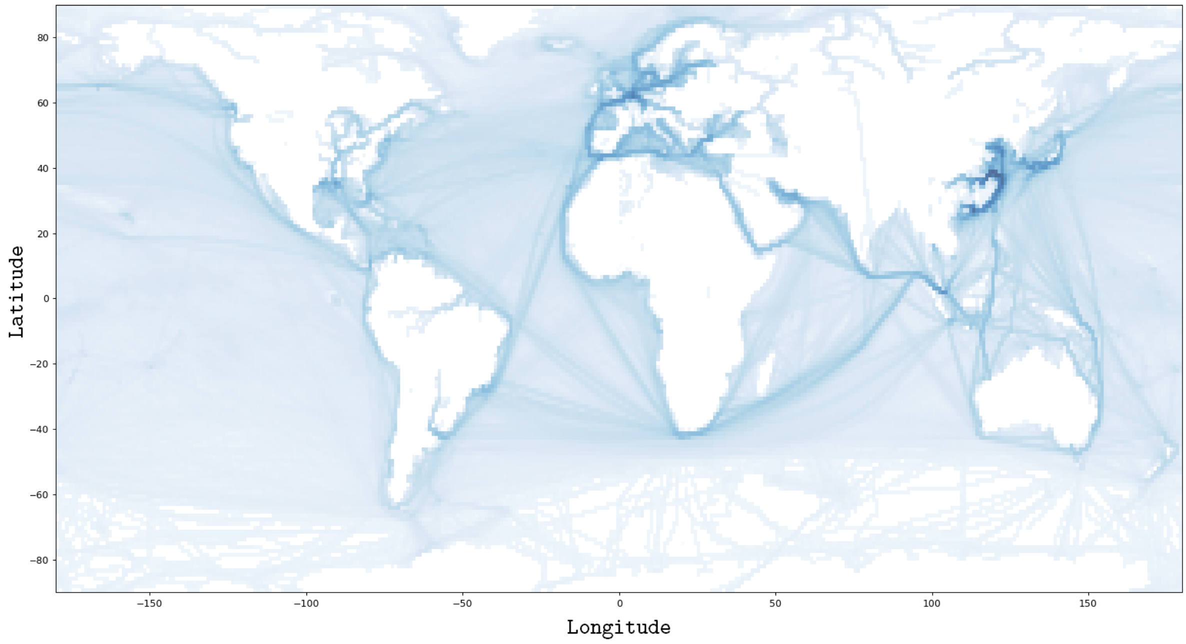


Figure 7.2: Global vessel density, 2014
Source: Graph made by author, data gathered from a contribution with [Wu et al., 2016]

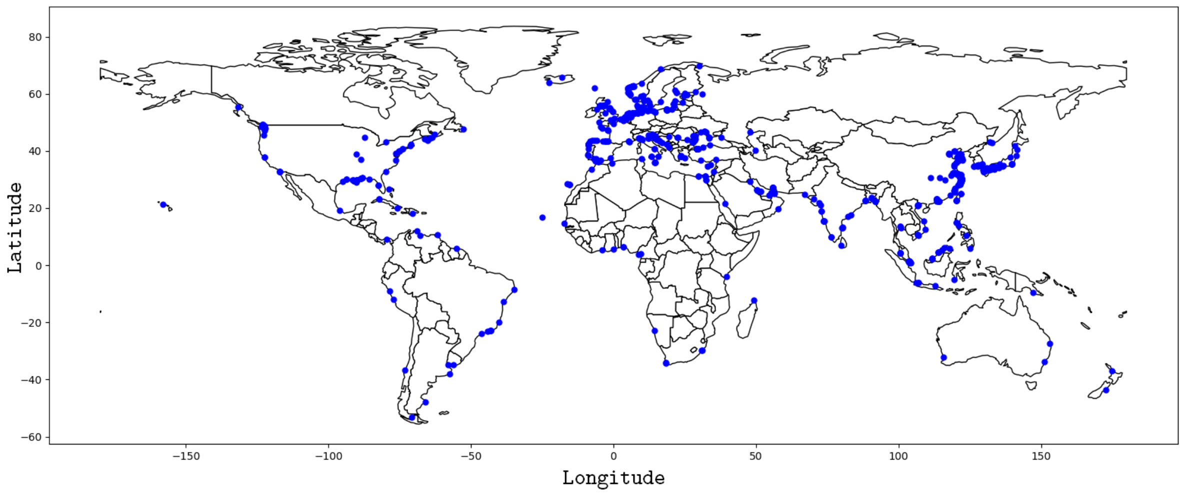


Figure 7.3: Global shiprepair yard locations
Source: Graph made by author, data gathered from a contribution with www.trusteddocks.com

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A

Technical Information Wagenborg floatel

ROYAL WAGENBORG

FLOATEL

Welcome to Royal Wagenborg

Whatever transport is important to your business: Royal Wagenborg has been looking for the most intelligent and reliable transport solutions for more than a century. Royal Wagenborg finds them with committed people and state of the art equipment. Wagenborg, a sign of solutions since 1898.

VERDI

Wagenborg Offshore owns and operates several accommodation floatels with comfortable cabins, together with recreational spaces, offices, workstations and meeting rooms. All floatels are suited for duty in sheltered waters, ideally moored alongside berth or quay.

The floatel "Verdi" has an accommodation capacity of 80 cabins and can be used in a single, double or quadruple person per cabin configuration.

"Verdi" can potentially be used at:

- onshore and offshore oil, gas and LNG construction sites
- projects with changing accommodation requirements
- project management accommodation
- Staff accommodation housing
- refugee accommodation

"Verdi" is fully compliant with the applicable marine regulations and meets the oil & gas safety standards.

