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University of Stavanger

HALLIBURTON

Utilization of Specialized Vessel for Selective Offshore Services – A Feasibility Study

by
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15.06.2016

"Change is the law of life. And those who look only to the past or present are certain to miss the future."

- John F. Kennedy

Preface

With this thesis, I am finishing off my master´s degree within Industrial Economics at the University of Stavanger, building on my bachelor´s degree within Energy Technology from Høgskolen in Bergen.

Based on the areas of study mentioned above, I sought to write a thesis that could combine these fields of interest. That is, a thesis which ensured both a technical and economic perspective was of great motivation for me.

With some ideas in mind, I got in touch with Henry Magne Håkstad to discuss the opportunity of writing my thesis for Halliburton, resulting in an agreement of a thesis which was of interest for both parts. Hence, the thesis has been carried out in collaboration with Halliburton during the spring 2016.

The work contained in the thesis is the result of interaction with mentors, advisors and co-students. I would like to use this opportunity to thank all the people who have guided and aided me in my work and provided valuable input during the conduction of this thesis. Firstly, a great thank you goes to my main mentor in Halliburton, Henry Magne Håkstad, for the opportunity of writing this thesis. Also, I would like to thank him for his commitment towards the thesis, and for all the support he has provided me with along the way. Secondly, I would like to thank Martin Toft, Per Magnus Skretting, and Mario Roberto Freitas, all employed in Halliburton, for their good help through my work. Finally, a great thanks goes to my faculty supervisor at University of Stavanger, Atle Øglend, who has been of good help during these months.

Stavanger, June 2016.

Abstract

This master´s thesis is based on a case study with the main objective of evaluating the feasibility of a new concept, and further to assess whether the concept may have been a preferred solution among customers.

The concept suggests that operations related to delivery of equipment to offshore installations in the North Sea, in addition to retrieval of waste from them, could be solely dependent on a specialized vessel. In order to determine the feasibility, both qualitative and quantitative analyzes have been conducted. The feasibility of the concept is dependent on technical aspects, as well as the amounts of equipment the vessel would have needed to supply to the various fields and the amounts of waste it would have needed to retrieve from them. Moreover, the desirability of the concept among customers is considered to depend on whether the concept can be deemed as better than solutions currently used, particularly in terms of efficiency.

More specifically, the idea of the concept is that the specialized vessel would work as a shared delivery and retrieval facility among the fields in the North Sea. Results revealed that the concept can be regarded as feasible, and that the specialized vessel may have replaced a number of the vessels currently being used to conduct these activities. Also, it was proven that it would utilize time more efficiently than currently used vessels.

Furthermore, the operators within the oil and gas sector may reduce their costs related to delivery and retrieval operations, if adopting the concept. The concept would also provide Halliburton with economic benefits, based on results revealing the concept to be profitable with high probability. In addition to benefits in terms of economy, both for potential customers and Halliburton, the concept could contribute to innovation within the oil and gas sector as the vessel would be able to prepare waste retrieved for a potential future treatment process onshore by fractioning during transportation.

Globally, no service company within the oil and gas sector offers a complete service as the one evaluated within this thesis, making Halliburton the only provider of such a service if initiating the concept. Based on this, it can be stated that the concept would have been a game changer – for Halliburton, as well as the operators.

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Definitions

Brine - A saline liquid normally used in completion operations.
Bulk – Shipping term used to describe transportation of wet or dry materials, respectively wet bulk or dry bulk.
Casing - Steel pipes that are assembled and inserted into sections of a borehole that has recently been drilled.
Cuttings - A mixture of rock particles that are contaminated by adherent drillings fluids.
Dissolved oil – Oil that is highly soluble in water.
Emulsion – A mixture of two non-mixable fluids (for example oil and water).
Offshore installation - Rigs and platforms.
Oil Based Mud – Drilling fluid based on oil.
Slop - All waste liquids that contain oil or chemicals generated on an offshore installation, with an oil content of more than 30 mg/l.
Slurry – A mixture of cuttings and a fluid, typically water.
Undissolved oil – Oil that is soluble in water to a limited extent.
Water Based Mud – Drilling fluid based on water.

Abbreviations

CST – Cuttings Storage Tank
CTT – Cuttings Transportation Tank
DP – Dynamic Positioning
HCB – Honey Comb Base tank
HSE – Health, Safety, Environment
IRR – Internal Rate of Return
NCS – Norwegian Continental Shelf
NPV – Net Present Value
NS – North Sea
OBM – Oil Based Mud
OSPAR – OSlo-PARis
OSV – Offshore Supply Vessel
PLONOR – Pose Little Or NO Risk
PSV – Platform Supply Vessel
SG – Specific Gravity
SWOT – Strengths, Weaknesses, Opportunities, Threats
THC – Total HydroCarbons
TOC – Total Organic Carbons
TPH - Total Petroleum Hydrocarbons
WACC – Weighted Average Cost of Capital
WBM – Water Based Mud

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I

PRESENTATION OF THESIS

1 Introduction and Motivation

1.1 About Halliburton

Halliburton is one of the world´s largest providers of products and services to organizations within the oil and gas industry, and is involved throughout all phases related to oil and gas extraction. Halliburton was founded in 1919, and established in Norway in 1966. The headquarter in Norway is located in Tananger.

In terms of this thesis, the Baroid department and the disciplines related to this is necessary to specify. The Baroid department´s core services are centered around the following:

- Waste Management Solutions.
- Drilling and Completion Fluid Solutions.
- Solids Control Equipment and Services.

1.2 Reason for Choice of Topic

As the focus on sustainability and the environment increases, the authorities put pressure on the oil and gas sector. For instance, stricter rules, regulations and requirements are implemented, in which companies within this sector have to adhere to. This concerns emissions related to discharge of drilling waste, among other things. Hence, it has become more important than ever for oil and gas companies, as well as service companies, to think a step ahead and prepare for the future situation.

Due to the environmental focus, the processes for how to handle drilling waste are constantly sought streamlined, typically by implementing better and more efficient treatment technologies. This causes an increasingly competitive market, as organizations within the sector of interest are basically forced to adopt the new and improved technology and solutions on a regular basis in order to be capable of competing in the market.

Moreover, such units can advantageously be improved and implemented. However, thinking outside the box and rather improve the concept of how drilling waste is handled may be an even more beneficial solution, both for the operators and for the environment. This can also be regarded as a part of Halliburton´s mission, i.e. to create sustainable value by delivering services and solutions to help their customers meet their technical and economic objectives in the exploitation of their energy resources. As a part of this, Halliburton´s Baroid department wishes to provide distinctive service quality within waste management services and solutions related to drilling operations.

Based on this, Halliburton is evaluating to introduce and offer the organizations within the oil and gas sector an “cradle-to-grave” concept for how to handle drilling waste. As there are no oil service companies that offers similar services as the concept to be evaluated, Halliburton seeks to be the first and only company providing such a complete service.

1.3 Presentation of Topic

Offshore activities require delivery of equipment and services needed for the various operations that take place on-site. In addition, retrieval of drilling waste generated at offshore installations and transportation of such waste to shore is required to a varying degree.

The thesis explores the possibility to offer operators within the oil and gas sector a new concept for handling drilling waste generated in the North Sea, and for delivery of necessary equipment to the area of interest. The evaluated concept is considered to be a possible future solution for how such activities may be carried out in the years to come.

In short, the concept evaluated concerns how drilling waste and disposal is handled, from the waste is generated and until it is delivered to a proper treatment facility onshore. More specifically, the concept addresses the process of retrieving and transporting the drilling waste from site to shore, in addition to delivery of necessary equipment to the various sites. Hence, the concept is based on the idea of Halliburton offering the operators in the North Sea a complete service related to delivery of various equipment, as well as retrieval of drilling waste.

The concept relies on using one specialized and dedicated vessel to conduct these activities. Thus, the vessel would be a shared facility for operators within the oil and gas sector, as it would provide its services at the various sites in need for it. Additionally, the concept enables the possibility of preparing drilling waste for a subsequent treatment process onshore, by fractioning during transportation.

1.4 Objectives

The main objective of the thesis is to evaluate whether a feasible solution for the new concept proposed exists, and if so, to determine the following objectives:

- If the concept could have been a preferred solution in the market, and what that may involve related to Halliburton`s market share.
- If the concept could be a positive contributor to Halliburton´s financial performance.

The objectives described above are the main decision criteria for Halliburton to decide whether to initiate the concept.

1.5 Refinements

The geographical area of interest in the first instance is the North Sea. Thus, the thesis will entail delivery of equipment to offshore installations in the North Sea, as well as retrieving and transportation of drilling waste generated, to onshore facilities. Other product supplies, such as base oil and dry bulk chemicals, will not be covered within this thesis.

Additionally, fractioning of drilling waste during transportation is evaluated as a preparation stage for a potential future treatment process onshore. However, as this thesis is founded on activities that occur offshore, it will delineate from such treatment processes.

The thesis disregards the commercial aspects related to delivery of waste onshore. That is, the revenues and expenses related to delivery of drilling waste to shore, and the revenues and expenses related to potential future treatment of the drilling waste, will not be discussed.

An intentional choice was made for the thesis to mainly cover the rigs and platforms that contributed to the delivered waste to Halliburton´s onshore facilities during the year 2015. Such a choice was made as those offshore installations reflect Halliburton´s current market situation, as well as the present necessity for retrieval of waste and delivery of equipment. Hence, a realistic perspective regarding the Halliburton´s present situation was obtained.

Furthermore, a selection of certain preferred rigs and platforms with limited geographic spread was not necessary to make. As a result, the credibility and reliability of the case increases. In order to assess what the situation may look like in the years to come was also assessed.

1.6 Disposition

This thesis is divided into five parts, each comprising one or several related sections. More specifically, the various parts comprise:

Part I

- Presentation of Thesis:
  Introduction and motivation of the thesis.

Part II

- Literature Study:
  Technical theory related to the thesis.
  Economic and market related theory related to the thesis.

Part III

- Approaches:
  Methodology used within the thesis.
  Analyzes and Results, both qualitative and quantitative.

Part IV

- Closure:
  Discussion of various analyzes and results.
  Conclusion of the thesis.
  Suggestions for Future Work on the thesis.

Part V

- Ending:
  Bibliography of the various references used within the thesis.
  Appendix of the most important analyzes and results.

1.7 Use of References and Footnotes

Part II consists of theory considered as essential knowledge for the reader, in order to get a good insight in the topic of the thesis and in order to understand the conducted analyzes. Hence, references have been linked to this theory.

In addition, part III is also partly based on theory. More specifically, as this part includes both qualitative and quantitative analyzes based on Halliburton´s internal data and documents, in addition to the personnel´s background knowledge, references have also been linked to various sections within this part.

Moreover, if a major part of the text within a paragraph is derived from a reference, this reference will be given in the end of the paragraph. If certain sentences have been obtained from a reference, the reference will be given after the specific sentence.

Footnotes are used throughout the entire thesis. These are used to inform about use of abbreviations, or where the author wishes to provide the reader supplementary information such as descriptions of terms and expressions.

II

LITERATURE STUDY

2 Technical Theory

Offshore activities require different types of equipment and services. Among other, there is a necessity for drilling and completion fluids, as well as casing, when drilling a well.

In addition to such equipment and materials needed to be supplied offshore, there is a need for retrieval of the masses that are generated from the boreholes during drilling and production. That is, several by-products that may harm the environment are generated during these operations. Such by-products are defined as drilling waste, which can be divided into three main components; base oil, water and solids. Hence, drilling waste comprises slop, cuttings, and discarded drilling and completion fluids. As these masses are considered hazardous waste, they cannot be treated together with household waste due to that they may cause serious pollution or involve risk of injury to people and animals. Thus, according to §11-3 in Concerning Protection Against Pollution and Concerning Waste, they need to be treated before a potential discharge (Lovdata, 2015).

2.1 Generation of Waste and Necessity of Equipment

When a well is drilled, there is a need for drilling and completion fluids during the drilling and completion operation, respectively.

A drilling fluid, also referred to as mud, is circulated through the drill string during the operation. Drilling fluids can be oil based, water based, or synthetic based, but today it is mainly used oil or water based drilling fluids. Which drilling fluid used depends on the characteristics of the bedrock where the well is to be drilled (Skaugen, 1997).

The drilling fluid is sticky and viscous, and has several functions during the drilling operation. Primarily, it ensures transportation of the drilling waste known as cuttings to the surface of the well, it lubricates and cools the drill bit, prevents corrosion of equipment, and keeps the pressure in the well under control to prevent uncontrolled flow of oil and gas (Skaugen, 1997).

During drilling and production operations, drilling waste such as slop and cuttings is generated. Even though both operations generate drilling waste, the main contributing operation is drilling.

2.1.1 Cuttings

The primary contributor to the waste generated during drilling operations is cuttings. Cuttings consist of crushed rock mass from the bedrock, which is transported to the surface together with the drilling fluid during drilling operations for oil and gas. That means, cuttings are a mixture of rock particles, and are contaminated by adherent drillings fluids. The composition of drilling fluids and rock particles in cuttings varies, together with the size of particles (Aabel, et al., 2003). The drilling fluid adhered can be a water based or an oil based fluid, which determines how the cuttings need to be handled, further explained in subsection 2.2.2.

2.1.2 Slop

Subsequent to cuttings, slop is the other main contributor to the category drilling waste. Slop can be generated on offshore installations[1] in several ways. A major contributor is when drilling and producing from an oil well takes place, which includes a number of processes where oil and water is in circulation (DNV, 2013). Other contributors to slop generated offshore are wash water from cleaning of decks, tanks and pipes, in addition to rain and drainage water where the water is contaminated with oil.

As several types of slop exist, slop is commonly used as a generic term to describe oily water and oil emulsions, and it is categorized as hazardous waste (DNV, 2013). For further use in this thesis, an appropriate definition is to consider slop as all waste liquids that contain oil or chemicals generated on an offshore installation, with an oil content of more than 30 mg/l (Toft, 2016).

Besides the necessity of drilling and completion fluids when drilling a well, another highly required equipment related to drilling activities is essential to specify; casing.

[1] Offshore installations include rigs and platforms, also known as mobile and fixed installations, respectively. A rig takes care of drilling operations, while platforms conduct both drilling and production operations.

2.1.3 Casing

Casing can be described as steel pipes that are assembled and inserted into sections of a borehole that has recently been drilled. The gap between the pipes and the walls of the borehole is cemented, primarily to prevent fluid loss from the wells, and in that way to prevent contamination to surrounding areas (Wittmeyer, 2013).

More specifically, a casing with a slightly smaller diameter than the borehole is inserted and cemented after a borehole is drilled. Thereafter, more casing is run down into a smaller hole and cemented. This process is repeated until proper depth is achieved. Hence, the well is made of several pipes screwed together, where the pipes are surrounded by cement and the diameter narrows with greater depth (Wittmeyer, 2013).

As presented in Figure 2.1 (Offshore Post, 2014), four types of casing are used in a well. The casing known as the conductor casing has the largest diameter among the four, and is placed in the upper section of the well. A casing called the surface casing is thereafter placed inside the conductor casing, and is led down the well a longer distance than the preceding one. The same principle applies to the casing which are to be placed next, i.e. the intermediate and production casing, respectively. The latter, and hence inner casing, is led all the way down to the bottom of the well for production.

Finally, after the casing is run in the borehole and cement is pumped behind it, the drilling fluid in the well is displaced by a completion fluid. The completion fluid may be a clear fluid or brine[2], formulated to be nonreactive with the formation (Flatern, 2012).

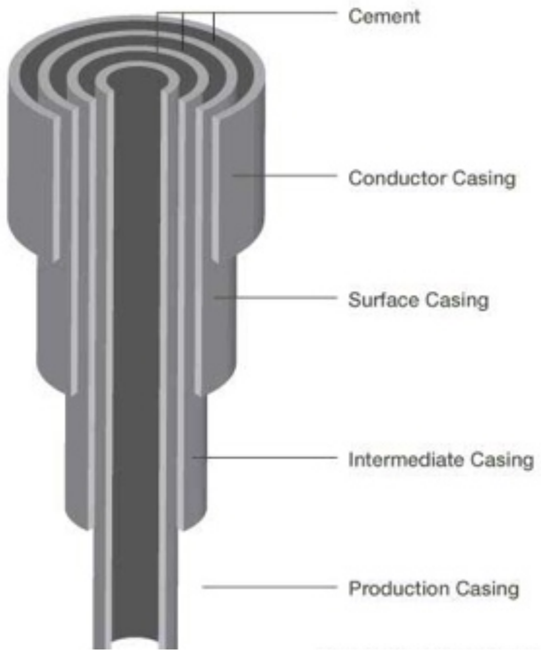

Figure 2.1: Well Casing Diagram

[2] A saline liquid normally used in completion operations.

2.2 Handling Slop and Cuttings

Discharges from drilling operations to the ocean has over the last 50 years, represented one of the greatest environmental negative impacts of petroleum activities on the Norwegian Continental Shelf[3] (NCS), including the discharge of slop and cuttings. Thus, proper handling of these masses is considered essential to further elaborate, in terms of legal requirements and various methods for disposal.

2.2.1 Legislations

The Pollution Control Act, more precisely § 7 in chapter 2, states that one is obliged to avoid pollution, but if pollution already has occurred, measures have to be implemented in order to stop, remove or limit the impact of the pollution (Lovdata, 2015). As slop and cuttings are polluted masses, rules and regulations have to be adhered to, in terms of how to handle them. There are several contributors which set guidelines and requirements related to this, including the Oslo-Paris[4] (OSPAR) convention.

As the area of interest in this thesis is the North Sea[5] (NS), of which the NS is a part of the North-East Atlantic, the OSPAR convention from 1992, effective from 1998, applies. This is a legally binding agreement between 15 member countries, which sets guidelines for laws and regulations, to ensure cooperation for protecting the marine environment in the applicable area. The convention combines the Oslo Convention from 1972, regarding discharges to sea, and the Paris Convention from 1974, regarding onshore sources of marine pollution. Hence, OSPAR includes attachments regarding regulation of pollution from land based and offshore sources, as well as discharge and monitoring of polluted masses to sea, among other (Miljødirektoratet, 2013).

Additionally, the OSPAR convention provides a key list of the chemicals that are considered to Pose Little Or NO Risk[6] (PLONOR) to the marine environment. Thus, chemical compounds not mentioned in the list are considered harmful to the marine environment, and must be treated prior to a potential discharge (Miljødirektoratet, 2004). Based on this list, together with the European waste list of which is provided in attachment 1 in The Regulations on Recycling and Treatment of Waste chapter 11 Hazardous Waste (Lovdata, 2015), it can be ascertained that slop and cuttings are considered harmful to the marine environment. Therefore, such masses need to be handled properly in order to prevent unnecessary amounts of emissions related to potential discharges of them.

[3] Hereafter referred to as the NCS
[4] Hereafter referred to as OSPAR
[5] Hereafter referred to as the NS
[6] Hereafter referred to as PLONOR

However, it is necessary to clarify the distinction between cuttings with adhered water based drilling fluids, also known as Water Based Mud[7] (WBM), and cuttings with adhered oil based drilling fluids, also known as Oil Based Mud[8] (OBM) (Aabel, et al., 2003). As stated in section 2.1.1, the distinction makes a difference in terms of how the two types of cuttings are handled, more specifically how they are disposed.

2.2.2 Alternatives for Disposal of Cuttings

Discharge of cuttings with adhered OBM was not prohibited until 1993. Moreover, the OBM was in fact based on diesel in the early Norwegian oil age (Toft, 2016). Nowadays, one has the option of discharging one type of cuttings to the sea, cuttings with adhered WBM, whilst this is not an option for cuttings with adhered OBM.

Normally, cuttings with adhered WBM are considered non-hazardous waste and are usually not required to be treated, as WBM solely consists of PLONOR chemicals. That is, cuttings with adhered WBM can typically be discharged to sea or injected into dedicated subsurface wells.

Contrary to cuttings with adhered WBM, cuttings with adhered OBM are also known as oily cuttings, and hence they contain oil or hazardous substances. Oily cuttings are considered hazardous waste; therefore, these cuttings are not allowed discharged to sea. Consequently, such cuttings have to be treated before a potential discharge, of which both onshore and offshore treatment is possible and currently practiced. However, offshore treatment of cuttings is not practiced in the NS today, due to earlier attempts resulting in the finished treated masses not meeting the requirements. In latest cases, the hydrocarbon content was proven not to be within the applicable discharge requirement (Skretting, 2016).

If not directly discharged, the cuttings can be injected into dedicated subsurface wells, or transported to shore for disposal or treatment in approved facilities (Skretting, 2016). Thus, oily cuttings are the type of cuttings of interest within this thesis, and oily cuttings will therefore further be referred to as cuttings.

In terms of handling slop and cuttings, this thesis will not go into details regarding various treatment methods and emission limits for such masses, as treatment typically occurs onshore today and this thesis emphasizes offshore activities. However, if it is of particular interest for the reader to delve the limits, reference is made to The Regulations of Conducting Activities in the Petroleum Industry Chapter XI, Discharges to the Environment § 60 a, b, and § 68. These paragraphs provide specific discharge limits of oily water such as slop, and cuttings, sand and solid particles, respectively (Petroleumstilsynet, 2016). Also, recycling and reuse of such masses after treatment is possible and can advantageously be conducted (Miljødirektoratet, 2014). This option will be briefly discussed in section 8.

[7] Hereafter referred to as WBM
[8] Hereafter referred to as OBM

2.3 Pollution within Slop and Cuttings

As mentioned in the previous section, slop and cuttings need to be handled properly. More specifically, it is required that the polluted substances within the masses are reduced to certain levels. Several substances related to pollution of slop and cuttings exist, but for this thesis it will be expedient to clarify the two following; Total Organic Carbons[9] (TOC) and Total Petroleum Hydrocarbons[10] (TPH).

2.3.1 Total Organic Carbons

TOC is a measure of organic matter in water, of which organic matter includes living materials. In terms of carbon content, both dissolved and undissolved organic substances in the water are included, thus dissolved oil[11] and undissolved oil[12] can be mentioned as examples of substances to pay particular attention to in this thesis. The level of TOC can therefore be used as an indicator of the degree of pollution in a water sample (Environmental Protection Division, 2016).

2.3.2 Total Petroleum Hydrocarbons

The proportion of oil in slop and cuttings mainly consists of hydrocarbons, measured as Total Hydrocarbons. In the petroleum industry, and hence in terms of slop and cuttings, it is common to refer to this as TPH. TPH is defined as the amount of petroleum-based hydrocarbons that can be measured in an environmental media. Even though TPH mainly consists of hydrogen and carbon, the term TPH describes several hundred individual chemicals that come from petroleum (Todd, Chessin, & Colman, 1999).

TPH is considered an environmental contaminant (Todd, Chessin, & Colman, 1999). Due to TPH being a mixture of various oils, it is more practical to measure the total amount of TPH at a site or in a particular sample of soil, water or air, than to measure each individual oil separately. Accordingly, the name *Total* Petroleum Hydrocarbons (EPA, 2016). As the measured value of TPH represents a mixture of chemicals, the value can be used as an indicator for the degree of petroleum contamination at a specific site or in a specific sample.

[9] Hereafter referred to as TOC
[10] Hereafter referred to ac TPH
[11] Oil that is highly soluble in water
[12] Oil that is soluble in water to a limited extent

2.4 Fractioning – Separation of Various Phases in Waste

As already mentioned, various treatment methods for drilling waste will not be emphasized in this thesis as they typically occur onshore. However, to further facilitate downstream handling and processing, a first step for a potential future treatment process onshore can be conducted offshore. More specifically, fractioning can be conducted during transportation. Hence, the various substances which composes the mass to be fractioned are separated and can be further treated if necessary. This thesis will not cover how further treatment can be conducted, but it should be mentioned that after treatment, the content of oil, solid or chemicals in slop should be close to zero, which also applies in terms of oil content in cuttings.

Several methods for how to fraction a mass exist. The objective of fractioning is, regardless of method used, to separate various substances within the mass. As a result, some substances can be used for other purposes, while other substances can be removed for e.g. further treatment. In this context, the purpose of fractioning is to separate water from oil, chemicals, and solids.

2.4.1 Fractioning by use of Evaporation

An option of fractioning drilling waste, more specifically slop, is by use of evaporation. The method enables the possibility of removing various undesirable substances from the slop as a preparation for a potential future treatment process, as it separates the slop into distillate and condensate. Distillate consists of finished treated water, while condensate consists of excreted substances. These will be referred to as produced water[13] and sludge, respectively.

Moreover, the fractioning process enables a separation of the masses, resulting in a possibility of recycling and reusing desired substances for other purposes. That means, after the fractioning process has taken place, it is solely the sludge that comprises polluted substances such as TOC and TPH. The oil content in the sludge can be disposed or recycled and reused for purposes such as making new OBM. Contrary, the produced water does not comprise polluted substances. However, similar to the sludge, it can advantageously be recycled and reused for other purposes, such as washing water or for making brine or new WBM (Halliburton, 2016).

[13] This produced water must, under no circumstances, be mistaken for the water produced from reservoirs as a part of the process for producing hydrocarbons.

The process is conducted by use of an evaporation plant, which contains a circulation system tank with a heating loop around it. Figure 2.2 presents the principle of evaporation through a schematic diagram. The separation takes place through two stages, where an evaporation process occurs in the first stage and a condensation process occurs in the second stage.

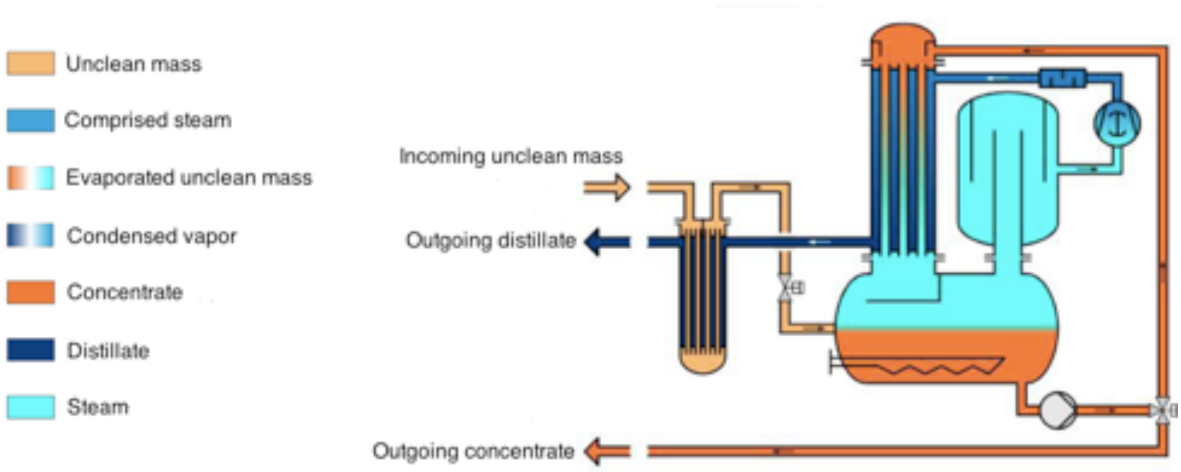

Figure 2.2: Process Scheme for Evaporator

The slop is sent into the tank, where the evaporation process in stage one takes place as an evaporator inside the tank increases the temperature of the slop, making it boil and transit to vapor. The vapor is led upwards for the condensation process to take place, while the sludge is led to a buffer tank for deposition or recycling and reuse. The condensation process occurs as the vapor goes through a condenser and cools it down, making the vapor change back to liquid. After this liquid is led through a security filter, it can be referred to as produced water.

3 Economic and Market related Theory

In order to determine how a specific decision will affect a company´s profitability, a business case can be conducted. A business case is a decision tool used to determine how a specific decision will affect a company`s profitability. The business case should indicate how the decision will change the cash flow over a period of time, and how the costs and earnings will change (Schedlbauer, 2014).

There are two sides of a business case; a qualitative side and a quantitative side.

3.1 The Qualitative side of the Business Case

The qualitative side of a business case typically addresses fields that are not measurable in monetary units or in other objective ways (Schedlbauer, 2014), such as the market concerned with related competitors, or strategies of implementing new concepts.

The following subsections define key aspects in terms of qualitative measures. More specifically, they describe how a Strength, Weaknesses, Opportunities, and Threats[14] (SWOT) analysis, in addition to how streamlining a value chain, can be helpful indicators for which qualitative sides that should be taken into consideration.

3.2 Strengths, Weaknesses, Opportunities and Threats

A SWOT analysis can advantageously be conducted to review a business, in order to evaluate a new strategy to be implemented against the current market before committing to the strategy. The analysis can further be used as a guide for business planning as it provides a good basis for decision making. The objective is to identify which factors that are essential for achieving organizational goals.

More specifically, a SWOT analysis is an effective tool used to identify the strengths, weaknesses, opportunities and threats an organization faces. The strengths typically include the factors that separates the company from the competition, while the weaknesses can be areas where the company has to improve to remain competitive. Opportunities are areas where the company can grow, and the threats describes the competition the company is facing, the overall economy or other issues that could harm the organization. That is, the SWOT analysis can be used to determine which measures that can help an organization in accomplishing its objectives, in addition to which barriers that must be overcome or minimized to achieve the desired results (Håkstad, 2016).

[14] Hereafter referred to as SWOT

The analysis is constructed from a model that distinguishes between internal and external issues, more specifically the internal issues comprises strengths and weaknesses a company can influence directly, while the external issues comprises opportunities and threats that a company have no control over (Håkstad, 2016). A SWOT analysis is typically presented in a matrix, and the principle of the analysis illustrated in Figure 3.1.

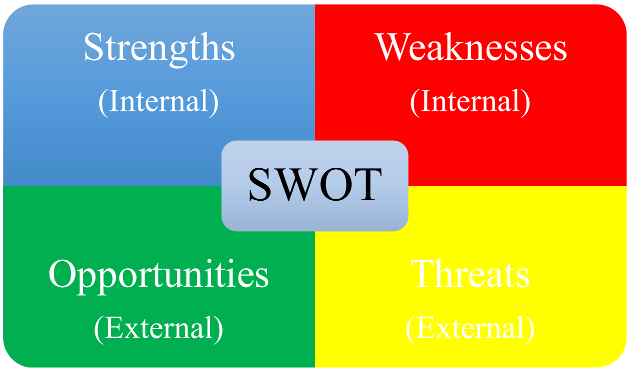

Figure 3.1: SWOT Analysis Matrix

3.3 Streamlining the Value Chain by Use of Lean

The term value chain was developed by Michael Porter in 1985, to be used as an analysis tool for identifying causes of an organization´s competitive advantages (Porter, 1985).

A value chain describes the created value within an organization, in that raw materials are purchased and stepwise undergo activities that make them more valuable for potential customers, in form of an end product or a service offered. As all the activities contribute to the organization´s competitive advantages, all activities in addition to the connections between them have to be assessed when assessing a value chain (Porter, 1985).

Several strategic concepts for streamlining and optimizing an organization´s value chain exist. One such concept is known as “Lean”, which can be described as a concept on how an organization produces value. Western scientists launched the concept inspired by the Toyota Production System[15] (TPS) in the late 1980´s, and is currently one of the most widespread management concepts within all industries worldwide (Modig & Åhlström, 2012).

The development of TPS was a result of the Japanese finding themselves in a challenging situation after World War II, as they experienced lack of resources. Toyota´s way of approaching the situation was to focus on flow efficiency, which resulted in Toyota becoming globally leading within the automotive industry. Inspired by this, lean seeks to achieve a fairly balance between them, but with main emphasis on flow efficiency.

[15] Hereafter referred to as TPS

Resource efficiency focuses on creating value for an organization by efficient use of resources, while flow efficiency focuses on the time it takes from a unit´s need is identified, until the need is met. This time is defined as the unit´s cycle time, which is dependent on the system boundaries set, i.e. the starting and endpoint. In services, a unit is typically a customer that gets a need fulfilled through different activities (Modig & Åhlström, 2012).

As presented in Equation 3.1, high flow efficiency is obtained when the proportion of value adding activities compared to the cycle time is large, hence the proportion of non-value adding activities compared to the cycle time is small.

Equation 3.1 $$Flow\ Efficiency = \frac{Proportion\ of\ Value\ Adding\ Activities}{Cycle\ Time}$$

Value adding activities are activities that result in customer needs being met, by transforming raw material, as indicated in Figure 3.2. That means, a value adding activity is an activity in which the unit is treated. Contrary, a non-value adding activity is any activity that takes time, resources or space, but which do not treat the unit. Thus, such activities do not add value to the product or service itself. Together, all the activities form a process to meet the flow unit´s need. Based on this, lean seeks to identify value- and non-value adding activities, and reduce or eliminate the activities that are non-value adding. Hence, all forms of inefficiency are reduced, resulting in an enhanced flow (Modig & Åhlström, 2012).

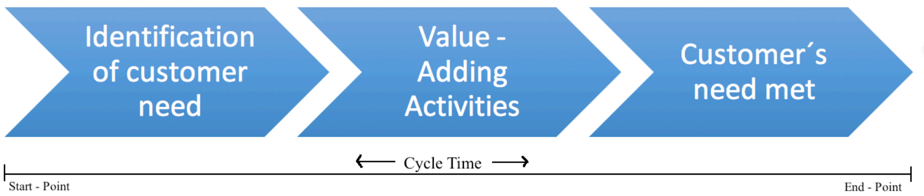

Figure 3.2: Lean - Flow Efficiency

Another measure that contributed to Toyota`s maximized flow efficiency and which also is sought in the concept of lean, was to improve efficiency by understanding the relationship between all parts of a process and to emphasize customer needs by focusing on communication. Toyota focused on doing the right things as well as focusing on doing things right, meaning that Toyota emphasized to offer the customers exactly what they needed. Awareness of only investing in the technology and materials that was necessary to offer the customers what they needed was essential, as well as quality assurance and control. Hence, the probability of customer dissatisfaction was reduced. If problems were discovered, they were seen as opportunities for further development and improvement (Modig & Åhlström, 2012).

Summarized, the concept of lean is inspired by the TPS. More specifically, emphasis on maximizing flow efficiency, in addition to understanding the process and customer needs, have impacted the development of lean. Implementing lean principles can provide benefits to any value chain, and thus provide competitive advantages for organizations focusing on the concept (Modig & Åhlström, 2012).

3.4 The Quantitative side of the Business Case

The quantitative side of a business case focuses upon monetary units related to a project such as capital, costs and earnings, in addition to rates of change (Schedlbauer, 2014).

The following subsections define key aspects in terms of quantitative measures which are regarded as essential tools to increase confidence related to the decision of accepting or declining a project. More specifically, they describe how an investment´s profitability can be calculated and how uncertainty related to the profitability can be assessed.

3.4.1 Calculations of an Investment´s Profitability

A number of methods can be used when deciding if a project should be accepted or declined within an organization. Often, a project is evaluated by using several methods for estimating the value of its investment, in order to ensure credibility in the results. Two of the most frequently used methods are estimating the Net Present Value[16] (NPV) and the Internal Rate of Return[17] (IRR) (Brealey, Myers, & Allen, 2014).

NPV

Estimating NPV provides a clear answer when deciding if a project should be accepted or declined. According to the rule of NPV, a project should be accepted if the NPV is greater than zero and rejected if the NPV is less than zero. That is, a positive NPV represents that a project will result in earnings, while a negative NPV represents that a project will result in loss. As for the latter, a negative NPV means that the earnings of a project will be lower than the discount rate. In between the negative and the positive NPV, is the NPV of zero, indicating that the investment gives a profit equal to the discount rate, meaning that the projects is exactly marginal.

To find the NPV, factors such as yearly cash flows and discount rate are essential to look into. Yearly cash flows through a project´s life cycle need to be forecasted when estimating a NPV. Cash flows are simply the difference between predicted income and outcome (Brealey, Myers, & Allen, 2014). Outcomes are costs related to a project, also known as expenditures, which are separated into Capital Expenditures[18] (CAPEX) and Operating Expenses[19] (OPEX). These differ in terms of what type of costs they address in an investment, and how they are treated for accounting and tax purposes.

CAPEX are the funds that a company uses to purchase physical goods or services in order to expand its ability to generate profits, both new assets and improvements or additions to existing assets are considered as CAPEX. Contrary, OPEX are ongoing costs that a company has to pay in order for their business to run.

[16] Hereafter referred to as NPV
[17] Hereafter referred to as IRR
[18] Hereafter referred to as CAPEX
[19] Hereafter referred to as OPEX

Cost of items that ordinarily would be regarded as CAPEX, can rather be assigned as OPEX if the company leases the item instead of purchasing it (Maverick, 2016).

As CAPEX and OPEX differ in large degree, they are also treated very differently. If purchased assets, i.e. assets regarded as CAPEX, have a lifespan of more than a year, the company has to use depreciation to spread the cost over its estimated lifespan to capitalize the expense. OPEX differs from this, by being deductible in the year they occur (Brealey, Myers, & Allen, 2014). As both CAPEX and OPEX need to be assessed when calculating the NPV of a proposed investment, which items that are treated as capital investments and how rapidly they are depreciated plays a major role in the results.

When using the method of NPV, all cash flows for a project are used. Contrary to other methods, the reduced value of cash flows in the future is taken into account, i.e. the time value of money is taken into consideration by discounting the value of the investment.

This is a particularly important principle that should be included when calculating an investment´s profitability, as it is common that the earnings of an investment occur at different times in the future. Hence, future cash flows should be discounted so that the value is comparable to the money an organization holds today. More specifically, a discount rate is implemented in the equation of NPV, due to the possibility of getting a return of the investment in the future, if the money would be received today. Choosing a proper discount rate is important to be able to carry out a realistic value for the NPV of a project (Ross, Westerfield, Jaffe, & Jordan, 2011).

In addition to making the NPV value more accurate, the discount rate also reflects factors as risk and opportunity cost in a project. A fitting discount rate for a company´s potential investment in a project can be decided by using several methods, such as Weighted Average Cost of Capital[20] (WACC).

However, this is a complex field where many considerations have to be undertaken, hence operating discount rates in organizations are typically a matter of judgment and preferences (Goodwin & Wright, 2004). Commonly, organizations have fixed discount rates that they use in NPV calculations, where the different discount rates vary in terms of project type, in addition to how much uncertainty and risk that is associated with a project.

[20] Also known as WACC, but hereafter referred to as the discount rate.

Finally, calculation of a project´s NPV is the result of present values of future discounted cash flows, subtracted the present value of initiating the. Equation 3.2 presents the formula for calculating a NPV.

Equation 3.2 $$NPV = -C_0 + \frac{C_1}{(1+r)^1} + \frac{C_2}{(1+r)^2} + \cdots + \frac{C_n}{(1+r)^n} = -C_0 + \sum_{t=1}^{n} \frac{C_t}{(1+r)^t}$$

Of which the different symbols represent:

C_0 = Investment cost in year 0 (t=0)
C_t = Surplus in year t
n = Lifetime for the project
r = Discount rate

The results obtained by using the NPV method reflect uncertainty. In general, there will be uncertainty related to factors such as the size of future cash flows and the lifetime for a project. It can therefore be helpful to use a simulation tool such as @Risk in Excel to explore what the results may prove to be if these deviate from the assumptions. Doing so, uncertainty related to a project is included in a larger extent than solely through the discount rate. (Goodwin & Wright, 2004). Some methods for analyzing uncertainty are reviewed in section 3.4.2.

IRR

The main alternative to the NPV method for estimating an investment´s profitability, is to calculate the IRR. Generally, the IRR is the discount rate that causes the NPV of a project being equal to zero. A basic investment rule says that one should accept the project if the IRR is greater than the discount rate, and reject the project if the IRR is less than the discount rate. The greater the IRR of a project is, the greater the return of the project will be (Ross, Westerfield, Jaffe, & Jordan, 2011).

Equation 3.3 presents the formula for calculating the IRR.

Equation 3.3 $$NPV = 0 = C_0 + \frac{C_1}{(1+IRR)^1} + \frac{C_2}{(1+IRR)^2} + \cdots + \frac{C_n}{(1+IRR)^n} = C_0 + \sum_{t=1}^{n} \frac{C_t}{(1+IRR)^t}$$

Of which the different symbols represent:

C_t = Surplus in year t
C_0 = Investment expenditure
n = Lifetime
IRR = Internal Rate of Return

As for the method of NPV, the method of IRR is based on discounted cash flows, resulting in an improved precision of the calculated profitability related to an investment. The NPV is positive for discount rates lower than the IRR, and negative for discount rates greater than the IRR. That is, the rules for the IRR and the NPV coincides and provide us with the same conclusion, however, this solely applies under normal circumstances. Normal circumstances imply that the initial investment of a project is solely followed by a series of cash flows. If this is not the case, the rule of IRR and the rule of NPV do not necessarily coincide (Ross, Westerfield, Jaffe, & Jordan, 2011). This concern related to the IRR, among others, will however not be further discussed in this thesis.

As the prior sections have indicated, it might seem like the choice of accepting or declining a project is solely based on estimating proper cash flows, choosing the right discount rate and finally calculating the NPV. However, investment decisions should also include analyzes of uncertainty related to the value of NPV, in order to increase the probability of making the right decision related to accept or decline a project.

3.4.2 Analyzing Uncertainty

Several methods exist for analyzing uncertainty related to an investment´s profit. In terms of investing in a project, a great amount of "what if" questions can be asked to explore what could go wrong. By use of different techniques, one can develop a better understanding of how surprises may change the estimated NPV, which can be advantageous in terms of making a well-informed decision regarding whether to accept or decline a project. The following subsections describe different methods for analyzing uncertainty related to a project.

Sensitivity Analysis

A sensitivity analysis is a method used to calculate the consequences of misestimating the variables related to a project. More specifically, the method is used to decide how sensitive the NPV is to changes in the assumptions, i.e. the variables. Hence, inappropriate forecasts may be exposed and it can be indicated where additional information would be most useful (Brealey, Myers, & Allen, 2014).

The sensitivity analysis is conducted by specifying so-called base values, i.e. pessimistic, expected and optimistic estimates for the variables. Thereafter, what happens to the project´s NPV if the variables are changed one at a time to their pessimistic, expected and optimistic values, can be evaluated. Thus, the various values for a variable provide different scenarios for the NPV, i.e. a worst-case scenario, a most-likely scenario, and a best-case scenario, respectively. Hence, the analysis reflects the uncertainty associated with each variable defined, and shows how great the impact of each variable has on the NPV (Brealey, Myers, & Allen, 2014).

As an additional exercise to the sensitivity analysis, a break-even analysis can be conducted. Doing so, break-even points can be found, hence it is revealed at which point a project has a NPV equal to zero and hence a more comprehensive insight of the uncertainty related to the potential investment is conducted. More specific, the present value of the inflows and outflow under different assumptions can be plotted in a diagram or graph, and provide us essential information about e.g. how much a company must sell of a service they are offering, for the project to contribute to a positive result (Brealey, Myers, & Allen, 2014).

Even though sensitivity analysis advantageously can be conducted, it should be mentioned that there are some challenges related to it, such as interrelations between the variables and subjective interpretations of the results. That is, the outcomes from the analyzes of which the variables are considered to be isolated may be misleading if the variables in fact are interrelated. Also, the outcomes may be interpreted differently by various people, and can therefore not be considered as objective. Finally, the sensitivity analysis does not include probabilities related to the possible outcomes. These challenges indicate that supplementary uncertainty analyzes beneficially can be conducted, in order to seek more objective results. Such an analysis, can be to conduct Monte Carlo simulations (Ross, Westerfield, Jaffe, & Jordan, 2011).

Monte Carlo Simulations

The sensitivity analysis only allows considering the effect of changing one variable at a time. Consequently, the consideration only includes a limited number of combinations of variables. In comparison, use of Monte Carlo simulations enables consideration of all possible combinations of variables and enables inspection of the entire distribution of outcomes for a project (Brealey, Myers, & Allen, 2014). Hence, using a Monte Carlo simulation provides a more precise and complete result compared to what is provided from a sensitivity analysis (Ross, Westerfield, Jaffe, & Jordan, 2011).

Simulating by using the Monte Carlo method is an attempt to model the true uncertainty (Ross, Westerfield, Jaffe, & Jordan, 2011). The simulation is computer based, and needs a precise model to provide a precise simulation. Thus, interrelations between variables need to be specified and interdependence between different periods and different variables must be included in order to simulate a whole project. The complete model of a project will include a set of equations for each of the variables. In addition, probabilities need to be specified for the variables for conducting the simulation. In terms of the simulation, the computer samples from the distribution of the forecast errors and calculates a result. After many iterations, the estimates of the probability distributions of cash flows for a project start to get accurate. That is, the result is as accurate to the extent that the model and the probability distributions of the forecast errors are accurate. Finally, the distributions enable calculation of expected cash flows. After discounting these, the NPV can be calculated (Brealey, Myers, & Allen, 2014).

A tool to conduct Monte Carlo simulations is Excel´s @Risk.

III

APPROACHES

4 Methodology

Method is an approach used to arrive at new knowledge. Except from examination techniques, method involves collecting, organizing, processing, analyzing and interpreting facts in a systematic way, so that others can verify the results the researcher arrives at. That is, a method involves how to proceed to gather necessary information, which further can be used to conduct analyzes (Halvorsen, 2008).

As for this thesis, the methodical approach chosen is to do a case study.

4.1 Case Study

Case studies deal with gathering as much information as possible related to the topic to be studied. The objective is to provide an extensive description and to develop a comprehensive understanding of the topic to be studied. Which type of information that is desirable to obtain and to further base the analyzes on, determines in large degree which type of analyzes that can be conducted and which results one arrives at. A key distinction is between quantitative and qualitative information. For the results to reflect credibility, a case study can advantageously be conducted by using both quantitative and qualitative approaches (Halvorsen, 2008).

Quantitative information is measurable, and can often be expressed in numbers. Such information is referred to as "hard data". Conversely, qualitative information cannot be measured, but is rather information which expresses characteristics of the topic to be examined in form of text or verbal statements. As this information is obtained from people who interpret and perceive a specific topic differently, the information is impossible to quantify. Such information is referred to as "soft data", and is often used to convey understanding, to develop coherence and to ensure a holistic picture of the topic. The main distinction between quantitative and qualitative approaches is therefore whether the information can be expressed in numbers or text.

The case study in this thesis is based on a combination of quantitative and qualitative information, as a result concerning the concept´s feasibility and profitability was sought, in addition to if it could be a preferred solution. That means, such evaluations were based on both hard and soft information, to ensure a comprehensive result based on multiple aspects.

4.1.1 Primary and Secondary Data

As a case study consists of collecting as much information as possible regarding a specific topic, various types of data can advantageously be used. A distinction is usually made between two types; primary data and secondary data. In this thesis, both primary and secondary data is used to elucidate the topic, to ensure that the information obtained is seen from different points of view.