ROYAL WAGENBORG

Wagenborg Offshore

As an international offshore specialist and with many years of experience in the global oil and gas transport business, Wagenborg Offshore has committed professionals at its heart, carrying out complex logistic projects worldwide.

Wagenborg Offshore is a specialist in shallow water transport and has been operating in the Caspian Sea for decades with its dedicated vessels. The company also has vast experience and knowledge of ice navigation in Baltic and Scandinavian waters.

Wagenborg Offshore has state-of-the-art equipment and technologies that comply with the highest quality industry standards.

Our floatels

Bellini	320 PoB
Debussy	290 PoB
Kurmangazy	316 PoB
Puccini	300 PoB
Ravel	286 PoB
Rossini	440 PoB
Verdi	320 PoB
Vivaldi	600 PoB

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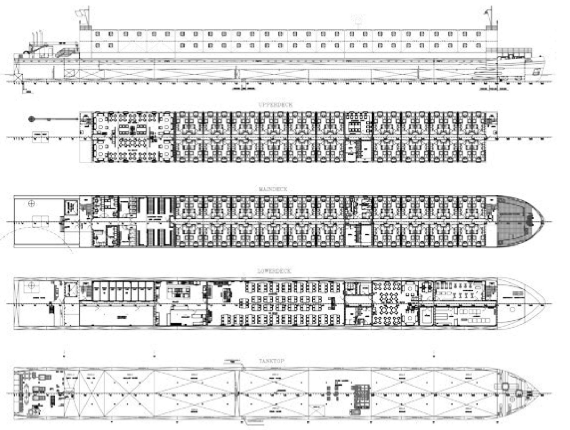


GENERAL

Call sign	UNAH
Yard	De Hoop, Lobith
Year	2009
Classification	BV, || HULL . MACH Special service/Accommodation Barge-no propulsion/Sheltered area SHELTERED AREA (OFFSHORE SHELTERED ENCLOSURES-CASPIAN SHELF, Hs MAX 0.5mts)
Flag	Republic of Kazakhstan

DIMENSIONS

Length overall	116,50	meters
Length B.P	116,15	meters
Breadth over all	11,45	meters
Breadth (moulded)	11,40	meters
Depth (moulded)	4,25	meters
Draught	2,50	meters
Height main deck	4,28	meters
Deadweight	1.866	ton
Gross Tonnage	3.593	ton
Nett Tonnage	1.441	ton
Light ship	1.993	ton

CAPACITIES

Fuel oil bunkers	119,40	m^3
Fresh water tank	305,70	m^3
Sewage tanks	914,90	m^3
Dirty water tank	59,20	m^3
Water ballast tank	260,00	m^3
Watermakers	5 x 12,5	tons/day at degrees

ACCOMMODATION

Complement	320 persons
Cabins	80 cabins
Other facilities	Two laundries, internet room, cold/dry store, freezer, messroom, reception, offices, gymnasium, 3 changing rooms, incinerator, hospital, bar, pub, galley

HEAT/COLD SYSTEM

HVAC system inside the accomodation is designed for:

Summer:	outside +40C°/ 70% RH inside +27C°/ 50% RH
Winter:	outside -36C° inside +18C°

MACHINERY / PERFORMANCE

Main Diesel Gen.	3 x Engines, Scania CV AB , Model D11655M, Test D2, Rated Power (kW) and Speed (rpm) 426/1500 each

DELIVERY RATES

Fuel oil:	4.0bar/ 4" TODO only receive
Sewage:	50 m^3/hr @ 3.0 bar/ 4" TODO
Freshwater:	20 m^3/hr @3.0 bar/ 3" TODO
Fire pump:	30 m^3/hr

DECK EQUIPMENT

Aft Deck	Capstan aft deck with anchor
Deck crane	10 ton @ 10m,
Fore Deck	Windless fore deck with anchors

SAFETY EQUIPMENT

4 x Life rings
320 Life jackets

ELECTRONICS

1x AIS
3x Portable radio GMDSS
2x Mobil radio VHF
1x EPRIB
5x Portable radio VHF
1x Inmarsat C

ENVIRONMENTAL

H2S Gas detection on board
Zero dumping provisions

Particulars believed to be correct, but not guaranteed.

FLOATEL

A cost effective choice

Our floating hotel "Verdi" has a shallow draught and can be used to accommodate personnel on projects in more remote area's or where existing shore accommodation is not available due to economic or safety reasons. Having accommodation close to a working area of construction site is essential keep costs within budget in large scale projects. Deploying our comfortable floating hotel close to an onshore or offshore working area means more productive hours and less travelling time for the workers. Moreover, "Verdi" has a minimal environmental impact and limited infrastructure requirements.

Comfortable accommodation facilities

Good personnel is hard to find and comfortable accommodation facilities with adequate recreational facilities is paramount. All cabins are fully air conditioned with bathroom, lockers, desk and chair. "Verdi" has a structured cabling system installed with internet, telephone and television. Further a restaurant with quality catering, bar, recreation rooms, gymnasium and laundry facilities are available to all guests on board. Office facilities and meeting rooms complete the facilities.