Primary data is new data collected by the researcher. Contrary, secondary data is data obtained by others. That is, secondary data is information which is already present, and which is more or less processed and accessible (Halvorsen, 2008).

As for this thesis, primary data consists of information obtained by the researcher. This information is based on the knowledge that the personnel within Halliburton possess regarding the topic. Mainly, such information has been gathered through conversations, meetings and e-mails with the employees within the organization. Due to having the opportunity of using Halliburton´s headquarter in Tananger as a place to work, the meetings and conversations have varied in terms of formality, making it possible for the researcher to collect information on a daily basis.

Those in Halliburton who have contributed to the thesis´ primary information, with their related positions and intentions, are listed in Figure 4.1. Additionally, information has also been provided from The Norwegian Petroleum Department, The Petroleum Safety Authorities, The Exploration & Production Information Management Association, and The Norwegian Mapping Authorities through e-mails and phone conversations. Based on this, the information obtained and further used as primary data is regarded as differentiated, which provides an interesting and professional view of the topic to be studied.

Figure 4.1: Contributors to Primary Information

Secondary data has been provided from Halliburton´s internal systems. Such information has consisted of historical data, documents and presentation of products, which has contained requested information that not necessarily could have been found elsewhere. Information from other organizations, such as The Norwegian Petroleum Department, The Petroleum Safety Authorities, The Exploration & Production Information Management Association, and The Norwegian Mapping Authorities, has also been valuable. In addition, the thesis has been supplemented with theoretical information, e.g. academic literature and scientific articles, to increase the credibility of the thesis.

Together, all sources of information have contributed to forming a good basis for the researcher to find a way to reach the objective of the thesis.

4.1.2 Quality Control of Data

To assure a high quality study, it should be seen as essential to ensure that the quality of the data is adequate. For this reason, the quality of the data obtained needs to be evaluated as it may vary. Commonly, data are assessed in terms of reliability and validity to decide the quality and reveal possible error sources. To which degree the data collected responds to these characteristics is a key question that needs to be answered before using the data in the analysis, hence allowing them to be decisive for the results (Johannessen, Tufte, & Christoffersen, 2010).

In terms of validity, it is essential to ensure relevance of the data related to the topic to be studied. Speaking of reliability, the term describes the extent to which the information represents the reality (Johannessen, Tufte, & Christoffersen, 2010). In addition to assessing the data´s validity and reliability, possible error sources should also be evaluated in deciding the data´s quality. Data could be wrong, outdated, incomplete, or unreliable, which are all factors that may provide incorrect results in an analysis (Halvorsen, 2008).

As for this thesis, data has been collected from several sources during the research. That is, it has been regarded as essential to search for information from multiple roles within different departments in Halliburton, in addition to collecting information from other organizations as well.

In terms of information obtained from Halliburton, it can be contemplated that validity and reliability is ensured as the organization has intrinsic value related to the thesis. Hence, it is of Halliburton´s interest that correct data is used. Further on, those who have provided the thesis with information based on their knowledge are professionals with high expertise within their respective fields, which supports this statement.

However, different roles have different background knowledge, concerns and responsibilities. This causes different interpretations and perceptions of the topic, hence objectivity may be weakened and the results of the analyzes will be affected. Also, to which extent the persons who have provided information to the research have ownership to it and are motivated for assisting it, can be varying. For example, guidance can be provided in a particular direction for the analyzes to arrive at certain results, or information can be withheld for the same purpose.

Regarding information collected elsewhere, such as theoretical information, the researcher has been particularly critical of sources. Only authors that seem trustworthy in terms of the information they provide and information that can be considered not to be expired, have been further used in the thesis. However, the information provided have been questioned throughout the research. That is, further exploration of other sources describing the same has been sought, and such information has been validated with personnel in Halliburton to ensure that the data can be trusted.

An exception is made related to Halliburton´s internal data and documents, which has provided information that could not have been easily found anywhere else. Hence, such data has been trusted without seeking to find similar information elsewhere, but the researcher has, in cooperation with Halliburton´s personnel, reflected around the information to ensure that the data seem genuine for further use in the thesis.

Lastly, errors related to the researcher should be included. The researcher could interfere with the results due to misunderstandings or misinterpretations, among other. As a large proportion of the information used has been received orally, it cannot be ensured that the researcher has understood the information correctly. However, the researcher has had a consistently good dialogue with Halliburton´s personnel throughout the entire process of conducting the thesis, and has listened and provided suggestions and questions to the various informants throughout the process to ensure that the information is interpreted correctly. Hence, potential ambiguities and confusions have been corrected so that a mutual understanding is ensured. This has also contributed to forming the thesis in a direction where everyone is satisfied.

Summarized, several sources of information are used to ensure validity and reliability. All the information has been validated by employees in Halliburton, so that the information is ensured to be consistent and will further provide the most accurate results.

5 Analyzes and Results

Various analyzes were considered essential in order to determine if there exists a feasible solution for the concept, whether the concept could have been preferred over solutions currently use, and if so, what that could mean for Halliburton`s market share. Also, how the initiation of such a concept could have affected Halliburton`s income was regarded necessary to assess. In order to determine this, both qualitative and quantitative analyzes were conducted.

This chapter presents approaches of the various analyzes conducted, in addition to the results arrived at. The results represent the foundation for whether Halliburton should proceed with the idea and introduce the concept to the market, or not.

The chapter is separated into two main sections; qualitative and quantitative analyzes and results. The analyzes, in detail, can be found in an enclosed memory stick comprising various Excel Spreadsheets. Additionally, extractions of the most important analyzes and results are provided in the Appendix. The relevant files and parts of the Appendix will be presented eventually.

5.1 Qualitative Analyzes and Results

In order to decide if the concept could have been a preferred solution in the market, it was necessary to investigate how the situation currently is operated, and how the situation possibly could have been operated in the future. The latter also applies in terms of deciding if the concept would be feasible, technically speaking. More specifically, the qualitative analyzes and results comprise research on how the current situation suggests that drilling waste is handled and how equipment is supplied to offshore installations, in addition to how such activities possibly could have been carried out in a future operation, if implementing the proposed new concept.

5.1.1 Research of Current Operation

The following section will elaborate today´s solutions for delivery of equipment and retrieval of waste. As a result, a value chain based on the operation is presented.

Current activities of interest comprise how drilling waste is retrieved and transported from offshore installations, including which transport units, equipment and methods that are used. The same applies for delivery of equipment.

As already stated, treatment of drilling waste typically takes place in approved facilities onshore. A reason for this is that onshore treatment outperforms offshore treatment in terms of efficiency, as it can use technology that is not applicable on offshore installations (Oljedirektoratet, 2008). However, onshore activities are not of interest within this thesis. Even though treatment of slop does occur offshore, the proportion is minor compared to the proportion that takes place onshore, and hence offshore treatment methods are neglected from this thesis. Thus, onshore and offshore treatment is not discussed within this thesis.

Drilling waste generated at offshore sites within the NCS is typically collected in tanks at the offshore installations and temporarily stored until retrieval for further transportation to shore. This indicates that it is necessary to have enough room at the offshore installations for the containers storing the volumes. Today, waste generated in the NS is in general delivered to one of the bases presented in Figure 5.1 (Håkstad, 2016).

Figure 5.1: Currently used bases

Retrieval and Delivery by use of Platform Supply Vessels

Necessary equipment and aids for offshore use, such as casing, together with drilling and completion fluids, are delivered by Platform Supply Vessels[21] (PSVs) and in some cases shuttle vessels. Additionally, drilling waste is retrieved and transported to shore by these vessels.

The vessels which conduct the retrieval and delivery, are leased from ship-owners by the operators. In addition, these vessels deliver necessary equipment to the offshore installations (Håkstad, 2016). That is, PSVs are vessels designed particularly for transporting equipment to offshore installations, as well as retrieving and transporting drilling waste from the installations to shore.

Typically, an offshore installation leases one or two PSVs for a longer period of time. However, the installation´s necessity of the vessels´ services varies throughout the specific time period, which indicates that the vessels are available for the installation even in periods of time of which their services are redundant. This comprises a significant cost for the operators. Moreover, if an offshore installation has need for extra capacity, shuttle vessels are available for lease. These vessels follow regular routes between rigs and platforms, and further to shore (Håkstad, 2016).

How a rig or platform typically makes use of PSVs can be further described by an example, which also provides insight in how a specific period of time is utilized. The example is based on information obtained from Statoil, regarding how the field Krafla was operated during April 2016. The complete analysis can be found in the Excel Spreadsheet “Operation of Krafla April 2016”.

The information supports the allegation above, that there is typically one or two PSVs providing their services to an offshore installation. That means, each offshore installation generally depends on the PSVs for retrieval of waste, and delivery of necessary equipment.

[21] Hereafter referred to as PSVs

Moreover, the rig Songa Delta operated at Krafla during the time period in question. Songa Delta made use of one PSV, hereafter referred to as PSV 1, for retrieval of waste from the rig and delivery of equipment to the rig. Hence, PSV 1 operated between the field Krafla and the base Mongstad, described by the solid line in Figure 5.2.

Additionally, another PSV, hereafter referred to as PSV 2, was used for delivery of casing from the main base for casing, i.e. Florø, to Mongstad. This is described by the dotted line in Figure 5.2. Thus, PSV 1 could retrieve casing and other necessary equipment from Mongstad, and could further transport it to the the field.

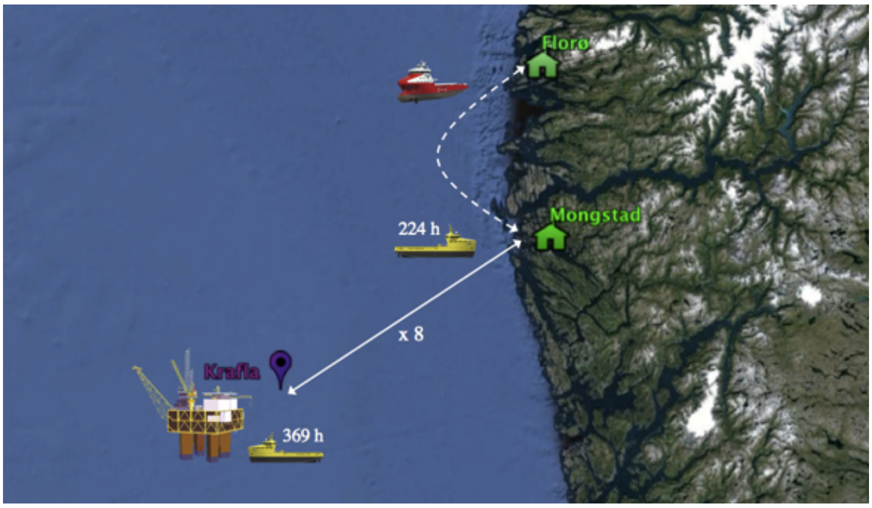

Figure 5.2: Currently Operation of Krafla

The analysis regarding how the specific field was operated during the month, reveals that PSV 1 spent a total of 369 hours, or just over 15 days, staying at the rig. The time PSV 1 spent at the various locations is presented in Figure 5.3.

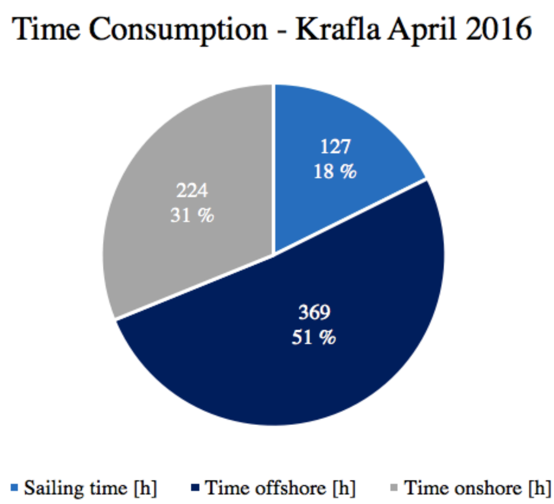

Figure 5.3: Time Consumption - Krafla

Furthermore, the waste needed to be retrieved from the rig in addition to the equipment needed to be delivered to the rig within a month, indicates that PSV 1 sailed back and forth between the field and Mongstad a total of eight times during a month.

Approaches for Storing and Transferring Drilling Waste

Today´s solution for retrieving drilling waste is to store and transport it in cargo carriers. The cargo carriers vary in terms of how they are filled up, whether they are mobile or not and thus if they need lifting operations, and how they are emptied. As it differs how much waste that is generated at the various fields and hence the significance of the volumes that need to be transported to shore, the need for cargo carriers also varies (Skretting, 2016).

Whether the cargo carriers are mobile or fixed was necessary to assess, as this implies if the cargos are dependent on crane lift operations or not. In terms of health, safety and environment[22] (HSE), crane lifts are considered the most risky operations occurring offshore. That is, the number of crane lifts required indicates the risk exposal. Thus, if focusing on HSE, this number should be sought reduced to a level as low as possible. A second aspect in favor of reducing the necessary number of crane lifts, is challenging weather conditions. Bad weather can cause circumstances where the cranes may not be able to operate and can thus be regarded as unreliable under such circumstances. This may cause drilling operations to cease of which implies heavy costs for the operators (Halliburton, 2016).

In terms of storing slop, the offshore installation is normally equipped with sufficient integrated pits and liquid tanks, hereafter referred to as slop tanks, to handle the generated volumes. The size of the slop tank varies with each offshore installation, however, if the total liquid storage capacity is not sufficient, additional capacity can in general easily be made available if required (Toft, 2016).

Typically, the slop volumes are transported to shore for treatment and disposal. The slop is transferred from the rig or platform onto a PSV, which also has integrated tanks as a part of the vessel´s design and structure, through hoses. That means, the units storing the slop are fixed, both at the offshore installation and on the PSV (Toft, 2016). The tanks storing the slop on the vessels will be further referred to as wet bulk[23] tanks.

When the PSV has arrived to shore, the slop is transferred from the vessel into dedicated storage tanks. All offshore supply bases in Norway have an infrastructure that includes pipelines from the receiving plant to the quay site, however, a hose is typically utilized between the vessel and the quay site interface (Toft, 2016).

As for storing cuttings, the main cargo carriers utilized are closed cuttings skips[24] (skips), followed by Cuttings Transport Tanks[25] (CTTs). In rare occasions, Cuttings Storage Tanks[26] (CSTs) are used (Skretting, 2016).

[22] Hereafter referred to as HSE
[23] Bulk is a shipping term used to describe transportation of wet or dry materials, respectively wet bulk or dry bulk.
[24] Hereafter referred to as skips
[25] Hereafter referred to as CTTs
[26] Hereafter referred to as CSTs

Skips are mobile units and therefore have to be lifted from offshore installations onto PSVs or shuttle vessels by means of cranes, for transportation of cuttings to shore. This is in general referred to as "Skip and Ship" operations (Skretting, 2016).

A typical skip is presented in Figure 5.4. When the skips are transported to shore they are emptied by a forklift, which lifts one end of the tank as a hatch is opened at the other end. Hence, the cuttings can flow out or be excavated (Skretting, 2016).

Figure 5.4: A Closed Cuttings Skip

Similar to skips, CTTs are also mobile units. However, they are placed on the PSVs or the shuttle vessel during filling of waste from offshore installations. Hence, they are filled by use of a pump and hoses, in the same way as a wet bulk tank is filled (Skretting, 2016). A CTT is presented in Figure 5.5.

Figure 5.5: A Cuttings Transport Tank

Moreover, Honey Comb Base[27] (HCB) tanks developed by Halliburton Baroid are self-emptying, temporary storage tanks, typically used to increase storage capacity, redundancy and flexibility on the offshore installations (Toft, 2016).

The HCB tank receives cuttings air-conveyed from the offshore installations shale shaker[28], and transfers the cuttings to skips on the offshore installation, or to CTTs on the vessel. It is emptied by pressurizing it, and air-convey cuttings to skips on the offshore installation or to CTTs on the PSV. As a HCB tank fully encloses the volumes within the tank, risk of leakage from it is avoided. A HCB tank is presented in Figure 5.6 (Halliburton, 2016).

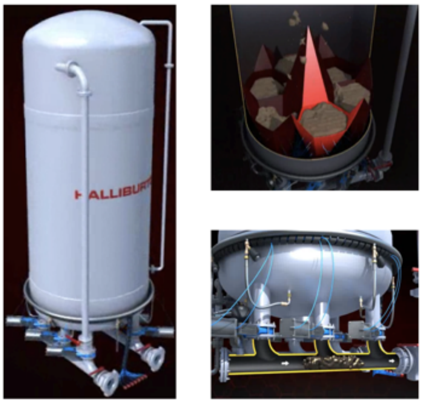

Figure 5.6: A Honey Comb Base Tank

CST tanks will be further explained in section 5.1.2, but it should be mentioned that the CSTs are fixed units and are thus filled with cuttings by use of a pump and hoses.

Table 5.1 summarizes how the various cargo carriers are filled and emptied, with related number of lifts required.

Table 5.1: Cargo Carriers – Approaches for Loading and Unloading

Cargo Carriers – Approaches for Loading and Unloading			
Cargo Carrier	**Loaded by**	**Unloaded by**	**# required crane lifts**
Wet bulk tank	Hose	Hose	0
Skip	Crane lift	Crane lift	2
CTT	Hose	Crane lift	1
CST	Hose	Hose	0

In terms of cargo carriers that are fixed or are emptied by use of a pump and a hose for other reasons, one centrifugal pump per PSV or shuttle vessel is used, which has a capacity of pumping an average of 30 ton/hour (Håkstad, 2016).

Further on, the volumes can be treated in approved land-based facilities, recycled and reused, or disposed of at certified landfills.

[27] Hereafter referred to as HCB tanks
[28] A drilling equipment component. Sending the cuttings through a shale shaker is the first phase of a solids control system, which roughly separates the cuttings from the adhered drilling fluid.

Value Chain – Current Operation

The current situation can be visualized by the value chain presented in Figure 5.7, which presents how operations related to delivery of equipment such as casing and retrieval of waste typically is conducted today. The operation of the field Krafla can once again be used to describe the value chain.

Figure 5.7 illustrates that a PSV, referred to as PSV 2 in the Krafla example, transports casing from Florø to any onshore base represented in Figure 5.1, depending on the location of the rig or platform to be served. As for the Krafla example, the base would be Mongstad.

Another PSV, referred to as PSV 1 in the Krafla example, retrieves casing from the specific base and further transports it to the rig or platform for delivery, e.g. from Mongstad to Songa Delta as for the Krafla example.

PSV 1 stays offshore for various lengths of time to retrieve the waste that is generated. As explained in section 0, the cuttings are mainly retrieved in skips or sometimes in CTTs, while the slop is collected in wet bulk tanks. This indicates that both the casing delivery and the retrieval of cuttings require crane lift operations.

Meanwhile PSV 1 delivers equipment such as casing and retrieves waste from the field, PSV 2 operates between Florø and the dedicated supply base, to load more casing, making sure that casing is available at the base when PSV 1 gets back for refilling of casing and other equipment, and unloading of waste.

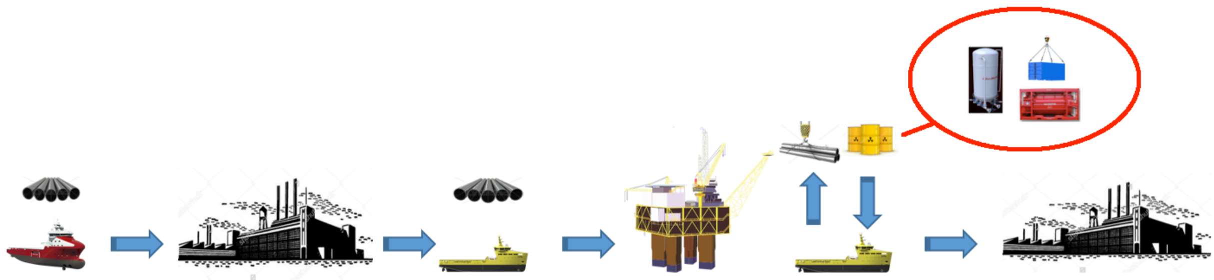

Figure 5.7: Value Chain - Current Operation

5.1.2 Research of Potential Future Operation

This section will present a new concept, which is regarded as a potential future option related to handling drilling waste and supplying equipment offshore. As a result, a value chain based on the potential future operation is presented, in addition to a market related analysis evaluating the strengths, weaknesses, opportunities and threats related to the concept.

The foundation of the concept is to eliminate or minimize the offshore installations` need for PSVs or shuttle vessels, by introducing and offer the services of a specialized vessel. That is, the vessel would be responsible for delivering necessary equipment to offshore installations, in addition to retrieval and transportation of waste volumes to shore. As of now, the equipment necessary to supply to the offshore installations will be referred to as casing, as casing is the equipment that would be the vessel`s capacity constraint.

Similar to the current situation, there will be a need for temporary storage capacity of the drilling waste at the offshore installations as the vessel would only be able to provide its services to one offshore installation at a time. The capacity at each rig or platform has to be sufficient to store the waste volumes in a period of time long enough for the vessel to be able to come and retrieve it.

Functions and Features of the Specialized Vessel

Initiating such a concept would not only depend on factors as mentioned above, but it would also require the vessel to have certain extraordinary functions and features. A vessel with such desired qualifications usually involves the need for reconstruction of a more basic vessel, which enables flexibility in having a vessel with characteristics exactly as desired.

As a mandatory criteria of the vessel, it would need to have a Dynamic Positioning[29] (DP) system. That means, such a system is necessary in order for a vessel to stay to the rigs and platforms, and is a Norwegian technology which can be found on most offshore vessel. The system is used as a tool for vessels to hold certain positions, or for vessels to move in certain directions. More specifically, a DP-system is an advanced control technology, which receives signals from gauges that measures wave height and current. The signals make it possible for vessels to achieve the desired positions, as the system estimates the exact course by using data from the various instruments. Hence, the vessels can adhere to these signals (Marine Technologies LLC, 2016).

DP-systems are separated into four categories; DP 0, DP 1, DP 2 and DP 3. These vary in terms of complexity, but a general rule is that every vessel which is going to operate within offshore installations´ safety-zones of 500 meters need to have a DP 2-system. Hence, a DP 2-system would be necessary for a vessel within this concept (Marine Technologies LLC, 2016).

[29] Hereafter referred to as DP

In addition to the functions of having a DP-system, the vessel would differentiate from the PSVs and shuttle vessels currently used in terms of design and related aspect ratios. That is, as the vessel is supposed to replace a number of other vessels, it would have to be of larger size and with higher capacity, than those it would replace. Also, the organizing of how the various tanks and equipment would be placed on the vessel was regarded as particularly important, as stability needed to be emphasized in order to ensure HSE.

In short, the casing would be stored on deck while the waste tanks would be stored below deck due to their weight. As such, the vessel´s deck ratio would determine the capacity for storage of casing. The vessel´s volume ratio and weight capacity would determine the possible number of tanks that could be stored, with related weight.

As described in section 5.1.1, tanks that can be filled and emptied by means of hoses are the most risk averse options in terms of HSE. Hence, CSTs were considered the best option for storing cuttings on the vessel, based on the amounts of cuttings that the vessel would have to transport. Such a tank is presented in Figure 5.8, particularly illustrating the larger size and capacity, and their locations below deck.