EXTERIOUR DESIGN

DECK CRANE

V-SAT

CABIN INTERIOUR

OFFICES

CHANGING ROOM

MESSROOM

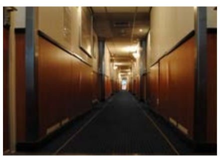
LAUNDRY

RECREATION ROOM

GYMNASIUM

GALLEY

HALLWAY



Photos as shown above can differ from reality, since these are taken from multiple floatels

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B

Technical Information of FCS 2610

FAST CREW SUPPLIER 2610
STANDARD

GENERAL

Hull materials	Aluminium
Superstructure	Aluminium
Basic functions	Crew and cargo duties
Classification	Bureau Veritas I ✠ Hull • MACH Light Ship / Fast Utility Vessel Sea Area 3

DIMENSIONS

Length overall	26.3 m
Beam overall	10.3 m
Depth at sides	3.7 m
Draught	2.4 m
Deadweight	20.0 t
Cargo deck area	100.0 m²
Deck load	1.5 t/m²
Crew	Up to 4 persons
(Industrial) personnel	Up to 12 persons

TANK CAPACITIES

Fuel oil	14.2 m³
Fuel trim	8.0 m³
Fresh water	1.8 m³
Sewage	0.9 m³
Bilge water/ dirty oil	0.4 m³

PERFORMANCES

Speed	Up to 25.0 kn
Range at max. speed	700 nm

PROPULSION SYSTEM

Main engines	2x Caterpillar C32 TTA
Total Power	Up to 1790 bkW
Gearboxes	2x Reintjes ZWVS series (two speed)
Propulsion	2x Fixed-pitch propellers
Bow Thrusters	2x 50 kW hydraulically driven

ELECTRICAL EQUIPMENT

Network	24V d.c. 230/400V 50 Hz. a.c
Generator sets	2x 22.5 ekW-28.0 kVA

DECK LAY-OUT

Anchor equipment	1x 150 kg HHP Pool TW
Fendering	Rubber "D" type and heavy duty foam fender
Anchor winch	Electrically driven

SHIP SYSTEMS

General service pump	2x electrically driven
Fuel trim system	1x 2800 l/hr at 4 bar
Engine room ventilation	8.000 m³/hr in each engine room
Fire extinguishing	Hand operated fire extinguishers Fixed Fi-Fi system in engine room (Novec 1230)

ACCOMMODATION

Below main deck	store
Main deck	12 seats, navigation console, crew cabins, wet gear room, pantry and toilet
Air conditioning	Up to 70.000 BTU/hr

NAUTICAL AND COMMUNICATION EQUIPMENT

Searchlight	1x
Radar	1x X-band
AIS	1x
Compass	1x Magnetic, 1x GPS
Autopilot	1x
Echo sounder	1x
Internal communications	Intercom and loudhailer
External communications	GMDSS A2
Weather system	1x

OPTIONAL

Flag	MCA, BG Verkehr, DMA, ILT
Moonpool	
Deck crane	Up to 5 tonm
Diving rescue platform system	
Rescue zone	
Rescue cradle	
Zero step boarding	
Fuel cargo pump	
Extra crew cabins for 2 persons	
Second searchlight	
Second radar	
ECDIS	
Chart plotter	
DGPS	
Satellite data communication	
External communication GMDSS A3	
Fleet broadband / V-SAT	
Wi-fi system	
CCTV	

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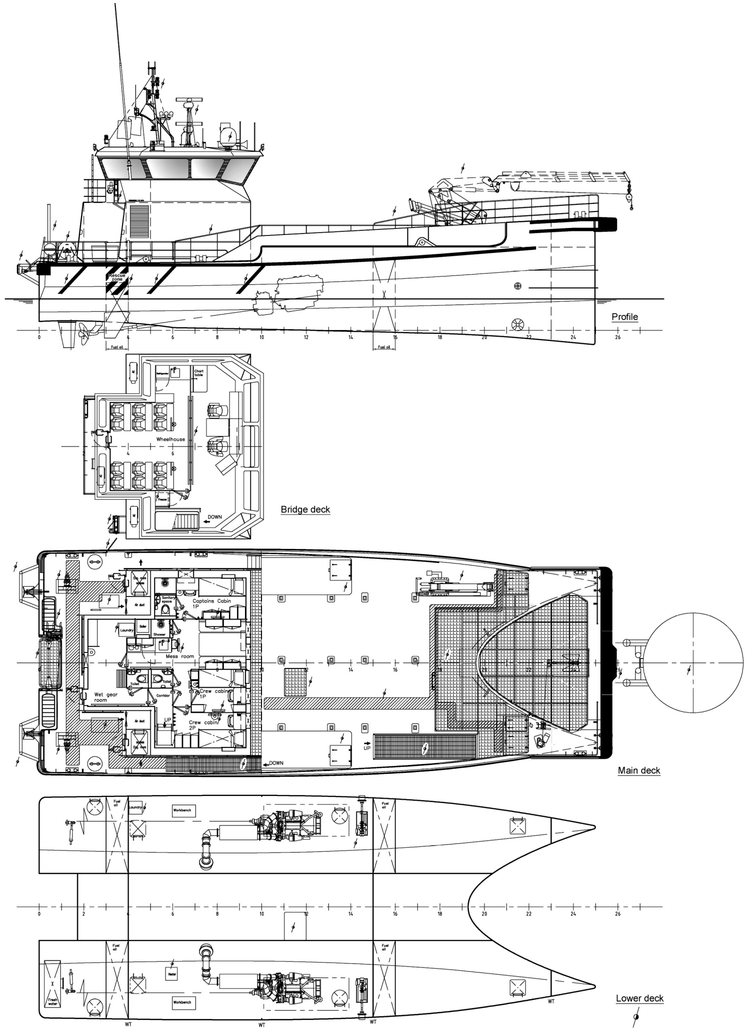
FAST CREW SUPPLIER 2610
STANDARD



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Items marked with ⌀ are optional equipment

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November, 2017

C
Technical Information of Stan Tug 2608

STAN TUG 2608

"BAT"

GENERAL

Yard number	509856
Delivery date	July 2017
Basic functions	Towing, mooring and fire-fighting operations
Classification	Bureau Veritas I ✠ HULL ● MACH Tug Unrestricted Navigation
Flag	Italy
Owner	Ocean S.r.l.

DIMENSIONS

Length overall	26.16 m
Beam overall	8.54 m
Depth at sides	4.05 m
Draught aft	3.90 m
Displacement (98% consumables)	385 t

TANK CAPACITIES

Fuel oil	76.2 m^3
Fresh water	12.3 m^3
Sewage	1.8 m^3
Bilge water	2.3 m^3
Foam	5.9 m^3
Dirty oil	1.9 m^3
Lubrication oil	1.9 m^3

PERFORMANCES

Bollard pull	45.3 t
Speed	12.6 kn

PROPULSION SYSTEM

Main engines	2x Caterpillar 3512C TA/C
Total power	2460 bkW (3300 bhp) at 1800 rpm
Gearbox	Reintjes WAF 675L / 7.476:1
Propulsion	2x Kaplan II Promarin fixed pitch 2350 mm diameter
Nozzles	Van de Giessen "Optima" type with stainless steel innerrings
Steering gear	Powered hydraulic 2x 45º + rudder indicator
Forced ventilation	40.000 m^3/h

AUXILIARY EQUIPMENT

Generator set	2x Caterpillar C4.4T 230/400 V, 64.5 kVA, 50 Hz
Bilge pumps	2x Sterling SIHI AKHA 5101 each 20 m^3/h
Fuel oil pumps	2x Sterling SIHI AOHA 3101 each 4.5 m^3/h
Cooling system	Closed cooling system
Sewage pump	Libellula L1-3H 6.6 m^3/h
Fuel oil purifier	Westfalia OTC 2-02-137
Fresh water pressure set	HBK 110 / Sterling AOHA 1202
Fifi set	Diesel driven 600 m^3/h
Fifi monitors	2x 300 m^3/h, water/foam

DECK LAY-OUT

Anchors	2x 270 kg Pool (High Holding Power)
Chain	Total 247.5 m, 17.5 mm diameter U2
Anchor winch	Electrically driven 10 m/min
Towing winch	Hydraulically driven winch with warping head and spooling device, pull 20 ton at 10 m/min, slack rope speed up to 30 m/min, 125 ton brake
Towing hook	Mampaey disc type, 65 ton
Life raft	2x fitted on each side of the bridge deck
Rescue boat	1x 4-meter inflatable rescue boat with 25 hp outboard engine

ACCOMMODATION

Air-conditioned accommodation for 8 persons, completely insulated and finished with modern linings, acoustical ceiling in the wheelhouse and floating floors. With a captain's cabin, chief engineer's cabin, three double crew cabins, galley, mess/dayroom and sanitary facilities.

NAUTICAL AND COMMUNICATION EQUIPMENT

Searchlight	Pesch 100 W
Radar system	Furuno FAR 2117
Magnetic compass	Cassens & Plath, Kotter type
GPS	Furuno GP-150
Echosounder	Furuno FE-800
VHF	2x Sailor Compact 6222, 25 W with DSC
Intercom	8 stations incl. fore and aft deck
Emergency telegraph	Eekels TG-1
Autopilot	Simrad AP-70
Navtex	Furuno NX-700A
AIS	Furuno FA-150
EPIRB	Jotron Tron-40S
Sart	Jotron Transart 20

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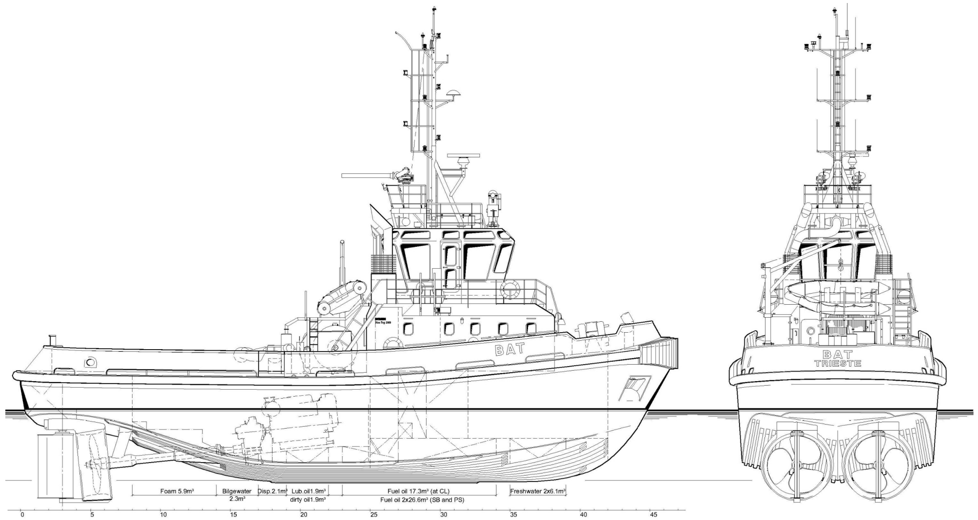
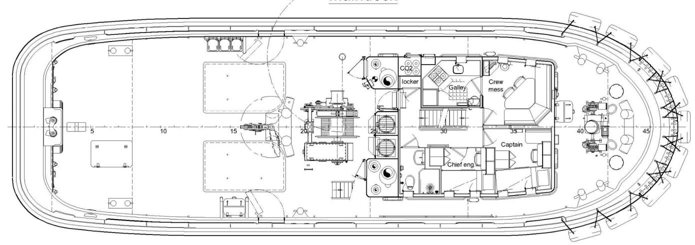
STAN TUG 2608

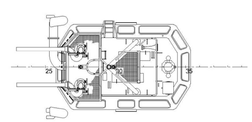
"BAT"