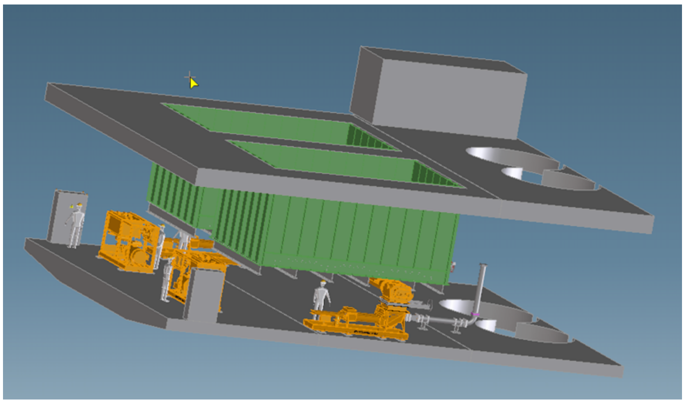

Figure 5.8: A Cuttings Storage Tank

CSTs is the only option for storing cuttings below deck as they neither require to be unloaded from the vessel, nor emptied by forklifts. Storing the cuttings below deck would be necessary due to ensuring stability for the vessel. In favor of using CSTs is also the concern that it is desirable to use as little time as possible to fill the cargo carriers, thus it is desirable to fill as few tanks as possible, but with greatest possible volume.

A CST has a volume of 375 m^3, compared to a CTT which has a volume of 20 m^3 (Håkstad, 2016). Thus, it would require less time to fill all the waste into some CSTs, than it would take to fill the same volume into many CTTs.

Additionally, using Halliburton´s patented HCB tanks was considered to be an appropriate option, as this would ensure an efficient transfer rate of the cuttings from the offshore installation, and to shore.

Moreover, wet bulk tanks would be placed below deck as fixed units together with CSTs. Both types would be filled and emptied by use of hoses. This would ensure the highest possible degree of HSE, and thus be the primary choice for tanks related to this concept. In addition, CTTs could be placed on deck in case of need for extra storage capacity for cuttings. This would however depend on the casing not occupying the whole deck area.

As for storing casing on the vessel, the most appropriate solution would be to use flat rack containers[30] (flat racks). A flat rack is particularly suitable for heavy loads and cargo that needs to be loaded from the top or the sides, e.g. pipes, as it can be collapsible or non-collapsible, and with or without walls (DSV, 2016). Hence, such containers were regarded suitable for storing casing, making it convenient to load and unload this equipment to and from the vessel. A flat rack is presented in Figure 5.9.

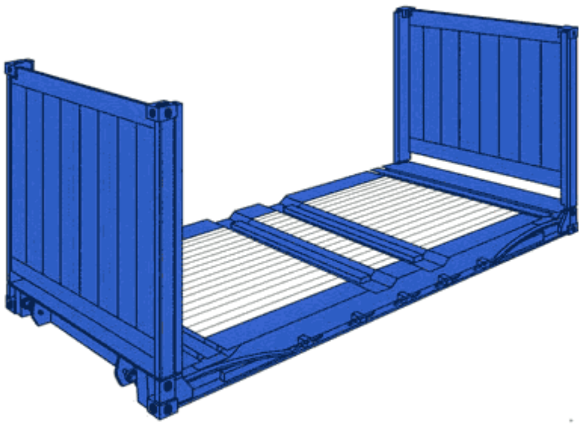

Figure 5.9: A Flat Rack Container

[30] Hereafter referred to as flat racks.

Offshore Solution

Regarding loading of waste and unloading of equipment at the offshore installations, the time this takes is crucial for the concept to be successful. Hence, measures that can reduce the necessary time for these activities were considered important in order to ensure a streamlined process. For example, such a measure could be to unload equipment and load waste simultaneously.

Another measure that could be implemented, is the process for loading the waste from rig to vessel. Due to the slop being more or less liquid volumes, the current process of loading these volumes from rig to vessel by use of one hose with a diameter of 5” is rapid and hence not considered necessary to implement measures to, indicated in Table 5.2. Contrary, the loading of cuttings from rig to vessel is more challenging, thus it was considered essential to implement a measure in order to speed up the process. More specifically, pumping the cuttings onto the vessel by use of two hoses of which each would have a diameter of 6” in addition to using air to assist the mass down through the hoses in a rapid process, would have streamlined the process compared to the current solution of using just one hose with a diameter of 5”, presented in Table 5.3.

Table 5.2: Delivery rate - Slop from rig to Vessel

Delivery rate – Slop from rig to vessel		
θ [inch]	**# of hoses**	**Delivery rate per hose [ton/h]**
5”	1	150

Table 5.3: Delivery rate - Cuttings from rig to Vessel

Delivery rate – Cuttings from rig to vessel			
θ [inch]	**# of hoses**	**Delivery rate per hose [ton/h]**	**Total delivery rate [ton/h]**
5”	1	30	30
6”	2	50	100

Extraordinary Principles

The perhaps most revolutionary principle of the potential future concept is mobile fractioning of waste. More specifically, the slop can be fractioned during transportation to shore. As explained in section 2.4.1, the circulation system of an evaporation plant consists of a tank with a heating loop around it. If initiating this concept, the evaporator would make use of the excess heat from the vessel´s exhaust gases in addition to heat produced from the DP-system.

Also, in order to improve the efficiency of the evaporator, the evaporation plant would be used under absolute vacuum conditions. Hence, the pressure would be reduced to a level below atmospheric pressure, with the purpose of making the slop boil at a significantly lower temperature than its natural boiling point at atmospheric pressure. As a result, the amount of energy needed to initiate and conduct the evaporation process of the slop would be considerably reduced compared to the original amount.

Doing so, a potential future treatment process onshore for the sludge extracted from the slop would be prepared for. That is, such a process would be less comprehensive as the various phases in the slop already would have been separated, which also would have streamlined the potential process. As a result, the transportation process would be streamlined as one would utilize the sailing time effectively.

Moreover, the sludge separated from the slop during the fractioning process could advantageously be used for preparing a slurry[31] before arriving onshore, by mixing it with cuttings. The mixing would take place in a slurrification system, presented in Figure 5.10, which consists of a coarse tank, a shale shaker and a fines tank.

Figure 5.10: Halliburton´s Slurrification System

[31] A mixture of cuttings and a fluid, typically water

The cuttings would be pumped from the CSTs into the coarse tank containing the sludge by using two piston pumps, which are pumps that ensure a rapid process for unloading large volumes. That is, such pumps shovel out the content, and are not dependent on the content needed to be compressed in the process. As cuttings cannot be compressed, this would be the only suitable pumping solution. More specifically, two piston pumps of the brand Putzmeister, presented in Figure 5.11 would be used simultaneously, ensuring a streamlined process for pumping the cuttings into the sludge tank. The placing of the pumps relative to the CSTs is presented in Figure 5.8.

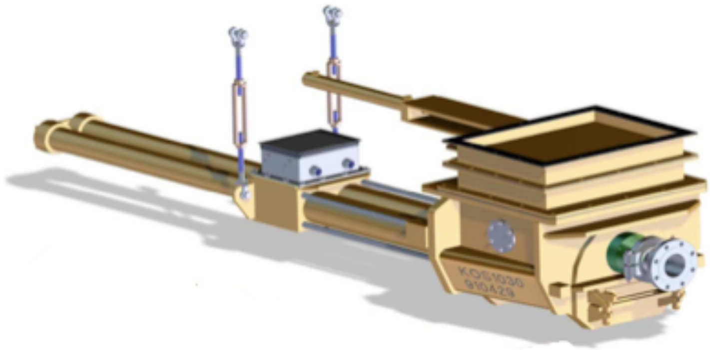

Figure 5.11: A Putzmeister Pump

After having pumped the cuttings into the coarse tank containing the sludge, centrifugal degradation pumps would be used for partly degrading the particle sizes. Moreover, the particle sizes would be further reduced in the shale shaker and by use of a grinder. When having obtained the desired particle sizes, the slurry would move through the screen of the shaker and enter the fines tank where the slurry would be conditioned. Finally, the slurry would be transferred into holding tanks, ready to be pumped to shore by specialized centrifugal mud pumps as a finely grounded mass (Ormeloh, 2014). In terms of this concept, it would be used two slurrification units on the vessel, i.e. one unit per Putzmeister pump. The slurrification units would be placed below deck together with three evaporator plants, the CSTs and the wet bulk tanks.

By mixing the sludge with cuttings, the combined volume would be relatively liquid, which would simplify the transfer of these volumes to shore. That is, making a slurry enables the possibility of pumping the volumes to shore by use of specialized centrifugal mud pumps. The criteria for the slurry would be that it should be liquid enough to allow for it to be pumped to shore.

If not preparing a slurry, it would solely be relatively liquid masses such as the sludge and produced water which could be pumped to shore, excluding the cuttings. As the CSTs would be placed below deck due to the weight they would carry, it would not be possible to empty these cargos in any other way. Also, HSE would be safeguarded if preparing a slurry enable the process of pumping to shore.

Onshore Solution
Similar to the importance of streamlining the process of loading and unloading the vessel offshore, the necessary time for the vessel onshore in order to unload the waste and refill equipment is of same significance. Hence, activities that would be conducted during the vessel´s stay onshore should be taken into account and sought streamlined. For example, loading casing should be done while the pumping takes place to save time. In addition, four specialized centrifugal mud pumps with 6” hoses connected would be used simultaneously to unload the waste, ensuring a total transfer rate of 450 m^3/h.

The concept would rely on two retrieval bases for casing; Florø and Risavika. Additionally, Risavika would be the delivery base for waste, more explained in section 5.2.1. Even though this thesis is limited to activities occurring offshore and does not go further into onshore activities such as treatment of waste, it is considered important to mention that environmental aspects as recycling and reuse of retrieved waste is a real possibility and helps to define the scope of what the concept could involve. Hence, Halliburton would facilitate that activities related to this could take place onshore, in order for the waste to possibly provide further value.

The oil content extracted from recycling of slop and cuttings could provide further value through being used for making new OBM, whilst the water produced from the fractioned slop could be used for making new WBM or brine, or for other purposes such as wash water.

As earlier exemplified, the field Krafla can also be used to explain how the concept could have operated at any field, and how this would deviate from the current operation. More specifically, the concept would mainly change how the field is operated in terms of retrieval of waste and delivery of casing. That means, if initiating the concept, casing would be directly supplied to any field in the NS, from either Florø or Risavika. Delivery of casing would be done by use of the specialized vessel. Additionally, the waste generated at the field would be retrieved by the same vessel, and further transported to Risavika for unloading.

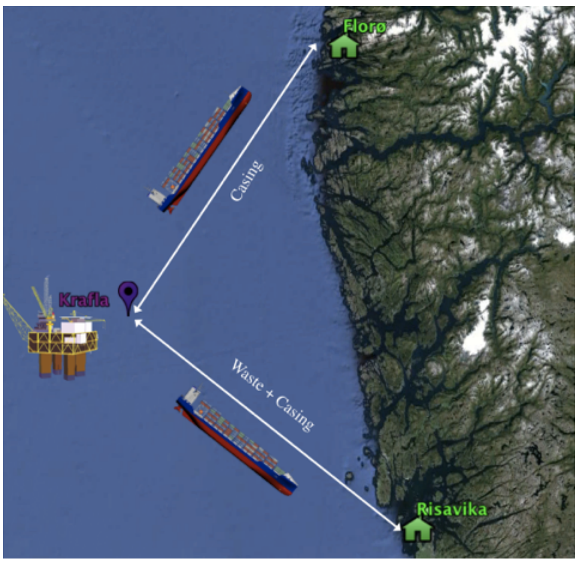

Figure 5.12: Potential Future Operation of e.g. Krafla

Value Chain – Potential Future Operation

A possible future operation can be visualized by the value chain presented in Figure 5.13, indicating how operations related to delivery of equipment such as casing and retrieval of waste could have been conducted if initiating the concept.

The value chain suggests that every rig and platform in the NS would be solely dependent on the specialized vessel. The vessel would retrieve casing from Florø or Risavika, and further deliver the necessary amount of casing to any rig or platform in the NS.

Simultaneously, the vessel would retrieve the generated waste from the field by using hoses and collecting the slop and cuttings in wet bulk tanks and CSTs, respectively. That is, crane lifts would be solely necessary in terms of delivering the casing, not for retrieving waste.

Further on, the vessel would sail to the next rig or platform in need for delivery of casing and retrieval of waste. The vessel would conduct the same activities at a number of *n* rigs and platforms, until it would have needed to sail to Florø or Risavika for retrieval of more casing, or to Risavika for pumping the collected waste to shore.

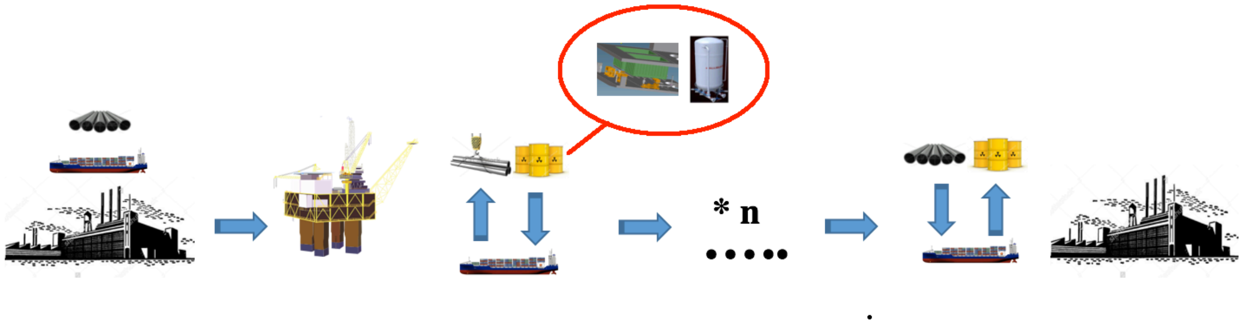

Figure 5.13: Value Chain - Potential Future Operation

Potential Future Operation – SWOT

As a part of the qualitative analyzes regarding the investigation of a possible future situation, a prioritized SWOT analysis concerning the total concept was conducted. Moreover, various contributions to the strengths, weaknesses, opportunities and threats related to the concept were presented in a SWOT analysis. Thereafter, the contributions were prioritized by seven employees possessing different roles in Halliburton, of which 1 is considered to be the most important factor.

For the complete SWOT analysis and related results, reference is made to the Excel Spreadsheet "SWOT Analysis". The results have been excerpted from the file, and can be found in Appendix A: SWOT Analysis.

Further on, the prioritizations form a bar indicating the importance of the contributions, in addition to the variance of them. That is, an importance bar of long size indicates an important contribution, while a long sized variance bar indicates that there is not consensus among the people ranking the contribution which may occur based on the people ranking the concept having different perspectives regarding what is important. Consequently, there is uncertainty related to the importance of such contributions.

Doing so, the results ensures a comprehensive insight of the concept and the importance of the various contributors. Hence, the results can provide information regarding e.g. which weaknesses Halliburton should seek to mitigate the impact of.

The most prominent results from the SWOT analysis conducted, are presented in Figure 5.14, Figure 5.15, Figure 5.16, and Figure 5.17.

S	Strengths (Internal factors)	Priority							Average	Importance	Variance
		Knut Are Strøm	Roger Iversen	Martin Toft	Henry Magne Håkstad	Per Magnus Skretting	Kristian Evjen	Aage Andreassen			
1	Capasity of slop and cuttings	17	2	5	11	3	2	5	6,4	1,6	26,8
4	Product supply: fluids , baseoil, mud, produced water etc.	4	3	3	2	4	5	14	5,0	2,0	14,3
18	Lowest cost in market	2	1	8	1	1	1	1	2,1	4,7	5,8

Figure 5.14: Strengths from conducted SWOT

W	Weaknesses (Internal factors)	Priority							Average	Importance	Variance
		Knut Are Strøm	Roger Iversen	Martin Toft	Henry Magne Håkstad	Per Magnus Skretting	Kristian Evjen	Aage Andreassen			
2	Frequency of retrieval and delivery	1	1	16	2	1	2	1	3,4	2,9	26,5
4	Vessel Stability	5	6	1	1	5	17	4	5,6	1,8	25,1
17	Long term contract for vessel	3	2	9	10	2	1	5	4,6	2,2	11,1

Figure 5.15: Weaknesses from conducted SWOT

O	Opportunities (External factors)	Priority							Average	Importance	Variance
		Knut Are Strøm	Roger Iversen	Martin Toft	Henry Magne Håkstad	Per Magnus Skretting	Kristian Evjen	Aage Andreassen			
2	Cost reduction for customer	1	1	1	1	1	1	1	1,0	10,0	0,0

Figure 5.16: Opportunities from conducted SWOT

T	Threats (External factors)	Priority							Average	Importance	Variance
		Knut Are Strøm	Roger Iversen	Martin Toft	Henry Magne Håkstad	Per Magnus Skretting	Kristian Evjen	Aage Andreassen			
2	Competition from new technology	4	2	1	2	4	1	4	2,3	4,3	1,6
3	TemporaryStorage Capacity at rig	8	3	2	3	1	2	9	3,3	3,0	6,9
4	Weather dependent	6	1	6	1	3	5	7	3,8	2,6	5,5

Figure 5.17: Threats from conducted SWOT

5.2 Quantitative Analyzes and Results

The concept`s feasibility relies on the results from both qualitative and quantitative analyzes. Hence, it was necessary to conduct quantitative analyzes in addition to the qualitative analyzes already conducted.

More specifically, the qualitative analyzes regarding the concept`s feasibility relied on technical aspects. However, the feasibility is also dependent on the various´ fields need for retrieval of waste and delivery of casing, in order to determine if the specialized vessel could have retrieved and delivered the same amounts. Also, which specifications the vessel would need to have in order to retrieve and deliver the amounts was necessary to assess.

Lastly, the concept`s potential profit with related uncertainty was assessed, as this would be essential when deciding whether to initiate the concept or not.

5.2.1 Retrieval and Delivery Analyzes - 2015

For complete analytical work on retrieval of waste during 2015, reference is made to the Excel Spreadsheet "Waste Analyzes 2015". An excerpt of the most important analyzes and related results can be found in Appendix B.1: Waste Analyzes 2015.

The analyzes presented in this section are, to a large extent, based on the amount of drilling waste delivered to Halliburton´s onshore facilities during 2015. Also, the amount of casing that was necessary to transport to offshore installations in 2015 was an important contributor to the evaluation of whether a specialized vessel could have retrieved and transported the same amount of waste and casing, or not.

In addition to using the data to identify how much waste that was received by Halliburton in 2015, the data were used to determine where the waste was generated. That is, the various rigs and platforms which contributed to the waste received were matched with coordinates for related wells, obtained from original NPD data. Hence, a file was constructed using Google Earth in order to identify and map the positions of where the waste was generated, as shown in Figure 5.18.This file has been used throughout this chapter, and can be found in the memory stick enclosed, under the name "Field Positions".

Scope of Analyzes

As earlier mentioned, the area of interest for this thesis is solely the NS. However, the internal data obtained from Halliburton comprises all rigs and platforms which delivered waste to their facilities in 2015, including rigs and platforms operating at fields located outside the NS. Therefore, different symbols and colors were used to explain the various representations, shown in Figure 5.18.

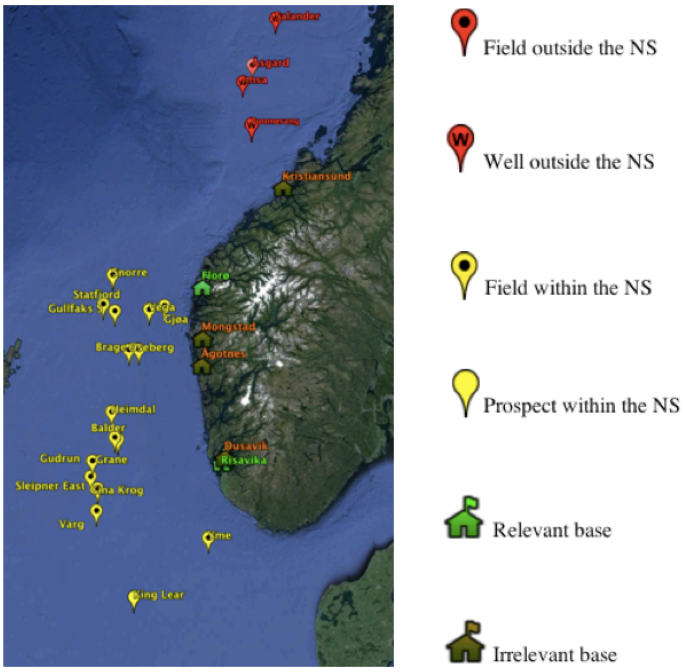

Figure 5.18: Mapping Field Locations of Waste delivered - 2015

Locations outside the NS were excluded, together with bases that are regarded as inappropriate for the concept and thus are irrelevant in further analyzes. That means, the yellow fields and prospectus[32], together with the green bases are emphasized in further analyzes.

In terms of choosing proper bases for the concept, Risavika was regarded to be the most suitable location for where waste can be delivered, due to the infrastructure and downstream solution[33] that already exists there. However, this thesis will not cover this solution.

Furthermore, Florø and Risavika were chosen to be the most suitable bases for retrieving casing as a part of the concept. That is, Florø is currently the main base for casing and was therefore evaluated to be the optimal location for retrieval of casing for this concept. However, due to Florø´s location north in the NS, it was regarded as advantageously to base the concept on one additional retrieval base located further south. Choosing the same location as the delivery base for waste was considered expedient, hence Risavika was chosen as a proper location.

[32] A mapped location of which hydrocarbon findings are regarded as possible. Hereafter referred to as a field.
[33] The solution for how waste is retrieved and further handled.

Figure 5.19 solely presents the fields and prospect located within the NS and which Halliburton received waste from during 2015, together with relevant receiving and delivery bases for the concept.

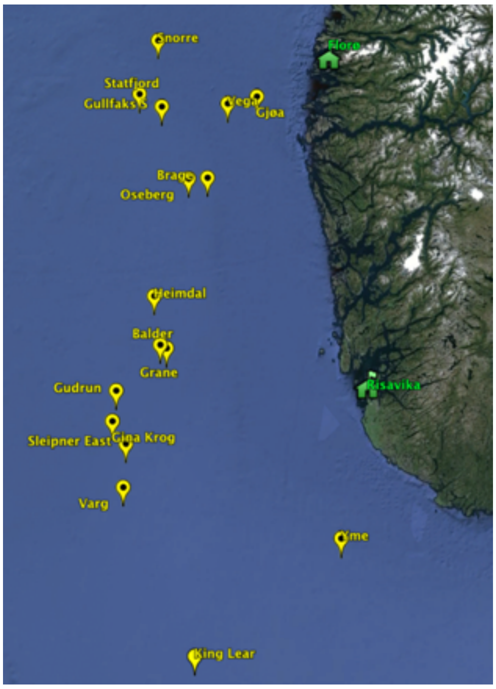

Figure 5.19: NS Field Locations of Waste delivered – 2015

Drilling Waste

Table 5.4 briefly reveals the total amount of drilling waste delivered to Halliburton´s onshore facilities from the NS during 2015, and how great the amounts of slop and cuttings were.

Table 5.4: Drilling Waste delivered from the North Sea - 2015

Drilling Waste delivered from the North Sea - 2015	
Slop [ton]	24 560
Cuttings [ton]	29 150
Total [ton]	**53 710**

Figure 5.20 presents the proportions of slop and cuttings that made up the total amount drilling waste received by Halliburton in 2015.