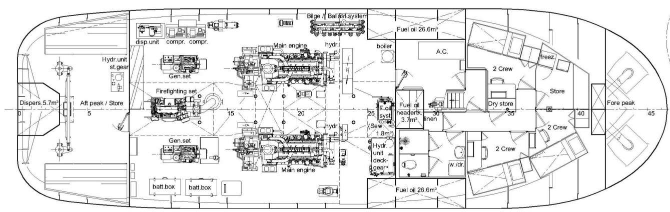
Maindeck



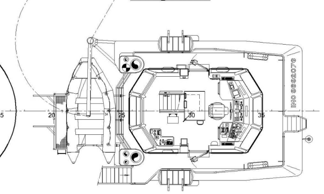
Topdeck



Below Maindeck



Bridgedeck



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D

Technical Information of Stan Tug 3011

STAN TUG 3011
STOCK

PICTURE OF SIMILAR VESSEL

GENERAL

Yard number	511804
Basic functions	Towing, mooring and Ø fire-fighting operations
Classification	Lloyd's Register ✠ 100 A1 Tug [✠] LMC UMS Ø Lloyd's Register ✠ 100 A1 Tug [✠] LMC UMS Fire Fighting Ship 1 Ø Lloyd's Register ✠ 100 A1 Tug [✠] LMC UMS Fire Fighting Ship 1 incl. Water Spray
Painting	Epoxy paint system

DIMENSIONS

Length overall	30.66 m
Beam overall	11.13 m
Depth at sides	4.60 m
Draught aft	4.80 m

TANK CAPACITIES

Fuel oil	162.0 m³
Fresh water	16.6 m³
Ø Foam	11.3 m³
Ø Dispersant	3.8 m³
Sewage	4.6 m³
Lubrication oil (clean)	3.4 m³
Lubrication oil (dirty)	2.6 m³
Bilge water	3.8 m³
Sludge	2.6 m³

PERFORMANCES

Bollard pull ahead	67.8 t
Speed	12.5 kn

PROPULSION SYSTEM

Main engines	2x Caterpillar 3516C TA HD/C
Total power	3730 bkW (5000 bhp) at 1600 rpm
Gearboxes	2x Reintjes WAF 873 / 7.526:1
Propeller	2x Kaplan II fixed pitch
Nozzles	2x 2800 mm Van de Giessen "Optima"
Ø Bow thruster	620 mm, 99 kW hydraulic

AUXILIARY EQUIPMENT

Main generator sets	2x Caterpillar C6.6 TA, 230/400 V, 125 kVA, 50 Hz
Bilge pumps	2x Sterling SIHI AKHA 6101
Fuel pumps	Sterling SIHI AKHA 5101 and AOHA 3101
Cooling system	Box cooling + anti-growth system
Fresh water pressure set	Fresh water Sterling HBK 111 / AOHA 3101
Ø Dispersant	Dispersant pumpset with 2 spraybooms
Ø Fifi set	Separate diesel driven pump, 600/1200/2400 m³/h
Ø Fifi monitors	2x 300 m³/h or 2x 600 m³/h or 2x 1200 m³/h water/foam

DECK LAY-OUT

Anchor	2x 495 kg Pool (High Holding Power)
Chain	302.5 m chain, 22 mm diameter, U2/Q2
Anchor winch	Electrically driven with warping head
Ø Aft towing winch	Hydraulically driven single drum two speed winch with warping head and spooling device, pull 35 ton at 9.2 m/min and reduced pull at 27 m/min and 150 ton brake
Ø Crane + winch	Heila HLM 20-3S, 1.7 ton at 10.60 m + MW 22 2150 kg
Ø Towing hook	Mampaey, disc type 70 ton
Stern roller	SWL 80 ton
Fendering	Rubber bow fender, W type block fender and D-fender at the sides

ACCOMMODATION

Air-conditioned accommodation for 10 persons, completely insulated and finished with durable modern linings, acoustical ceiling in the wheelhouse and floating floors. Captain's cabin, chief engineer's cabin and four double crew cabins, galley, mess/dayroom and sanitary facilities.

NAUTICAL AND COMMUNICATION EQUIPMENT

Searchlight	Pesch 1000 W
Ø Searchlight (FIFI 1)	2x Pesch 450 W Xenon
Radar system	Furuno FAR-2117
Compass	Magnetic Kotter type
Autopilot	Simrad AP-70
GPS	Furuno GP-170
Echosounder	Furuno LS-6100
Speedlog	Furuno DS-80
VHF	2x Sailor 6222, 25 W
Ø SSB	Furuno FS-1575
Navtex	Furuno NX-700
AIS	Furuno FA-150
Ø Inmarsat	2x Furuno Felcom 18, 1x with LRIT
EPIRB	Jotron Tron-60S
Sart	Jotron Tronsart20
Ø Anemometer	Obsermet OMC 115