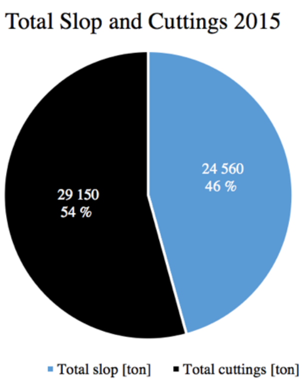

Figure 5.20: Proportion of Slop and Cuttings delivered from the NS - 2015

Moreover, analyzes provided information concerning how the waste amounts varied dependent on the month in question. Figure 5.21 presents the total amounts of slop and cuttings that Halliburton received to their onshore facilities per month in 2015. As indicated, the amounts varied to a large degree, with April as the month with the greatest peak throughout the year and July as the month with the lowest peak.

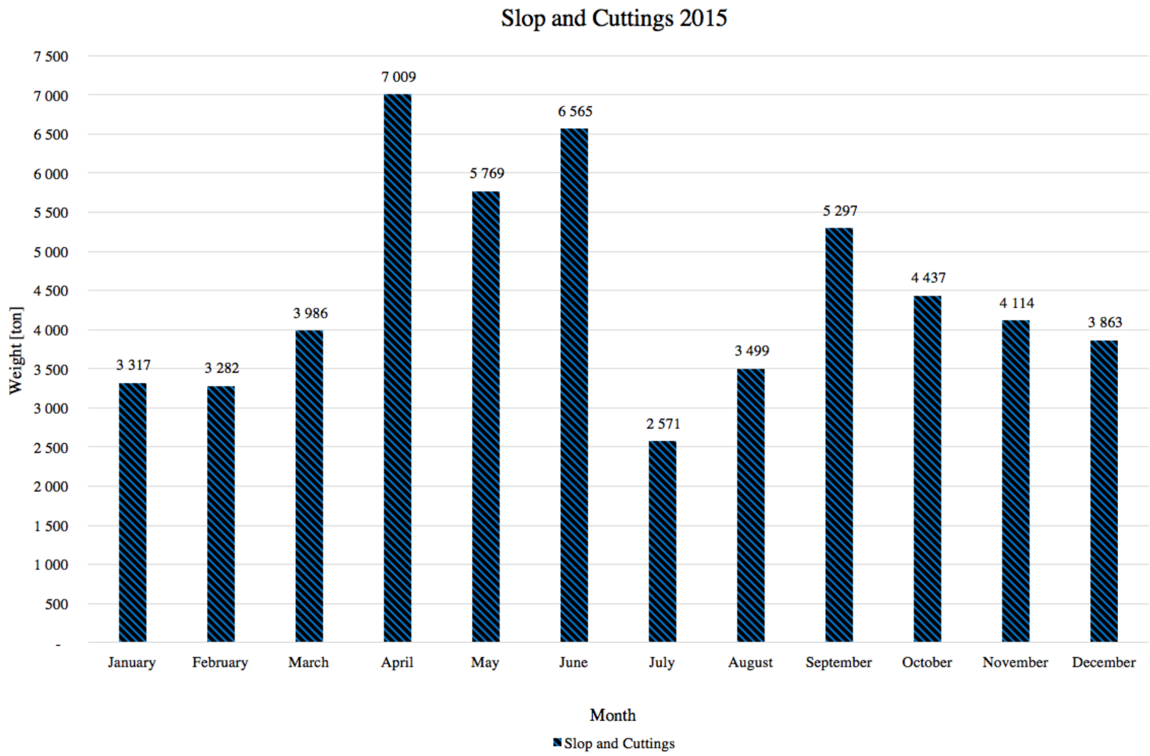

Figure 5.21: Seasonal Variations of Slop and Cuttings delivered from the NS - 2015

Furthermore, it was considered of interest to analyze how the amounts of slop and cuttings varied throughout the year, independent of each other. Figure 5.22 presents how the total weight of slop and cuttings varied throughout the year. Also, it reveals that the degree of such seasonal variations differs in terms of assessing slop and cuttings.

More specifically, the values of slop throughout the year was revealed to be relatively evenly distributed compared to the values of cuttings. This stems from the fact that cuttings are solely generated during drilling operations, which are highly dependent on good weather conditions. This phenomenon is known as Waiting On Weather[34] (WOW).

As a consequence, a peak period typically occurs in spring, as drilling activities have either been put on hold or have been delayed due to challenging weather conditions. Hence, when the operators start their drilling operations somewhat simultaneously, a peak occurs. Contrary to this, slop is generated as a result of various offshore activities and is not solely dependent on drilling activities, hence the amounts of slop during a year is more evenly distributed.

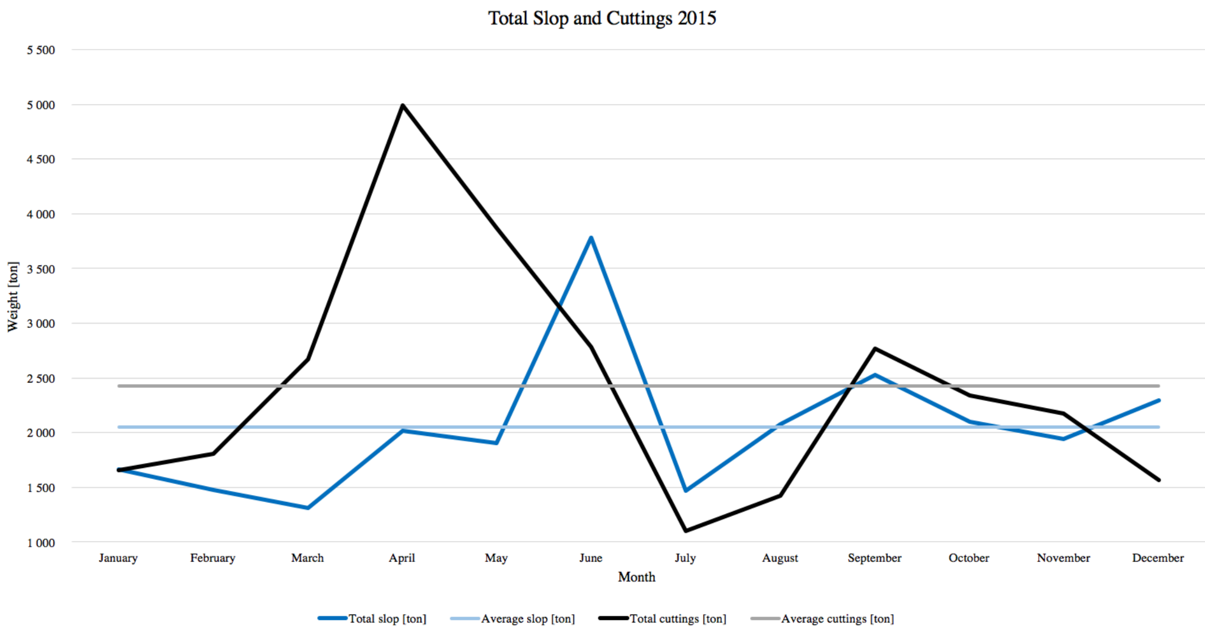

Figure 5.22: Monthly Amounts of Slop and Cuttings - 2015

Briefly summarized, the extremes and average values of slop and cuttings during 2015 is presented in Table 5.5.

Table 5.5: Extremes and Average Values of Slop and Cuttings delivered - 2015

Extremes and Average Values of Slop and Cuttings delivered - 2015			
	Minimum [ton]	**Maximum [ton]**	**Average [ton]**
Slop	1 313	3 781	2 047
Cuttings	1 102	4 990	2 429

[34] Hereafter referred to as WOW

As the monthly waste amounts varied to such an extent, it was deemed essential to further analyze which month that could be considered most critical. As seen in Figure 5.21, April was the month that had the greatest peaking value when assessing the amounts of slop and cuttings together. However, the most critical month in terms of greatest waste amount varies when assessing slop and cuttings, revealed in Figure 5.22. The peaking month in terms of slop amount in 2015 was June, while the peaking month in terms of cuttings amount was April. That is, the period of interest for further analysis did not coincide for slop and cuttings.

However, as indicated in Table 5.6, the peak value of cuttings in April deviates to a larger extent from the average monthly value of cuttings than the peak value of slop deviates from the average monthly slop value. Hence, the peak month for cuttings, April, was considered the most critical month and therefore chosen for further analyzes as it was regarded particularly interesting to analyze how the vessel could have operated during that month.

Table 5.6: Deviation from Average Monthly Waste Values delivered – 2015

Deviation from Average Monthly Waste Values delivered - 2015			
	Maximum [ton]	**Average [ton]**	**Deviation [ton]**
Slop	3 781	2 047	1 734
Cuttings	4 990	2 429	2 561

5.2.2 April – The most Critical Month in 2015

For complete analytical work on retrieval and delivery of waste and casing during the month of April 2015, reference is made to the Excel Spreadsheet "Waste and Casing Analyzes April 2015".

An excerpt of the most important analyzes and related results can be found in Appendix B.2: Waste and Casing Analyzes April 2015.

Scope of Analyzes

Which rigs and platforms that contributed to the waste delivered to Halliburton´s onshore facilities in April 2015 was analyzed. Also, the offshore installations were analyzed in terms of fields of operation, their contributing waste amounts, in addition to the dates of when the amounts were delivered.

Further on, the fields were mapped and proven to be quite geographically spread within the NS, with a center in the middle and some fields diverging from the center. The fields of interest are presented in Figure 5.23.

Figure 5.23: Fields delivering Waste - April 2015

Drilling Waste

Figure 5.24 presents the variations in amount waste delivered by the different rigs and platforms and whether the amounts consisted of slop or cuttings graphically. Moreover, Figure 5.25 clarifies the proportions of slop and cuttings delivered within the month. As presented, the proportion of cuttings was significantly greater than the proportion of slop in April. Due to this, fractioning of slop was not considered a potential option that month, as the amount sludge would have been insufficient to make a proper slurry.

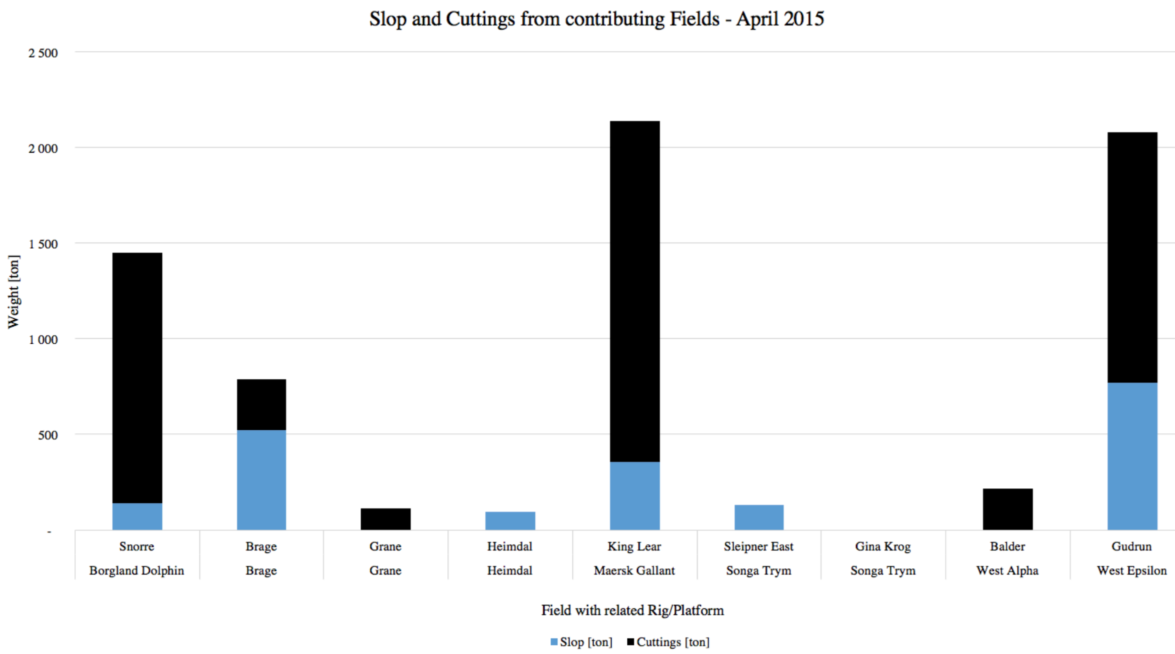

Figure 5.24: Waste Amounts delivered from Various Rigs and Platforms – April 2015

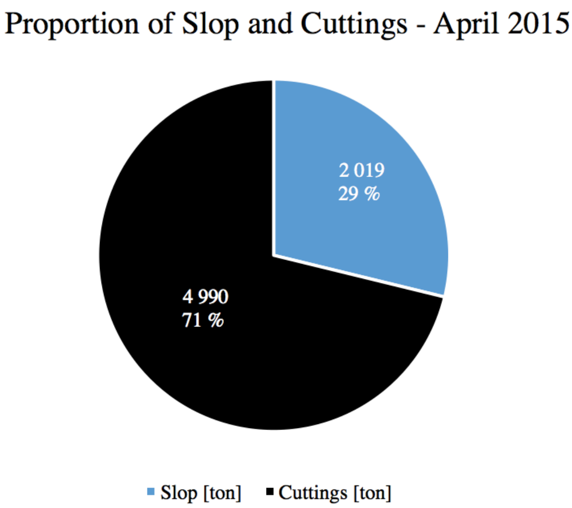

Figure 5.25: Proportions of Slop and Cuttings delivered - April 2015

Casing

In addition to waste volumes delivered, it was further regarded essential to analyze amounts of casing. More specifically, amounts of casing that would have been necessary to deliver to the fields of interest in April were determined.

An overview of data presenting meters drilled per rig and platform during April 2015 was the basis for determining meters casing needed per field of interest. However, the number of meters drilled does not equal the number of necessary meters casing, as the various types of casing used when drilling a well somewhat overlap. Furthermore, a fixed ratio for how many meters casing needed per meter drilled does not exist, as this varies in terms of e.g. the formations of where the well is drilled. Hence, a casing factor needed to be determined to be able to arrive at a representative number for the required meters of casing. By taking the overlap into account, an industry standard is recognized to be 1.2 (Lambrechts, 2016). Thus, the casing factor of 1.2 was utilized in further analyzes.

The data comprising the meters drilled per offshore installation, did not include information regarding which fields the rigs drilled at during certain times, which complicated the calculations of necessary amount of casing needed at each field as some rigs were present at more than one field during the specific time period. Hence, it was unknown how many meters the rigs drilled at the specific fields if they operated at more than one field during the month in question.

Nevertheless, as information on the amounts of waste delivered, together with which field the waste originated from, as well as detailed information on the respective drilling campaigns, a quantitative assumption was made. That is, it was assumed that the number of meters drilled at the different fields was dependent on the waste amounts generated, so that the amount casing needed at each field varied to the same extent as waste delivered from the field. Hence, proportions were calculated to ensure a realistic distribution of meters drilled per field.

For example, Table 5.7 indicates that the rig Songa Trym operated at the fields Sleipner East and Gina Krog during April 2015. The amount of waste received from the fields were 93 tons and 40 tons, respectively. With a total waste amount of 133 tons, proportions of approximately 70 % and 30 %, respectively, were calculated. Hence, as the total meters drilled by Songa Trym in April 2015 was 2 796 meters, it was assumed that 70 % of this was drilled at Sleipner East, and the rest was drilled at Gina Krog. Moreover, with a casing factor of 1.2, the related casing needed to be delivered is also presented.

Table 5.7: Extraction from Summary, Casing requirement per field – April 2015

Extraction from Summary, Casing requirement per field – April 2015					
Rig	**Field**	**Waste delivered [ton]**	**Drilled per rig [m]**	**Drilled per field [m]**	**Casing required [m]**
Songa Trym	Sleipner East	93	2 796	1 951	2 341
	Gina Krog	40		845	1 014

Figure 5.26 graphically presents meters drilled per rig or platform in April 2015 at the corresponding fields, with a related number of meters casing required.

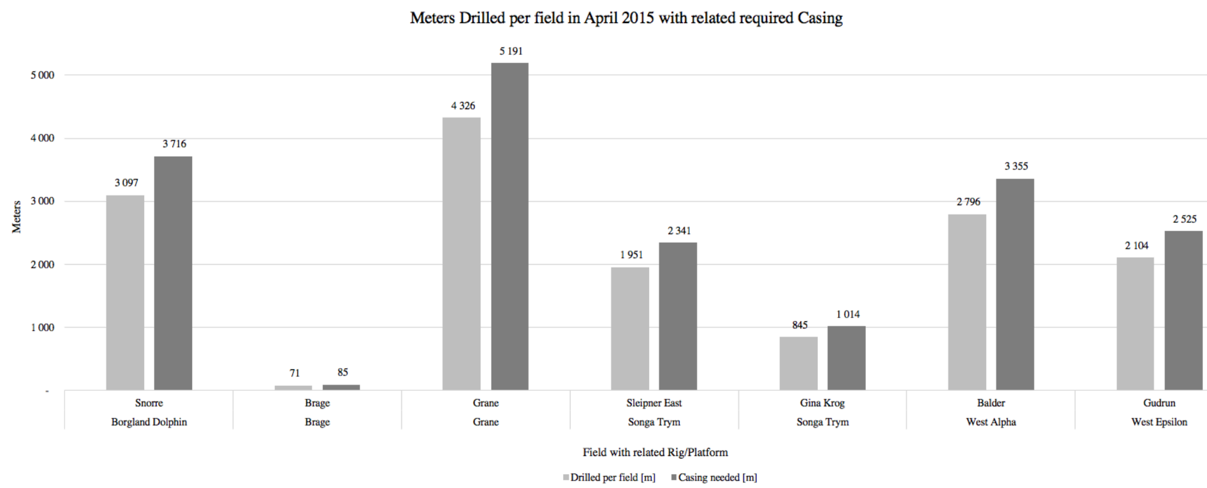

Figure 5.26: Meters drilled and Casing needed per field - April 2015

Storage Capacity of Vessel

Based on the waste amount analyzes in addition to the calculations of needed casing at the various fields, a potential route for the vessel could be determined. That means, it was necessary to see if the vessel could have retrieved the same amounts of waste and delivered the same amounts of casing, and to determine if the vessel could have operated the routes without exceeding various timeframes.

That is, the various deadlines were based on dates for when the waste was delivered to Halliburton´s facilities, to assess the vessel´s ability of retrieving the same amounts of waste within certain timeframes. Hence, a time lag was neglected in the analyzes, as the analyzes were based on information regarding *when* waste was received by Halliburton during 2015, and not *at what time* the waste actually was generated and would have been needed to be retrieved by the vessel.

As the time period for when the waste is generated is important in determining if the vessel could have retrieved it, it was considered particularly important to not exceed the temporary storage capacities on rigs and platforms. Such a temporary storage capacity would be highly necessary in order to conduct the concept at all, hence it was necessary to decide a proper and general capacity the rigs and platforms would need to have in order to having the opportunity of being a part of the concept. Thus, general storage capacities were set to be 200 tons for cuttings and 300 tons for slop.

Moreover, it should be mentioned that slop is generated on a consistent basis, while cuttings are generated more suddenly. Therefore, to determine a route with emphasis of the vessel being present at the various fields when cuttings was generated (or received, as the time lag is neglected), in addition to being present at the locations regarded most critical in terms of waste generated, determined in large degree the various tour indexes.

Potential Sailing Route

In order to determine the vessel´s required time to finish the route, the various sailing times, retrieval and delivery times, a buffer time for mobilization and demobilization of the vessel to the various locations, as well as the time it takes to unload the waste and load the casing at the bases, were necessary to calculate.

The first mentioned contributor to the vessel´s required time, i.e. the various sailing times, was calculated from measuring distances between the locations by using Google Earth and further based on the vessel sailing at a speed of 14 knots. The other contributors were calculated based on the amounts of waste needed to be retrieved from the various fields, in addition to the amounts of casing needed to be delivered. As the concept relies on these operations occurring simultaneously, the maximum time of these activities was set to be the offshore operation time. The same applies in terms of unloading waste and loading waste onshore, of which the maximum of these two comprised the onshore operation time.

To satisfy the needs for retrieval of waste and delivery of casing in April 2015, it was necessary to separate the potential route into three main tours as presented in Figure 5.27, further divided into 23 sub-tours.

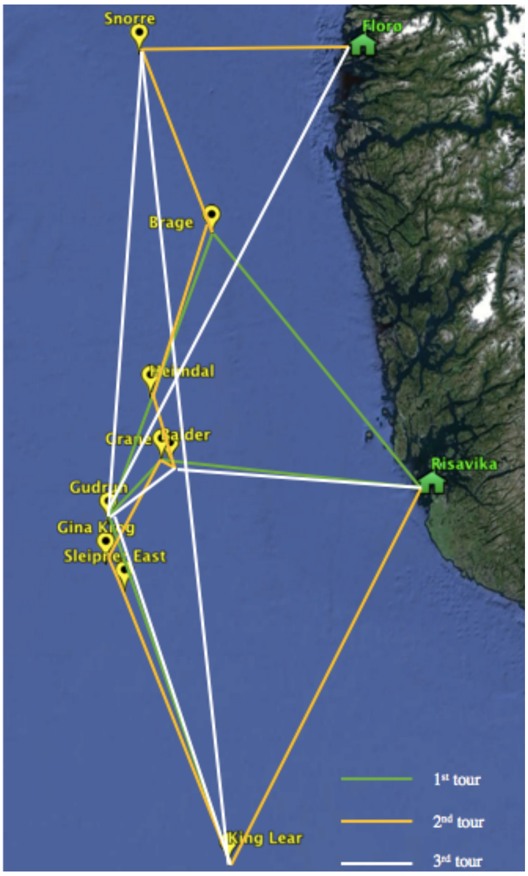

Figure 5.27: Potential Sailing Route - April 2015

As presented in Figure 5.28, both the tours of which would deliver drilling waste stay well within the vessel´s capacity limits for storing slop and cuttings.

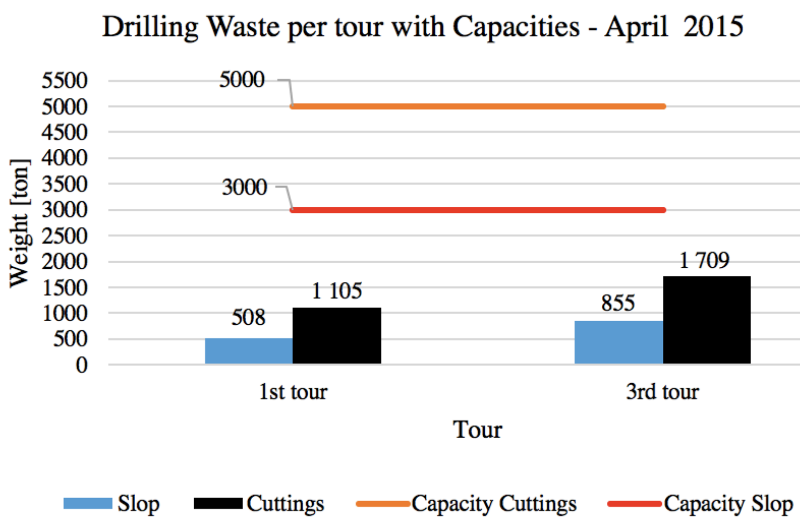

Figure 5.28: Drilling Waste per tour with Capacities – April 2015

Time Distribution

Based on the vessel´s required time to finish the route, the analyzes revealed that the vessel would have to be available in a time period of 25 days. That is, the vessel would start operating on the 6th of April, and stop operating at the 1st of May. Within this time period, it would have to sail to shore in Risavika the 12th of April to empty waste from the vessel, in addition to retrieve more casing. It would also have to sail to shore to Florø the 21st of April to retrieve even more casing, and finally sail to shore in Risavika for a final emptying of the waste the 1st of May.