Ø = Optional equipment

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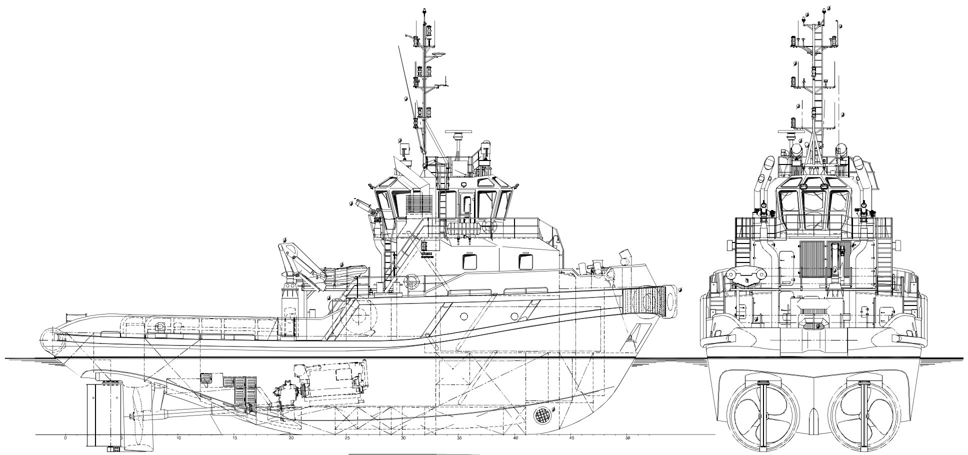
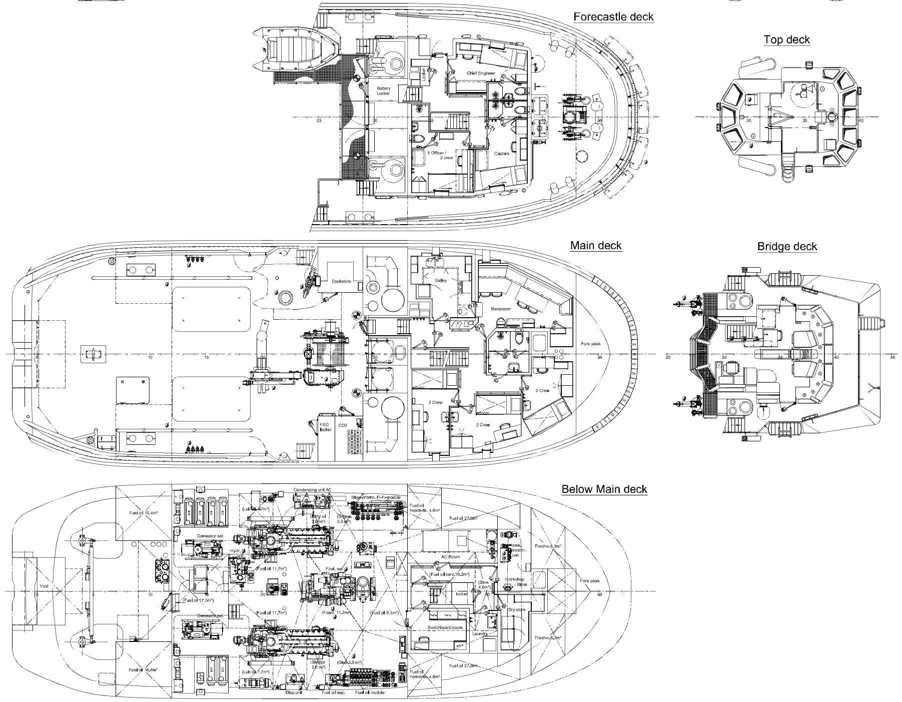
STAN TUG 3011
STOCK





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E

Technical Information of ST-Class Rolldock

TECHNICAL SPECIFICATION "ST"-CLASS

MULTIFUNCTIONAL HEAVY LIFT TRANSPORT VESSEL

FLOAT-IN FLOAT-OUT / ROLL-ON ROLL-OFF / LIFT-ON LIFT-OFF

ROLLDOCK

Together We know how

DOCK TYPE SEMI-SUBMERSIBLE MULTIFUNCTIONAL HEAVY TRANSPORT VESSEL "ST" CLASS

ROLLDOCK STAR
ROLLDOCK STORM

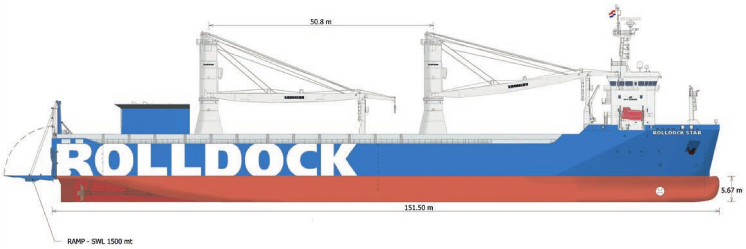
(all details abt. & w.o.g.)

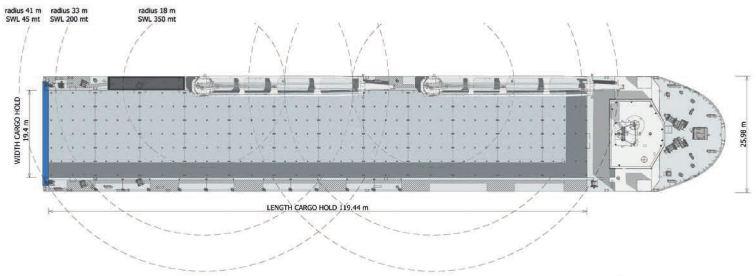
Type:	Dock type Semi-submersible Multifunctional Heavy Transport vessel Float-in Float-out / Roll-on Roll-off / Lift-on Lift-off
Flag:	Dutch
Class:	GL + 100A5 E2 BWM (ice class E2) Semi-submersible heavy lift ro-ro multi purpose dry cargo ship, strengthened for heavy cargo Classed as 'open vessel'
Design speed:	17 kts
Length o.a.:	151.50 m
Length b.p.p.:	145.04 m
Beam:	25.40 m
Draft Max (summer):	5.67 m
Draft Min (shallow draft):	4.50 m
Deadweight:	~ 9,000 mt (without hatch covers on board) ~ 8,000 mt (with hatch covers on board)
Depth to main deck:	5.90 m
Submerged draft of vessel:	12.50 m
Submerged draft in hold:	6.60 m
1 hold fully box shaped/dims.:	119.44 x 19.40 x 8.10 m
Hold capacity:	~ 18,768 cbm
Accommodation:	32 persons

Weather deck plus Ro-Ro stern ramp adjustable in 6 positions serving various quay heights for operations with exceptional loads. The Ro-Ro ramp is also removable to accommodate oversized cargo(s).

Ro-Ro Stern Ramp	
Dimensions:	19.40 x 9.50 m (excluding 2 m flaps)
Capacity:	Allowing Ro-Ro cargo upto 4,500 mt unit weight depending on cargo configuration
Deck (tank top) strength:	12 mt/m²
Hatch covers:	7 mt/m² without support (can be increased with support)
Cranes (Liebherr):	2 x 350 mt (combi 700 mt)
Outreach cranes - Main hoist:	350 mt @ 18 m & 200 mt @ 33 m
Aux. hoist:	45 mt @ 41 m
Main engines:	2 x MAK 9M32 / 9,000 kW installed power
Propulsion:	2 variable pitch propellors, 2 rudders
Auxiliary engines:	2x Caterpillar C32 / 1,140 kVA
Bow thruster:	Schottel 1,200 kW FP freq. contr.

SHIP OVERVIEW





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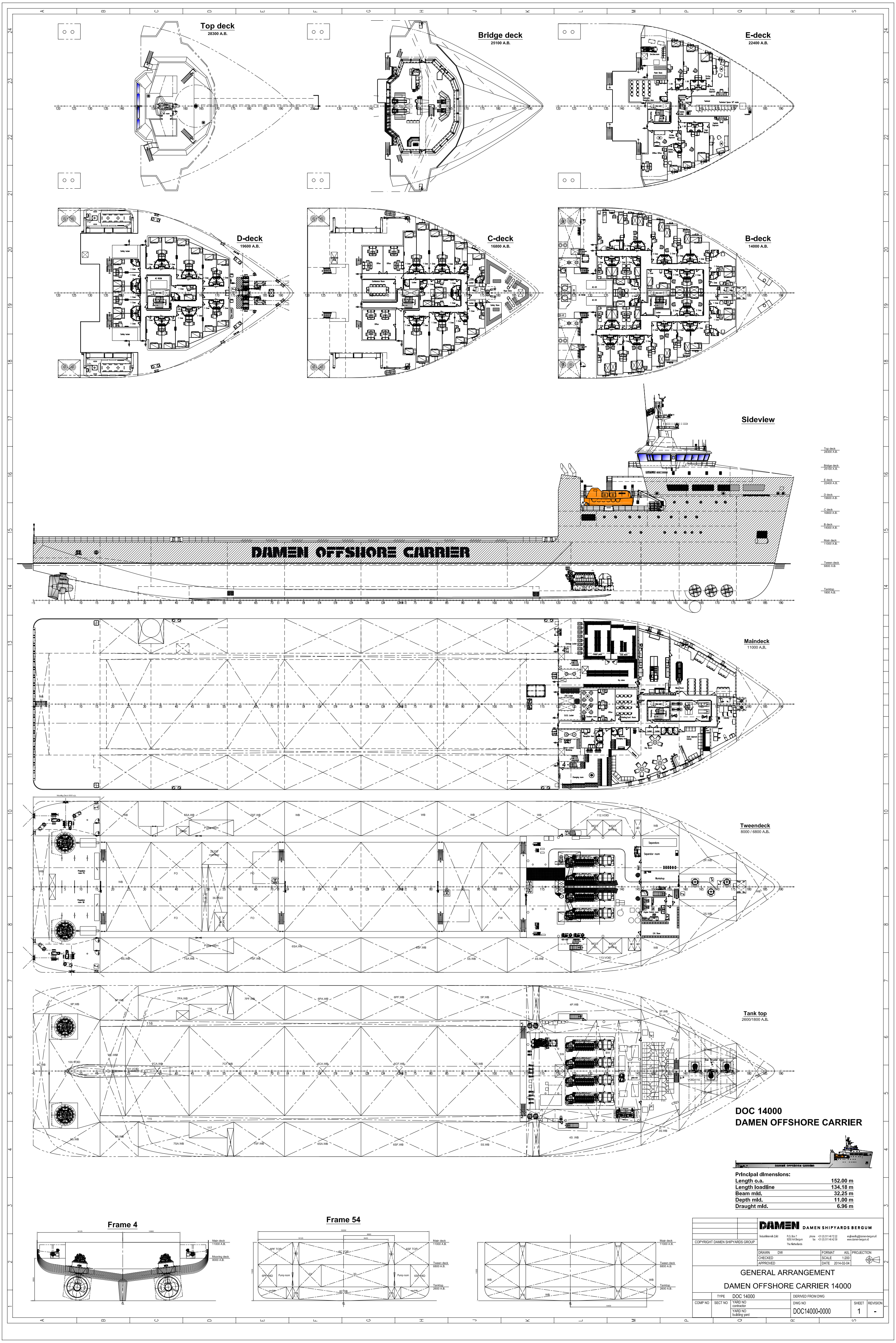
F

Technical Information of Damen Offshore Carrier 14000


Top deck
28300 A.B.
Bridge deck
25100 A.B.
E-deck
22400 A.B.
D-deck
19600 A.B.
C-deck
16800 A.B.
B-deck
14000 A.B.
Sideview
DAMEN OFFSHORE CARRIER
Maindeck
11000 A.B.
Tweendeck
8000 / 6800 A.B.
Tank top
2600/1800 A.B.
Frame 4
Frame 54
DOC 14000
DAMEN OFFSHORE CARRIER
Principal dimensions:
Length o.a. 152.00 m
Length loadline 134.18 m
Beam mld. 32.25 m
Depth mld. 11.00 m
Draught mld. 6.96 m
DAMEN DAMEN SHIPYARDS BERGUM
Industrieterrein Zuid
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www.damen-bergum.nl
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DRAWN DW
CHECKED
APPROVED
FORMAT A0L
SCALE 1:200
DATE 2014-02-04
PROJECTION
GENERAL ARRANGEMENT
DAMEN OFFSHORE CARRIER 14000
TYPE DOC 14000
DERIVED FROM DWG
COMP NO
SECT NO
YARD NO contractor
YARD NO building yard
DWG NO DOC14000-0000
SHEET 1
REVISION -