Figure 5.29 presents how the vessel´s required time was allocated between sailing time, operating time offshore, and operating time onshore.

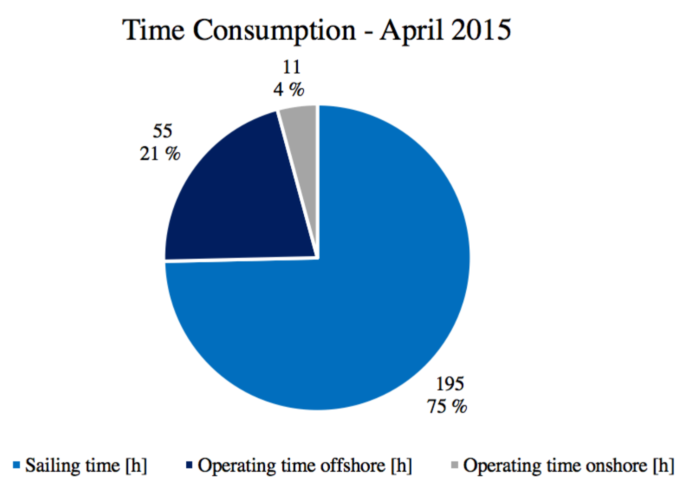

Figure 5.29: Time Consumption - April 2015

Moreover, an interesting result from the analyzes regarding required time for the vessel was that the available time within the specific time period was shown to be 331 hours, or almost 14 days. The total utilized time within the same time period was 269 hours, or 11 days. That means, the available time was greater than the utilized time within the specific time period, visualized in Figure 5.30.

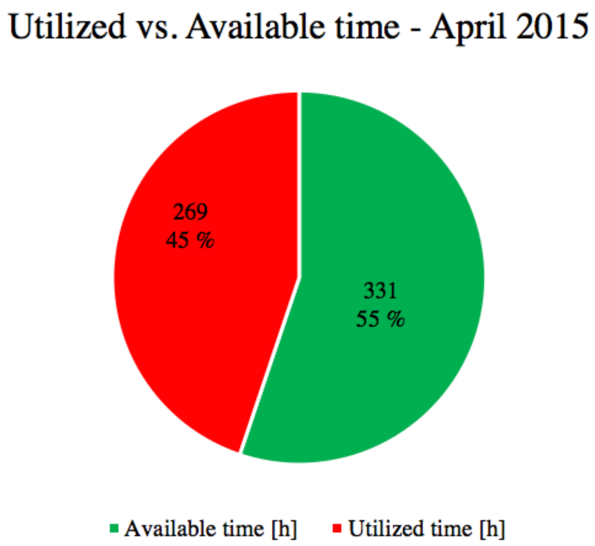

Figure 5.30: Utilized vs. Available time - April 2015

The results from the analyzes indicate that it would be possible to conduct the concept by use of one vessel during the month considered most critical and still have available time. Hence, it was regarded as interesting to challenge the concept by developing a fictional month and analyze how the vessel could have operated in such a month.

5.2.3 Fictional month 2015

For complete analytical work on retrieval and delivery of waste and casing during the fictional month of 2015, respectively, reference is made to the Excel Spreadsheet “Waste and Casing Analyzes Fictional month 2015”.

An excerpt of the most important analyzes and related results can be found in Appendix B.3: Waste and Casing Analyzes Fictional Month 2015.

The fictional month was custom designed in order to make the model more complex and extensive, and to assess a “worst-case scenario” that would challenge the vessel´s capacity. Also, as the available time within April was significant compared to the utilized time, it was considered essential to see if the vessel could have conducted a more complex and extensive route by sailing with a speed of 10 knots per hour. Hence, the former model comprising fields within the NS which delivered waste to Halliburton during 2015 was expanded and further challenged in terms of a slower moving vessel.

It was considered particularly important to include newly developed fields, in addition to fields that Halliburton earlier have received waste from and which are assumed to generate larger amounts of waste in the years to come, to get a comprehensive insight into which amounts Halliburton potential will have to deal with in the years to come. Doing so, an understanding of how a potential future situation would look like and how the vessel could have operated then could be obtained.

More precisely, a model of a fictional month was constructed based on three field-categories:

1. The fields within the NS which delivered waste to Halliburton during 2015
2. Newly developed fields
3. Fields which previously have contributed to the waste received by Halliburton, but which did not use their services in 2015

Scope of Analyzes

As for the former model, the fields delivering waste to Halliburton´s facilities during 2015 were still considered necessary to include, as these fields reflect the current situation. In terms of waste amounts and necessary casing for the rigs and platforms contributing to the waste received in 2015, an average monthly value was estimated for the related fields from the yearly value for each rig and platform, and divided by the number of months within a year. However, as the newly developed fields have not yet delivered waste, either to Halliburton or at all, estimates were necessary for being able to determine a contributing monthly value for such fields.

Newly developed fields were considered essential to include, as they will consistently generate large amounts of waste and need a significant amount of casing delivered in the years to come. For these fields, Statoil´s forecasts were used to determine waste and casing amounts. More specifically, the Utsira High[35] was regarded as essential to look further into. This area comprises the fields Gina Krog, Johan Sverdrup, Ivar Aasen and Edvard Grieg, of which only the first field delivered waste to Halliburton in 2015 and hence was already mapped. The three other field developments have recently been initiated, for this reason, drilling and production activities have barely started at these fields.

The estimates for waste amounts and casing necessary for the newly developed fields were conducted by Statoil/Halliburton, and are based on predictions of number of wells that will be drilled in the years to come, with their related aspects. These vary in terms of how many years the predictions are based on. Thus, there is uncertainty related to these data. It should be mentioned that some fields, e.g. Gina Krog, is relatively newly developed but has delivered waste to Halliburton within 2015. Therefore, data for this field exist. However, the predictions indicate that these data present a waste amount too small, and a number of meters drilled too few, due to the field being in a startup phase. For that reason, it was considered more proper to use the predictions for such fields for further analyzes.

Lastly, fields which earlier have been great contributors to the amounts of waste that Halliburton receives have been included, even though these fields did not make use of Halliburton´s onshore waste facilities in 2015. However, these fields are regarded as likely to generate great amounts of waste in the future, and will therefore need retrieval of this in addition to supply of casing.

Halliburton received waste from these fields in 2014 and therefore had access to similar data as for the fields contributing in 2015. Hence, data from 2014 were used as a basis with some adjustments to ensure a realistic picture of their future contributions to the waste amount needed to be retrieved, and amounts casing needed to be delivered.

[35] A limited area containing petroleum, of which several fields can produce from.

More specifically, the data from 2014 were downgraded by 20 % due to the greater activity in the NS in 2014 compared to the activity in 2015. This applies to the fields Fram, Troll, Tordis and Visund, located north in the NS. Due to including these, in addition to the Utsira High, a geographic spread was ensured. Other fields that are predicted to have relatively great amounts of waste generated in the years to come, are fields located outside the Bergen region in the NS; Ringhorne, Valhall, Ekofisk, Eldfisk and Martin Linge, among others. However, as these fields have injection as their primary waste solution, the amounts of waste needed to be transported to shore are small.

The various locations of interest for the fictional month is presented in Figure 5.31, with an additional close up in in Figure 5.32.

Figure 5.31: Fields of Interest – Fictional month 2015

Figure 5.32: Close-up, Newly developed and Likely fields– Fictional month 2015

Drilling Waste and Casing

The waste amount analyzes revealed the total amount of drilling waste that would have needed to be retrieved within the fictional month constructed. This is presented in Table 5.8, together with the shares of slop and cuttings.

Table 5.8: Total Amount of Drilling Waste - Fictional month 2015

Total Amount of Drilling Waste - Fictional month 2015	
Slop [ton]	5 397
Cuttings [ton]	7 412
Total [ton]	12 809

Moreover, the amounts of slop and cuttings that would have needed to be retrieved from the various fields of interest during the fictional month, is presented in Figure 5.33.

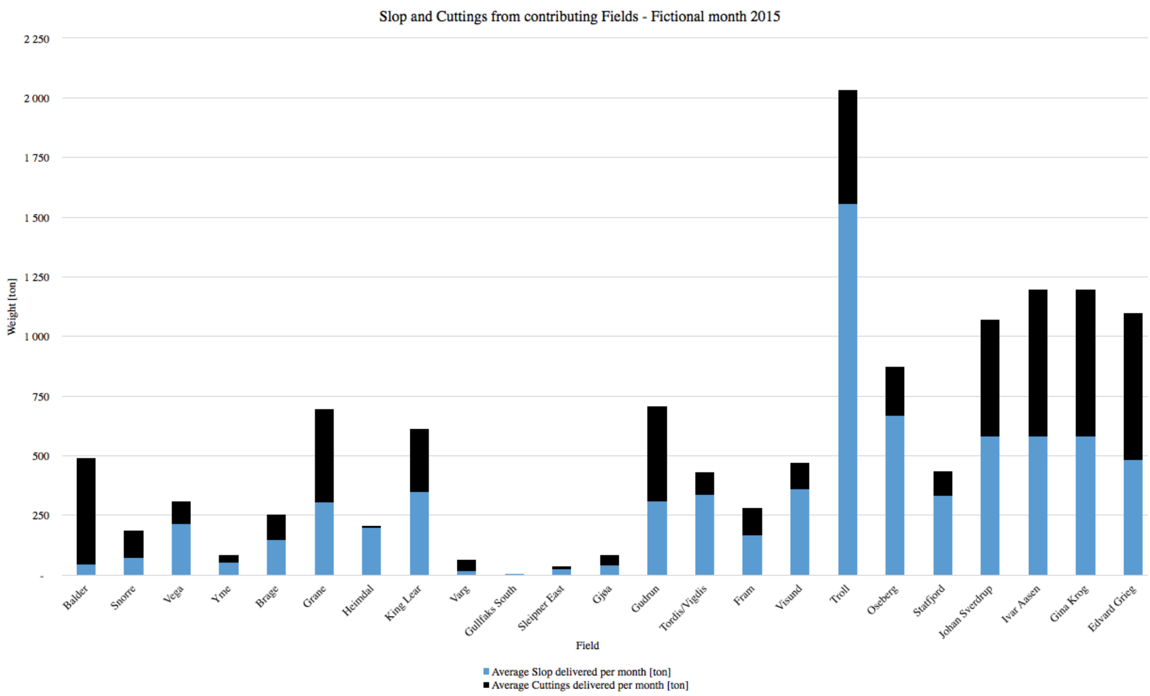

Figure 5.33: Waste Amounts delivered from Various fields - Fictional month 2015

Overall, a result from the analyzes presented that the amount waste which Halliburton received in 2015 from the NS represents approximately 28 % of the total waste sent to shore. However, by including newly developed fields and fields that delivered great amounts of waste to Halliburton before 2015, this proportion increased to approximately 80 % in a fictional month. As mentioned, fields that have injection as their primary waste solution were not included in the estimations of waste amount in the fictional month. The amounts belonging to these fields comprise the rest of the proportion not delivered to Halliburton in a fictional month, i.e. 20 %.

In terms of determining the necessary amount of casing for the various fields in the fictional month, the same approach as used for determining the necessary amount of casing for the various fields in April was used. However, as we are now speaking of a fictional month, the information regarding grand total meters drilled by each rig or platform in 2015 was used and divided by the number of months within a year. As for waste, necessary casing for newly developed fields and fields that Halliburton did not provide their services to in 2015, was estimated.

Figure 5.34 visualizes the required number of meters casing at each of the fields of interest.

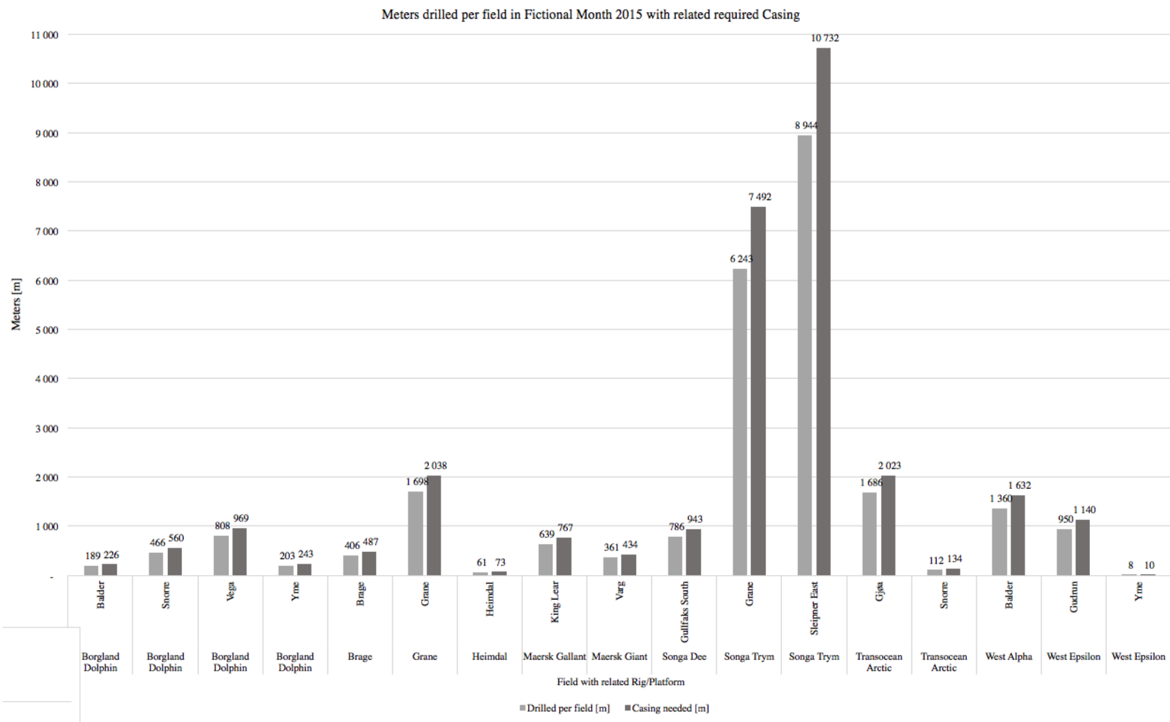

Figure 5.34: Meters drilled and Casing needed per field - Fictional month 2015

The waste amounts and necessary meters casing related to the various rigs and platforms, and thus fields, indicated how many times the vessel would have needed to visit the various fields. That is, the number of necessary visits for the vessel was based on the extent of waste needed to be retrieved, in addition to casing needed to be delivered.

Potential Sailing Route

Based on the analyzes, a potential route for the vessel was compiled. Moreover, to satisfy the needs regarding retrieval of waste and delivery of casing in the fictional month, it was necessary to separate the potential route into six main tours presented in Figure 5.35, further divided into 36 sub-tours of which the last sub tour in each main tour represents the vessel having to sail to shore to deliver waste, retrieve casing, or both of the above.

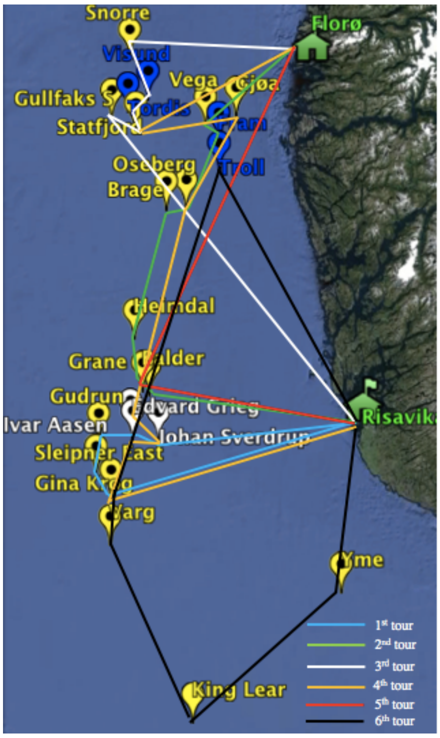

Figure 5.35: Potential Sailing Route - Fictional Month 2015

Figure 5.36 presents the various tours which would deliver waste to shore in the fictional month constructed, with the vessel´s capacities for storing slop and cuttings. As indicated, all the tours stay well within the capacity limits.

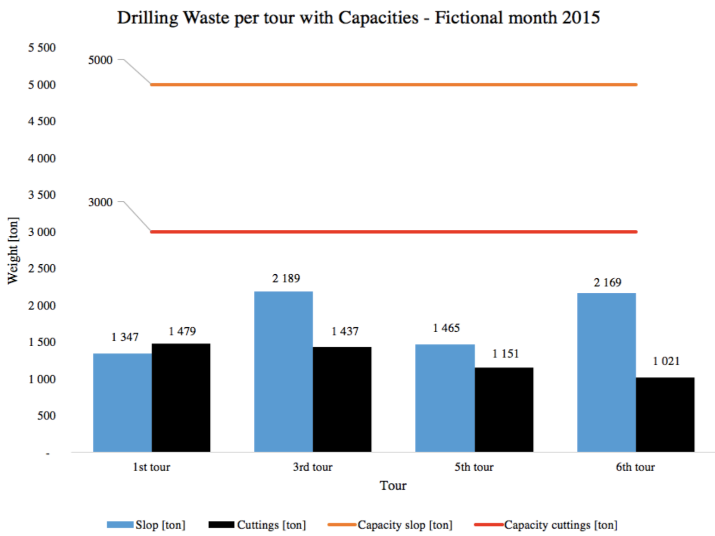

Figure 5.36: Drilling Waste per tour with Capacities - Fictional month 2015

Time Distribution

Based on the vessel´s required time to finish the route, the analyzes revealed that the vessel would have to be available in a time period of approximately 19 days in a fictional month. That is, the vessel would start operating at the 1st in the fictional month, and stop operating at the 20th in the same month. Within this time period, it would have to sail to shore in Risavika the 4th, 11th and 16th to empty waste from the vessel, in addition to retrieve more casing. The vessel would also have to sail to shore to Florø the 8th and 15th to retrieve more casing, and finally the vessel could have sailed to shore in Risavika for a final emptying of the remaining waste the 20th in the fictional month.

Figure 5.37 presents how the vessel´s required time to finish the route between the various fields would have been allocated between sailing time, operating time offshore, and operating time onshore.

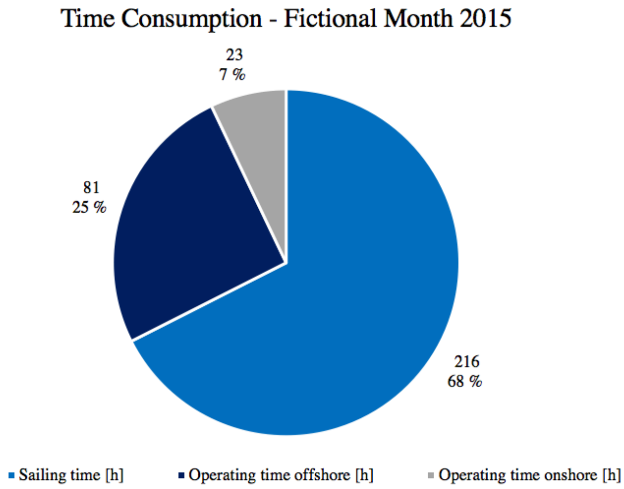

Figure 5.37: Time Consumption - Fictional month 2015

As for the analyzes for the month of April, a particular interesting result obtained from the analyzes on required time was the distribution of utilized and available time for the vessel´s operation during the fictional month. It was revealed that there would still be 123 hours of available time within the specific time period, or approximately 5 days.

The total utilized time within the same time period was shown to be 333 hours, or approximately 14 days. That means, the utilized time was almost three times greater than the available time within the specific time period, presented in Figure 5.38. Comparing this to the utilized vs. available time in April, the available time does no longer exceed the utilized time within the specific time period.

Hence, it can be stated that the vessel would utilize time better in the fictional month, that is, the difference changes from being more utilized hours than available hours, to having more available hours within a month than necessary utilized hours.

However, even though the analyzes indicates that there would be available time theoretically, it could be considered necessary to include a buffer time in case of e.g. bad weather.

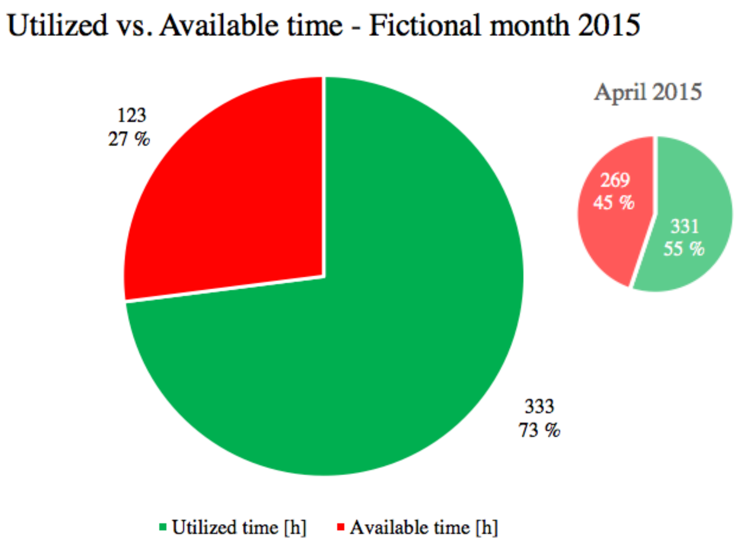

Figure 5.38: Utilized vs. Available time - Fictional month 2015

Fractioning

The analyzes also revealed that the proportions of slop and cuttings were relatively evenly distributed in the fictional month, as illustrated in Figure 5.39. As a result, fractioning was considered an option for the amounts of slop. By using three evaporator tanks with capacities of 2.5 m^3/h each, and efficiencies of 50 %, the proportions of sludge and cuttings are mixed into a slurry and can be pumped to shore. The proportion of slurry varies from approximately 6 % to 100 %, and for this reason, measures would have to be considered in terms of how much slop that should be put into the evaporator. That means, when the slurry consists of is as little as 6 % sludge, the proportion of cuttings is so large that the pump would have problems pumping the slurry to shore. Hence, when the amounts of slop are minimal compared to the amounts of cuttings, fractioning slop is considered undesirable.

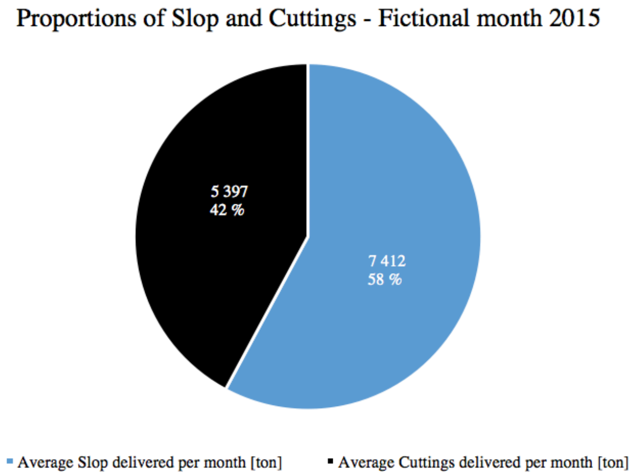

Figure 5.39: Proportions of Slop and Cuttings - Fictional month 2015

The proportions of sludge and cuttings should be relatively evenly distributed to get an efficient pumping of the waste to shore. In terms of this, the specific gravity[36] (SG) of the sludge becomes particularly important. The SG of the sludge is calculated from the average of the SG for the sludge and the SG for the cuttings, with related proportions of these substances in the slurry. From the analyzes, the average SG of the slurry based on the fictional month is 1.61 ton/m^3. This should not be a problem for the pump.

As presented in Table 5.9, the main tours which would conduct the pumping of the slurry to shore varies in terms of the SG, from 1.57 in main tour 6 to 1.67 in main tour 1.

Table 5.9: Pumping Slurry to Shore – Fictional month 2015

Pumping Slurry to shore – Fictional month 2015			
Tour	**Average SG Slurry [ton/m^3]**	**Slurry [ton]**	**Pumping to shore [h]**
1st	1.67	2 152.5	4.8
3rd	1.67	2 531.6	5.6
5th	1.63	1 883.7	4.2
6th	1.57	2 105.7	4.7

[36] Hereafter referred to as SG.

5.3 The Specialized Vessel

The amounts of waste needed to be retrieved from the offshore installations, as well as the amounts of casing needed to be supplied, indicated in what order of magnitude the vessel would have needed to be. Also, this provided an indication of what the various aspect ratios should be, with related necessary storage capacities for waste and casing.

A proper vessel for the concept was found to be an Offshore Supply Vessel (OSV). The vessel´s aspect ratios are given in detail in Appendix C: Vessel Specifications.

Having chosen a proper vessel, it was further analyzed how the various units should be placed on the vessel.

As mentioned in section 5.1.2, casing would be stored on deck while the waste tanks would be stored below deck to ensure stability of the vessel. According to the results from the conducted SWOT analysis, more specifically the weaknesses presented in Figure 5.15, vessel stability was considered as the third most important contributor to the concept´s weaknesses, and should therefore be carefully considered.

5.3.1 Storage Capacity below Deck

The vessel´s volume ratio determined the possible number of tanks that could be stored, with related weight. The various tanks that would be stored below deck are specified in Table 5.10, with related quantities.

Table 5.10: Specialized Vessel - Units to be stored below deck

Specialized Vessel – Units to be stored below deck	
Name of unit	**# of units**
Wet Bulk Tanks	18
CSTs	4
Evaporators	3
Slurrification Units	2
Putzmeister Pumps	2

As described in section 5.1.2, CSTs and wet bulk tanks are risk averse options in terms of HSE, hence these would be the primary choice for tanks related to this concept. The wet bulk tanks would be used for storing the waste retrieved, in addition to sludge and water extracted from the fractioning process. Also, these tanks would comprise drilling and completion fluids to be delivered. Table 5.11 presents the volume capacities for the wet bulk tanks and the CSTs, together with the total volumes these would comprise.

Table 5.11: Specialized Vessel - Storage Capacity below deck

Specialized Vessel – Storage Capacity below Deck		
Unit	**Volume capacity per unit [m^3]**	**Total Volume [m^3]**
Wet Bulk Tank	250	4 500
CST	375	1 500

In terms of weight, the vessel´s capacity for storing wet bulk tanks and CSTs is presented in Table 5.12.

Table 5.12: Specialized Vessel - Weight Capacity

Specialized Vessel – Weight Capacity		
Unit	**Volume [m^3]**	**Weight [ton]**
Wet Bulk Tanks	4 500	5 000
CSTs	1 500	3 000

The placing of the various units is visualized in Figure 5.40.

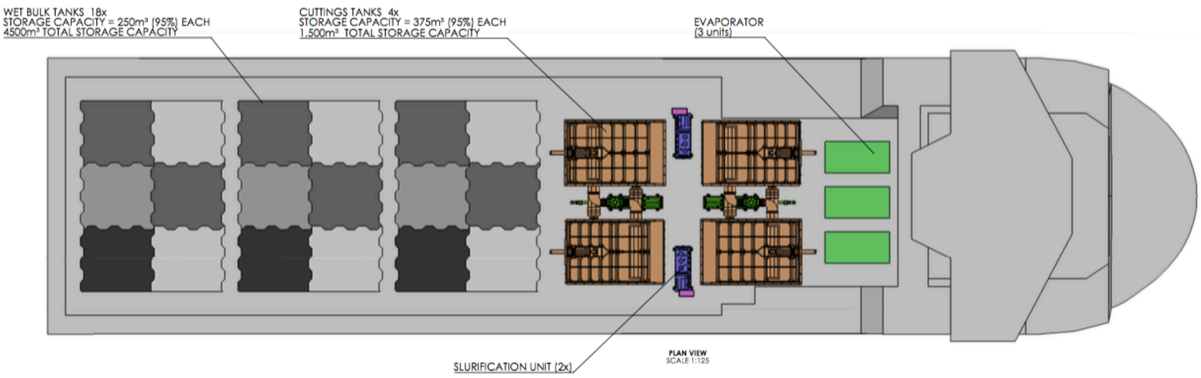

Figure 5.40: Specialized Vessel – Placing of Various Units below Deck

5.3.2 Storage Capacity on Deck

As casing would be stored on the deck of the vessel, the deck ratio of 1 220 m^2 determined the casing capacity. Based on the flat rack specifications from Table 5.13, the maximum and preferred number of flat racks to store on deck ,with related weights, are presented in Table 5.14.

Table 5.13: Flat Rack Specifications

Flat Rack Specifications	
Length [m]	13
Width [m]	2.236
Weight [ton]	32
Area [m^2]	29.068

Table 5.14: Specialized Vessel - Storage Capacity on Deck

Specialized Vessel – Storage Capacity on Deck	
Max Area [m^2]	1 220
Max # of FRs	40
Max Weight [ton]	1 280
Average # of FRs	30
Average Weight [ton]	960

A visualization of how the FRs would be stored on deck, is presented in Figure 5.41.

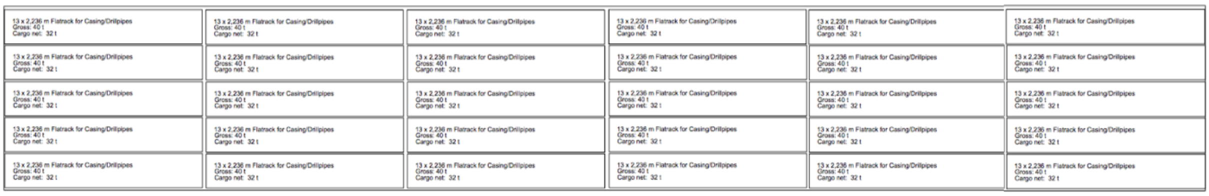

Figure 5.41: Specialized Vessel – Placing of Flat Racks on Deck

Moreover, as explained in section 5.1.2, CTTs could be placed on deck in the event that additional storage capacity for cuttings would be required, and if the casing does not take up the whole area. This is visualized in Figure 5.42.

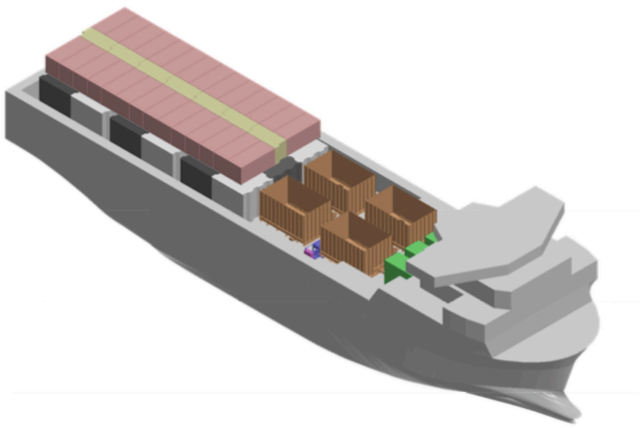

Figure 5.42: Specialized Vessel – Placing of CTTs on deck

5.4 Economic Analyzes with related Uncertainty

For complete analytical work on the economic perspective related to the concept, reference is made to the Excel Spreadsheet “BC Specialized Vessel”.

It was considered necessary to conduct economic analyzes, as it would not be an option to initiate the concept if these would present negative outcomes. As explained in section 3.4.1, the project is assumed to be profitable for Halliburton if the value of the NPV is greater than zero, and the concept will therefore be regarded as potential to initiate.

The economic analyzes were based on the expenses and revenues related to the concept, of which the expenses are comprised of both CAPEX and OPEX. Compiled, the expenses and revenue represent the potential NPV.

Some inputs that were used in the calculations are necessary to specify, and are presented in Table 5.15.

Table 5.15: General Inputs - NPV Analysis

General Inputs - NPV Analysis	
Discount rate	11 %
Project Lifetime	8 years
Yearly Operating days for Vessel	355
Yearly Escalation	2 %
Daily Leasing rate, incl. 8 % risk premium	$ 19 980
Yearly Salary Logistics Operator	$ 120 000
Yearly Allotted Assets	$ 1 000 000

As described in section 3.4.1, a proper discount rate should reflect the degree of risk related to a project. In terms of this concept, the discount rate was set at 11 %. This is a pre-determined and specific discount rate for Halliburton´s projects, reflecting the degree of risk involved to similar projects as the evaluated concept.

Moreover, the project`s lifetime was set to be eight years. That means, it is assumed that if the operators want to buy the services provided by the concept, they would commit to a contract that lasts for eight years. A period of eight years is a common duration of a contract within the specific industry. However, the SWOT analysis revealed that obtaining a long-term contract for the vessel was considered to be the second greatest weakness related to the concept, presented in Figure 5.15. Anyhow, the size of the bar reflecting the variance indicates that there is low degree of consensus among the individuals ranking this contributing factor.

Expenses associated with such a concept, are to a large extent based on the investment of the vessel with related reconstruction costs. The latter costs are necessary to include, as it would be essential to rebuild the vessel in order to make it more suitable for the concept.

However, if initiating the concept, expenses related to investment and reconstruction would apply a ship-owner, not Halliburton. That is, the concept would be based on Halliburton leasing the vessel from a ship-owner during the expected lifetime of eight years, at a daily rate in year one of $ 19 980, included an 8 % risk premium of e.g. reconstruction costs and a subsequently 2 % yearly escalation. The yearly escalation reflects growth in a financial perspective. Included in the daily rate, are costs related to manpower in order to operate the vessel, operating-, insurance- and port costs, in addition to repair and maintenance costs.

However, manpower to support the vessel from shore are not included in the rate. That is, there would be need for two logistics operators, with an assumed yearly salary in year one of $ 120 000 per operator and a subsequently 2 % yearly escalation.

Moreover, Halliburton would sublease the vessel to the operators. This is a part of Halliburton´s strategy, as the organization does not wish to undertake the risk of owning e.g. vessels. However, in order for a ship-owner to commit to such an investment, it needs to be ensured that the investment still would be valuable after the project´s lifetime. Hence, a yearly sum of $ 1 000 000 was included in the expenses applicable to Halliburton, to reflect allotted assets that potentially could buy the vessel from the ship-owner after eight years have passed, unless it would be desirable to renew the contract.

In terms of Halliburton subleasing the vessel to the operators, the daily rate that these companies are assumed to be willing to pay for the vessel´s services, would mainly comprise Halliburton´s potential revenue related to the concept. The various assumed daily rates based on the current recessionary period and within the project´s life time are presented in Table 5.16.

Table 5.16: Assumed Daily Rate for the Vessel – NPV Analysis

Assumed Daily Rates for the Vessel – NPV Analysis	
Minimum [$]	21 250
Most Likely [$]	23 750
Maximum [$]	26 250

Besides the daily rate, a second contribution to Halliburton´s potential revenue was calculated. That means, a yearly “pass through” income related to bunker consumption was necessary to include. More specifically, a yearly cost of bunker consumption was calculated from the estimated bunker consumption during a fictional month. The bunker consumption varies in terms of the vessel´s status, that is, if the vessel is using DP, if it is under transportation, or if it is located at shore. This is a cost that would apply Halliburton.

However, if buying the vessel´s services, it would be the operators paying for this in addition to an 8 % premium. Hence, a yearly "pass through" income of $ 48 666 would apply Halliburton in year one, with a subsequently 2 % yearly escalation. This is summarized in Table 5.17.

Table 5.17: Income Bunker Consumption, Pass Through – NPV Analysis

Income Bunker Consumption, Pass Thru – NPV Analysis	
Yearly Cost of Bunker [LNG]	$ 4 866 581
Premium	8 %
Pass Through Income, year 1	$ 48 666

The potential NPV was calculated to be $ 210 440, based on the general inputs, the assumed expenses and the most likely revenue that would apply Halliburton if initiating the concept.

However, it was regarded as necessary to include sensitivity analyzes to determine how vulnerable the NPV is to fluctuations related to some of the variables. More specifically, it was regarded as particularly interesting to see how the NPV would change relative to changes in the daily rate that the operators would be willing to pay for the vessel´s services, as this rate will change in terms of market conditions.

Furthermore, to evaluate at which daily rate the NPV would be equal to zero, i.e. the break-even point, was regarded as an interesting result to obtain and was found by using Excel´s function "Goal-Seeking". Thus, based on the values presented in Table 5.16 and values in between them, Figure 5.43 was constructed.

As presented in more details in Figure 5.43, the minimum daily rate would provide a negative NPV. The NPV would continue to be negative all the way to the break-even point, where it changes to become positive and is therefore positive for all daily rates above the break-even point. As the NPV is assumed to have no limitations in this example it would continue to increase with an increased daily rate. An excerpt from the various NPV values is presented in Table 5.18.

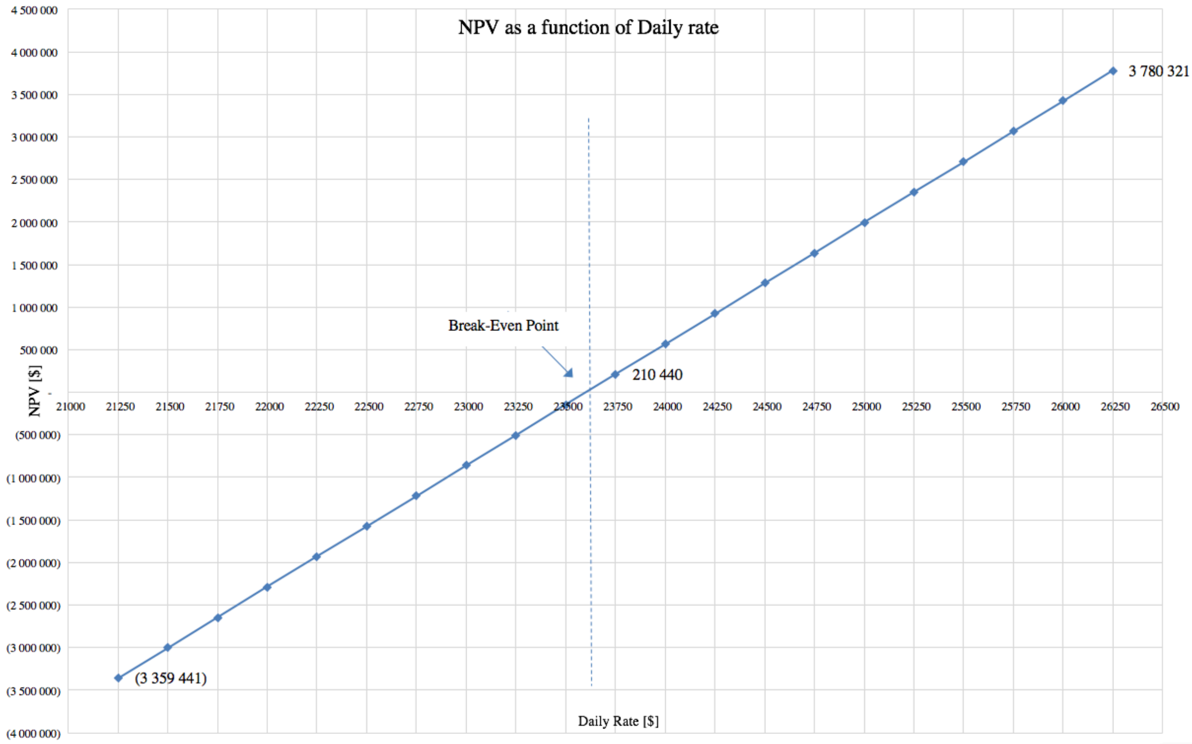

Figure 5.43: NPV as a function of Daily Rate

Table 5.18: NPV as a function of Daily Rates

NPV as a function of Daily Rates		
Daily rates	**Daily rate [$]**	**NPV [$]**
Minimum	21 250	-3 359 441
Most Likely	23 750	210 440
Maximum	26 250	3 780 321
Break-Even	23 603	0

The NPV does not only vary in terms of daily rate, in fact, all the variables have the ability of changing this value. Particularly important is the discount rate, which reflects risk involved with the concept. As presented in Figure 5.44, the NPV changes if the discount rate changes. That means, an increased discount rate results in a decreased NPV.

Another result of interest in order to determine the profitability of the concept, was the IRR. The potential IRR for the concept was calculated to be 15 %, meaning that the concept would break-even if the discount rate was set to be 15 %. This is also presented in Figure 5.44.

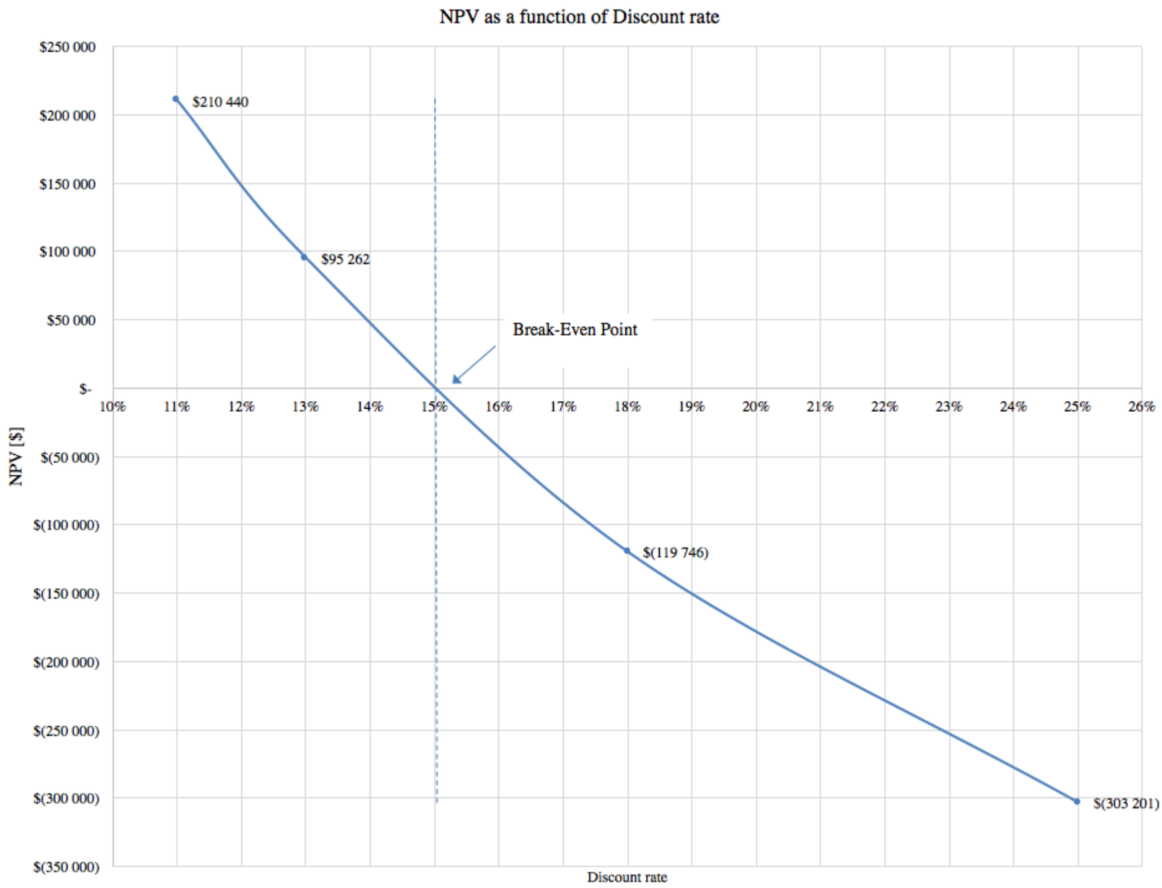

Figure 5.44: NPV as a function of the Discount Rate

As explained in section 3.4.1, the rule of NPV states that a positive NPV indicates that a project will be profitable. According to this, the concept would result in earnings if initiated. The same section explains that the NPV is positive for discount rates lower than the IRR, and negative for discount rates greater than the IRR, and that one should accept a project if the IRR is greater than the discount rate. That is, the IRR for the concept is greater than the discount rate, which results in a positive NPV. Hence, the rules for the IRR and the NPV coincides and provides the same conclusion on the financial performance related to initiating the concept.

5.4.1 Monte Carlo Simulations

Further on, Monte Carlo simulations were conducted in order to reflect risk related to the value of the NPV to a larger extent than solely what is reflected in the discount rate. Thus, the simulation was a continuation of the sensitivity analysis, hence variations to the daily rate for the vessel was still emphasized. For complete analytical work on the economic perspective with related uncertainty based on Monte Carlo simulations, reference is made to the Excel Spreadsheet "BC Specialized Vessel - Monte Carlo Simulations".

Additionally, the dollar exchange rate was of particular interest to properly reflect the risk associated with this variable. It was deemed imperative to select a representative range for the dollar exchange rate, hence, data from Norges Bank concerning the rate from the last 15 years was used.

The various values for the daily rates and the dollar exchange rates formed two triangular distributions, which further on were used to determine various outcomes of the NPV in @Risk. The simulation conducted was based on 10 000 iterations to ensure stable output statistics. The inputs of daily rates and the inputs of dollar exchange rate are presented in Table 5.16 and Table 5.19, respectively.

Table 5.19: Dollar Exchange Rate – NPV Analysis

Dollar Exchange Rate – NPV Analysis	
Minimum [NOK/$]	5.61
Average [NOK/$]	6.61
Maximum [NOK/$]	8.99

As presented in Figure 5.45, a worst-case scenario would provide a NPV of - $ 5 863 532, reflecting that the revenue is the lowest of possible projections. Contrary, a best-case scenario would provide a NPV of $ 18 034 218, reflecting that the revenue is the highest of possible projections. A most likely scenario, of which the revenue is based on an average daily rate and an average dollar exchange rate, would provide a mean NPV of $ 4 259 258.

Also, Figure 5.45 indicates that there is a 95 % probability that the NPV would be in the confidence interval of - $ 3 360 000 to $ 12 560 000, i.e., the values vary to a large extent within the confidence interval.