G

Technical Information of DG Jack-up 14380

DG JACK 14350 P
STANDARD

GENERAL

Design	In partnership with GustoMSC
Basic functions	Offshore Wind installation Oil & Gas drilling Oil & Gas well intervention / P&A Oil & Gas maintenance Accommodation
Classification	ABS ✠ A1 Self Elevating Unit, ✠ AMS, ✠ ACCU, ✠ CRC DNVGL: ✠ 1A1 Self Elevating Unit, ✠ E0, ✠ CRANE-Offshore

DIMENSIONS

Length overall	152.5 m
Length on main deck	142 m
Beam moulded	50 m
Depth moulded	11 m
Draught	6.5 m
Leg length	109 m
Variable load	9600
Cargo deck area	4600 m^2
Deck load	10 t/m^2

TANK CAPACITIES

Fuel oil (service)	1300 m^3
Potable water (service)	600 m^3
Sewage	200 m^3

PERFORMANCES

Speed	11 kn
Designed for survival	
High number of jacking cycles	
Frequent jacking	

ELEVATED SURVIVAL CONDITIONS (ABS & SNAME)

Water depth SWL	50 m	65 m
Airgap	12.0 m	10 m
Max wave height	16.0 m	13.0 m
Wind speed	40 m/s	37 m
Surface current	1.0 m/s	1.0 m/s

JACKING SYSTEM

Type	GMSC fixed, opposed Rack & Pinion
Pre load	14000 t
Jacking speed (hull)	0.2 - 0.8 m/min (step less)
Leg handling speed	0.2 - 1.2 m/min (step less)

PROPULSION SYSTEM

Main engines	Diesel electric, 6.6 kV, 60 Hz
Propulsion Power	3x electric motors aft of 3500kW each 3x electric motors fwd of 3000kW each
Azimuthing thrusters	3x 3.5 m FP in Nozzle aft 2x 3.1 m FP retractable fwd
Tunnel bow thruster	1x 3.1 m FP 3000kW

AUXILIARY EQUIPMENT

Grid	6.6 kV, 690 V, 440 V, 230 V 60Hz
Main generator sets	6x 3400 kW
Emerg. generator sets	1000 kW

DECK LAY-OUT

Anchor mooring winch	HHP anchor
Main crane	Leg encircling Stiff lattice boom crane with foldable fly jib
Main hoist fly jib	1250 t at 33 m 148 m above deck
Main hoist main crane	2000 t at 35 m, 105 m above deck
Aux crane	30 t at 45 m
Store crane	
Fast rescue craft	
Life boats	2x 130 persons

ACCOMMODATION

Crew / industry personnel	130 persons
Facilities	130 persons
(Galley / mess, etc.)	

NAUTICAL AND COMMUNICATION EQUIPMENT

Radar systems
DP systems
GMDSS

DAMEN

DG JACK 14350 P
STANDARD

DAMEN

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11 July 2018

H

Port calls Caribbean Sea

Dominican Republic
AES Andres LNG Terminal
Amber Cove
Barahona
Boca Chica
Cabo Rojo
Caucedo
La Romana
Manzanillo
Palenque
Puerto Plata
Puerto Viejo de Azua
Rio Haina
Samana
San Pedra de Macoris
Sans Souci Passenger Terminal
Santa Domingo
Cuban Ports
Antilla
Banes
Baracoa
Cabanas
Casilda
Cienfuegos
Felton
Guantanamo
Guayabal
Havana
Manati
Mariel
Matanzas
Moa
Nicaro
Nueva Gerona
Nuevitasv Palo Alto
Puerto Padre
Santa Lucia
Santiago de Cuba
Vita

Trinidad & Tobago
Brighton
Chaguaramas
Claxton Bay
Cronstadt Island
Crown Point
Caleota Point
Caleota Point BP SBM
Point Fortin
Point Lisas Ports
Pointe-a-Pierre
Scarborough
Jamaica
Falmouth Port
Kingston
Lucea
Montego Bay
Montego Bay Anchorage A
Ocho Rios
Port Antonio Cruise Terminal
Port Esquivel
Port Kaiser
Port Rhoades
Port Royal
Rio Bueno
Rocky Point
Curacao
Willemstad
Mexico
Veracruz
Bahamas
Freeport
Panama
Colon
Puerto Rica
San Juan
Colombia
Cartagena
Costa Rica
Puerto Limon Anchorage

Cost breakdown of the DOC 14000 conversion example

DOC 14000 MSRF editie		

000	General costs + man hours	€ 5,300,147.00
100	shipbuilding (hull / outfitting)	€ 12,699,141.00
200	Main machinery	€ 110,500.00
300	Primary ship systems	€ 1,116,060.00
400	Electrical system	€ 1,733,000.00
500	Deck equipment	€ 1,070,000.00
600	Secondary ship systems	€ 81,250.00
700	Joinery / accomodation	€ 1,334,125.00
800	Nautical, navigation & communication	€ 48,023.00
900	special equipment	€ -

	Total, excl. Margin and Options	**€ 23,492,246.00**

	Coverages	
004	Coverage for procurement	€ 15,888.00
093	Warehouse (inbound)	€ 19,723.00
006	Warehouse (outbound) + Transport	€ 7,122.00

	Total, excl. Unforeseen & charges	**€ 23,534,979.00**

	Unforeseen & profit building yard	
001	Profit construction yard	€ 856,602.00
099	Unforeseen	€ 941,399.00
	Unforeseen	€ 323,246.00
099	Reservation for client spec.	€ -
099	Price esacalation components	€ -

	Total, excl. Charges	**€ 25,656,226.00**

	Charges	
092	Building insurance	€ 130,699.00
094	Guarantee expenses	€ 261,398.00
095	Research innovation fund	€ 65,350.00
098	Coverage small parts	€ 26,140.00

	Total in EURO per vessel	**€ 26,139,813.00**