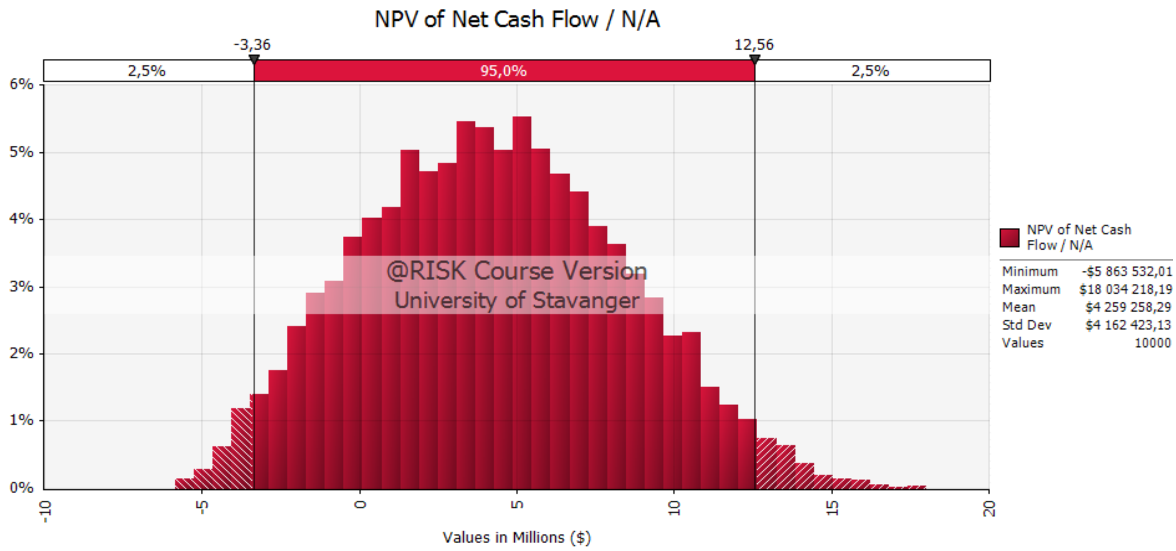

Figure 5.45: NPV as a function of Daily Rate and Dollar Exchange Rate

Further on, Figure 5.46 shows that there is an 83.2 % probability that the NPV is greater than zero.

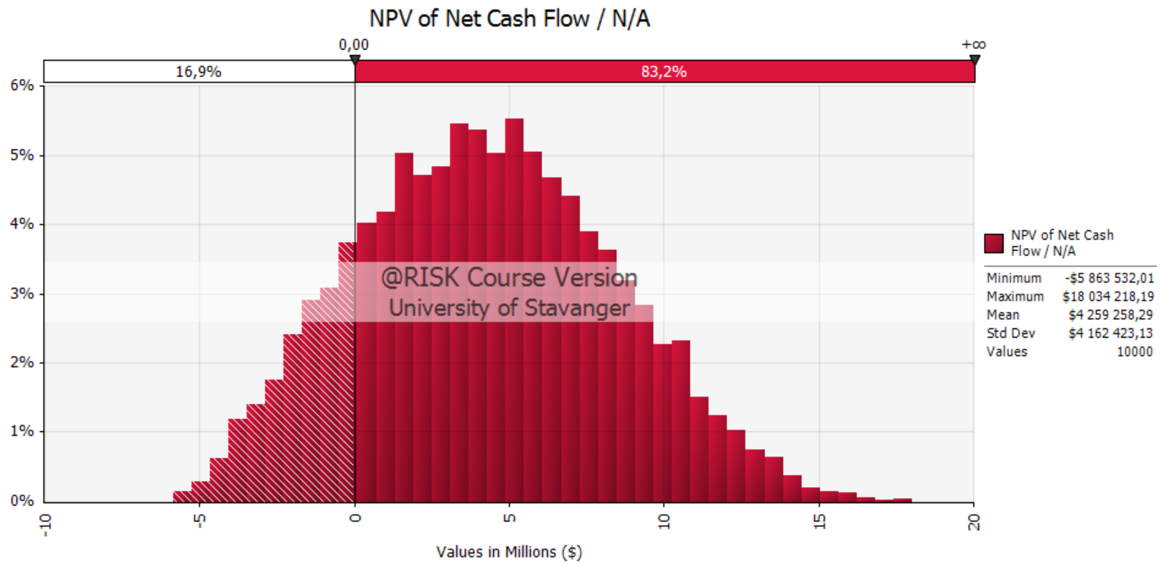

Figure 5.46: Probability of obtaining a NPV greater than Zero

As the extremes of the confidence interval are very sparse, it was considered interesting to analyze to what extent the various inputs, i.e. the various daily rates and the dollar exchange rate, affect the NPV. Two charts were considered proper to construct in order to evaluate this; a regression coefficient chart and a tornado chart.

The regression coefficients in Figure 5.47 indicates to what extent the various inputs, i.e. the dollar exchange rates and the daily rates, affect the NPV. The longer the bar or the larger the coefficient, the greater the impact of the specific input has to the output. Hence, the result of the chart indicates that the dollar exchange rate affects the NPV to a larger extent than the daily rate does. However, the bar describing the dollar exchange rate´s impact extends to the left, the coefficient is thus negative. Contrary, the bar describing the daily rate´s impact extends to the right, the coefficient is thus positive. This means that the dollar exchange rate has a negative impact on the NPV and an increase in this input will decrease the output. Contrary, the daily rate has a positive impact meaning that increasing this input will increase the output.

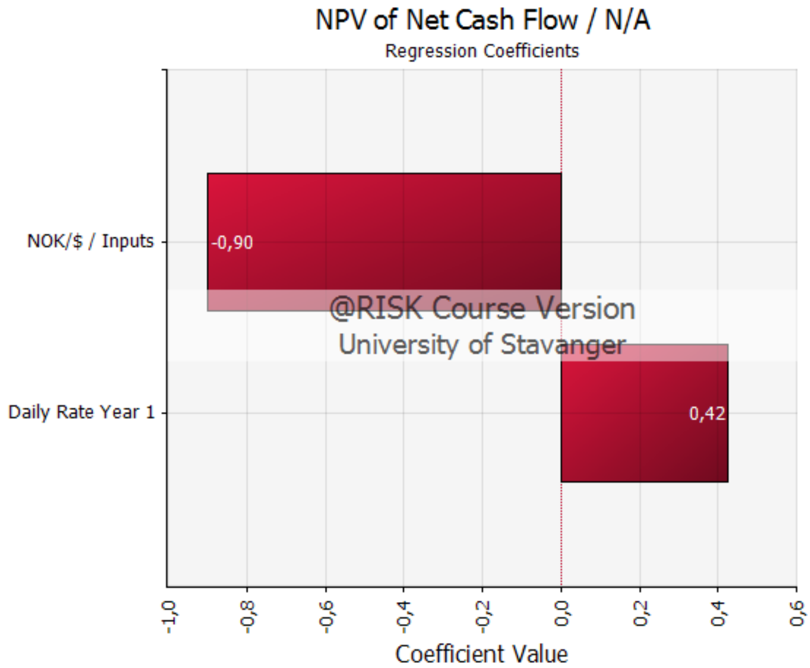

Figure 5.47: Regression Coefficients – NPV Analysis

Moreover, the tornado chart in Figure 5.48 was used as a tool to determine how the inputs, described by bars in the chart, affect the output if solely considering one input at a time. Hence, the dollar exchange rate and the daily rate is considered one at a time, and analyzed in terms of how they affect the NPV.

The chart indicates that if solely considering the dollar exchange rate´s impact, the NPV will vary from - $ 2 029 859 to $ 10 714 001. Similarly, the daily rate´s impact will make the NPV vary in a range from $ 1 615 472 to $ 7 523 217.

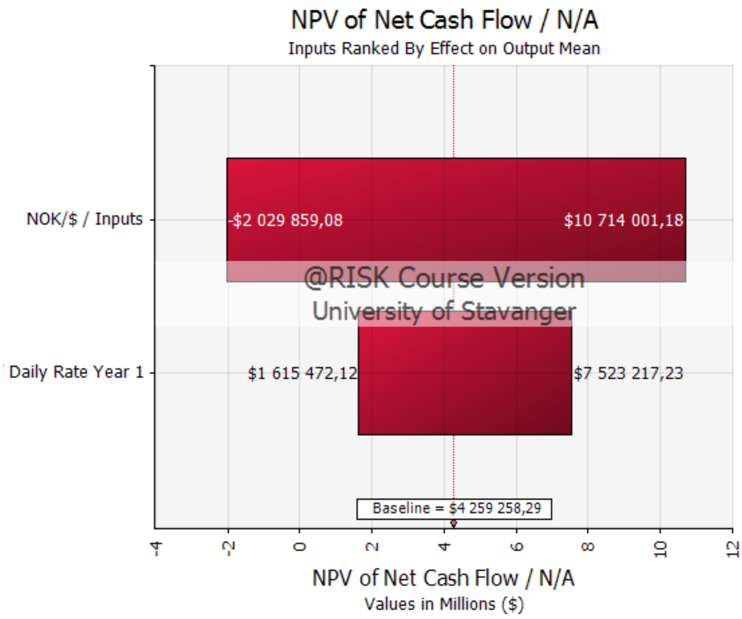

Figure 5.48: NPV affected by Daily Rate and Dollar Exchange Rate - Tornado Chart

IV

CLOSURE

6 Discussion

This chapter will discuss aspects related to the concept, and thus aspects that are related to the analyzes and results.

6.1 Streamlining the Value Chain

Reference is made to Figure 5.7 and Figure 5.13, respectively presenting how the current situation is operated and how the situation could possibly be operated in the future by use of value chains. More specifically, how activities related to delivery of equipment and retrieval of waste are, and how they possibly could have been conducted, are described by the figures.

If initiating the new concept and thus facing an operational situation similar to what is presented in Figure 5.13, Halliburton would offer the operators a complete service related to delivery of equipment and retrieval of waste. More specifically, initiating the concept would mean that Halliburton would sign an agreement with a ship-owner, who would purchase a proper vessel. The vessel would thereafter be reconstructed with the objective of making it a perfect fit for the concept. By doing so, Halliburton would be provided with competitive advantages as such a complete service related to delivery of equipment and retrieval of waste is not offered by any other oil service company worldwide. Moreover, the purchase and reconstruction of the vessel would be of great value for the operators in the NS through its offered services, and the benefits related to them.

The potential future operation includes both value adding and non-value adding activities. As explained in section 3.3, value adding activities are activities that result in customers needs being met. In this context, such activities are regarded to be reconstruction of the vessel, and the services it offers to the operators. Activities which do not match these requirements, are in this context regarded to be non-value adding.

As elaborated in section 5.1.2, the specialized vessel would provide its services to a number of fields, and hence rigs and platforms, in need for it. This indicates that the vessel would stay at each offshore installation just long enough for retrieval of waste and delivery of casing, which also applies in terms of the time spent onshore for retrieval of additional casing and unloading waste. That is, the vessel would exploit the allotted time to the fullest, maximizing the proportion of value-adding activities. The vessel would provide the same services as the PSVs, but it would not spend unnecessary time at one field or base, waiting to provide its services. Thus, comparing the vessel to the PSVs, it can be argued that it would utilize the time better. Hence, the time spent at the various rigs, platforms and bases would be significantly reduced, indicating that the proportion of non-value adding activities would be minimized or eliminated.

Additionally, the transportation time between the various locations would be reasonably accounted for, as some of the waste could potentially be prepared for a treatment process onshore, by mobile fractioning during transportation. Hence, also the transportation time would be efficiently used, and a potential further treatment onshore would not be as time consuming due to the slop already being separated into different phases. That means, the operational efficiency would be increased.

Disregarding the vessel´s utilization of time, another main difference between the potential future operation and the current operation is that one specialized vessel would replace an offshore installation´s need for typically leasing two PSVs and depend on both their services, for a longer period of time. That is, the specialized vessel would substitute both the PSV which has the primary mission of supplying casing from Florø to the other bases, and the PSV which delivers casing and retrieve waste to and from any field in the NS. By replacing the PSV which delivers casing from Florø to the other bases, a step would be eliminated within the value chain as there would no longer be need for its services.

In order to explain the extent of what the concept potentially could have replaced if initiated, the example of how the field Krafla is currently operated was extended to include several fields and bases geographically spread in the NS.

The left part in Figure 6.1 visualizes how each of the fields chosen makes use of one PSV to operate between the field and an appropriate base, in addition to how the current concept is dependent on another PSV to deliver casing from Florø to the other bases. Moreover, the right part indicated how the potential future concept could have solved the same challenges by use of one specialized vessel. As explained in section section 5.1.2, the specialized vessel would be operating between the fields. The vessel would have the option of retrieving casing from both Florø and Risavika, and would deliver the waste retrieved from the various fields to Risavika.

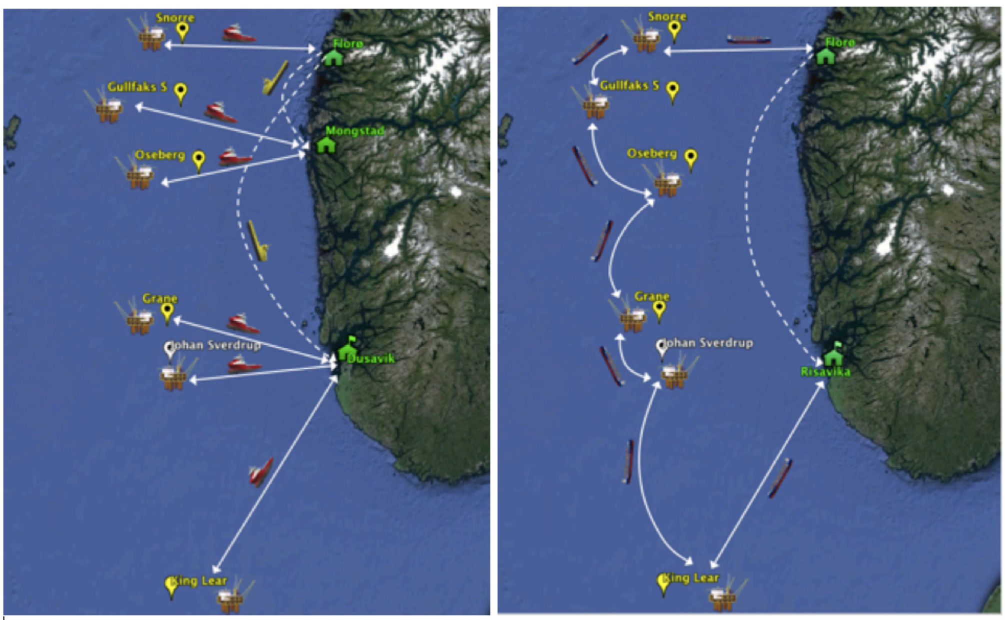

Figure 6.1: Current Sailing Pattern vs. Potential Future Sailing Pattern – Example

As the vessel would be able to replace a number of PSVs, in addition to maximize the proportion of value-adding activities, both resource and flow efficiency would have been ensured. More specifically, efficient use of resources would be ensured as the vessel would operate between the fields within certain timeframes and thus exploit the time diligently.

Furthermore, an efficient flow would be secured in that the customers would communicate their needs through the booking system, and Halliburton would fulfill their needs by providing them with the vessel´s services. Inefficiency and non-value adding activities would be reduced, or even eliminated by initiating the concept. Contrary, the current operation can be argued to consist of a significant proportion of non-value adding activities and thus to be inefficient, and to have a low level of both resource and flow efficiency.

Moreover, Figure 6.2 presents how the concept´s vessel would have been utilized the allotted time, compared to how the PSV operating between the field Krafla and the related base Florø utilized its time during April 2016. As the figure illustrates, the concept´s vessel would have an operating time at the various fields of only 25 %. Compared to how the PSV operating between the Krafla and Mongstad, the PSV´s operating time at the field was as great as 51 %. That is, the time the PSV spent at the rig exceeded half the time within the month, mainly for retrieving waste from it when necessary.

Also, Figure 6.2 further indicates that the time reduction also applies for the time spent onshore. While the PSV operating at Krafla spent 31 % of its time onshore in Mongstad for unloading waste and to retrieve equipment such as casing, the specialized vessel would only spend 7 % of its time within the fictional month for conducting the same activities.

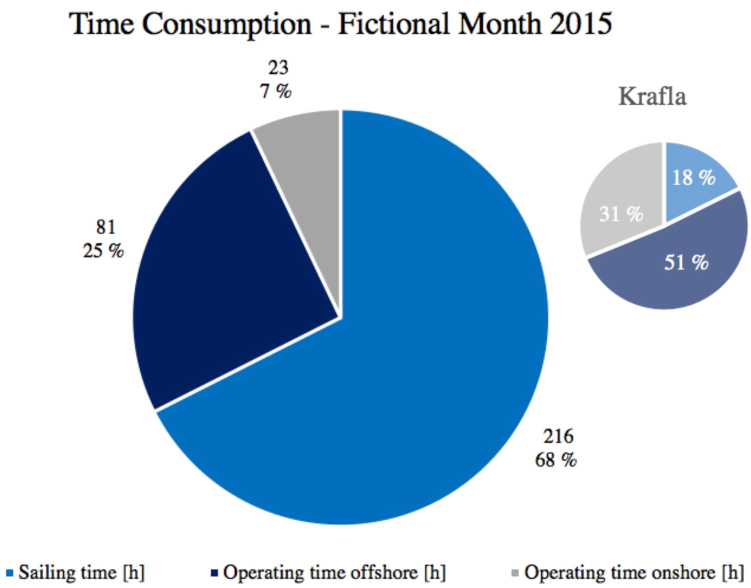

Figure 6.2: Time Consumption Fictional month vs. Krafla

Without the possibility of quantifying, it can also be claimed that the operators would reduce their costs related to the services provided by the PSVs used today, by adopting the concept if initiated. As earlier mentioned, the operators pay a daily rate for the PSVs used.

As for the PSV used at Krafla, it spent in total 24 days during a month serving the field, which represents a significant cost for the operating company. Contrary, if the field rather would have made use of a specialized vessel, the cost would be remarkably reduced as the time spent serving one field would be minor in comparison.

With reference to Figure 5.14, this was also considered to be one of the greatest contributing strengths to the concept. That is, five out of the seven people who prioritized the various contributions in the SWOT analysis ranked "Lowest cost in market" as the most important strength of the concept. Thus, the variance of this contributor was low, making the result to reflect credibility. Supporting this, Figure 5.16 presents that all seven persons ranked "Cost reduction for customer" as the greatest opportunity related to the concept, indicating total compliance of this contributor.

As a final factor in favor of the future concept, it can be argued that the focus would be on doing the right things and doing things right. In terms of doing the right things, the new concept would be more beneficial than the current, environmentally speaking. That means, the vessel´s necessary fuel consumption would be minor compared to the total fuel consumption necessary for a number of PSVs, in addition to that resources which are not used today are exploited.

That is, the excess heat from the exhaust gas and the heat from the DP-system would be utilized to run the evaporator. Also, it would ensure HSE to a larger extent compared to a current operation, as it would solely be delivery of casing that would require crane lift activities. As for doing things right, Halliburton is regarded as leading within the industry, of which the employees possess expertise, making it possible to offer the customers exactly what they desire.

6.2 General and Technical Aspects

The most sought result from the analyzes, is the feasibility of the concept. Hence, it is regarded as appropriate to discuss how the results arrived at in the analyzes developed as they did by generally explaining the approaches and conscious choices made in these analyzes. Also, general concerns and technical challenges related to the concept are discussed with possible measures to reduce their impacts.

6.2.1 Approaches and Choices

The quantitative waste amount analyzes were, to a large extent, based on data regarding drilling waste delivered from the NS to Halliburton´s onshore facilities during 2015. As already mentioned, some of the slop volumes generated are treated offshore. As those amounts are minor compared to the amounts sent onshore, in addition to internal forecasts within Halliburton indicating that the amount of drilling waste treated offshore in 2015 will be stable for the next years (Toft, 2016), the thesis further ignore the amounts slop which today is treated offshore. However, in a long-term perspective, these may be included if significant changes to regulations or technology occur. That is, the fields´ primary waste solution may change, voluntarily from the operator´s side or due to injection regulations.

Additionally, internal Halliburton data on meters drilled by various rigs and platforms, which delivered waste onshore in 2015, were used to determine the amounts of casing that the respective rigs and platforms would have needed to be supplied with. The objective of using these data to base the analyzes on, was to seek an answer regarding whether the vessel could have retrieved the same amounts of waste and delivered the same amounts of casing during specific periods of time. Together, the data used in the waste and casing amount analyzes formed the basis in determining the concept´s feasibility within the periods of time in question.

In terms of the overall retrieval and delivery analyzes, data from 2015 were solely used. As 2015 was a poor year in terms of offshore activities, it was evaluated whether the data should be adjusted as an attempt to anticipate how the next years may look like. However, Halliburton`s latest forecasts predict that the level of activity related to waste amounts needed to be retrieved in the NS will be approximately equal to 2015-levels in the years to come. It was therefore chosen to evaluate the concept based on the data from 2015 in the first instance.

As April 2015 was considered to be the most critical month that year in terms of waste amount, it was deemed particularly interesting to analyze how the vessel could have operated under such circumstances. Thus, if the concept was revealed to be feasible during this month, a conclusion could be drawn that the concept would be feasible during any other month within the same year. As the results from these analyzes were positive, and hence one could conclude with the above, a fictional month was constructed with the objective of challenging the concept. Hence, taking the concept to the next level and to analyze whether the concept still would be feasible, was of interest.

For the overall analyzes and the analyzes concerning the month of April, the fictional month was also based on data from 2015. However, additional information was implemented with the objective of obtaining a more realistic and comprehensive picture of what a potential future situation may look like. As the sector in question continuously develops and can be described as highly dynamic, it was regarded as inappropriate to base the analyzes on data from years before 2015. Instead, additionally sources of information were implemented in the analyzes in an attempt to make the results reflect more credibility and for the answer regarding the concept being feasible or not to be valid to a larger degree.

As a part of this, the amount of waste that Halliburton received from the NS to their onshore facilities during 2015 was analyzed as a proportion of the total waste sent onshore from the NS in 2015. The proportion was revealed to be approximately 20 %, which provided an indication of the amount drilling waste generated in 2015. From this, potential waste amounts that the concept´s vessel could have retrieved in a potential future situation were sought.

More specifically, forecasts concerning waste amounts predicted to be generated in the years to come, and meters to be drilled, were obtained from Statoil, in addition to data adjusted by Halliburton. The data were implemented in the analyzes of the fictional month to assess the years to come. However, such information was carefully considered before implemented, as they are not “real” data but rather data based on experts´ evaluations.

In retrospect, it can be mentioned that a specialized vessel operating during this period of time, was also revealed to be feasible. However, it should be mentioned that the route developed as a part of the fictional month analyzes indicates how the vessel could have operated under “perfect circumstances”, as it is not based on time limits between the sub-tours.

A real situation would reflect a more chaotic route, with time limits between many of the sub-tours. However, such chaos is sought avoided by basing the concept on a booking system, as explained in section 5.1.2. Also, a real route would be dependent on which operators Halliburton potential could have signed contracts with, and which fields the contracts would apply to.

It should be mentioned that the concept assessed belongs in a sector of which the conditions vary on a frequent basis. Hence, one should be careful to consider the results from these analyzes as consistently reliable, as the results solely reflect whether the concept is applicable for similar situations. Moreover, the precisely potential routes determined for April and the fictional month, are unlikely to occur in the future, making the solely interesting result from these routes developed being that the concept could be feasibly carried out by using a specialized vessel – with those specific amounts of waste and casing, and based on those specific time periods.

In addition to seeking to evaluate the concept in a long term perspective, seasonal variations should also be assessed to see if the concept would be a good solution throughout the year. That is, the results revealed that the concept was feasible in the month considered to be most critical in 2015, with the associated conclusion of that the concept then also would have been feasible in any other month during 2015.

As this thesis is primarily a feasibility study, the results have thus responded to the thesis´ question. However, it should be mentioned that it would not only be the feasibility that would determine whether the concept should be initiated, but also the profitability of the concept. The profit depends on how many days the vessel has earnings, which indicates that the profit increases in busy periods and is reduced in less busy periods such as WOW periods. That means, seasonal variations should be accounted for before initiating the concept. As shown in Figure 5.21, there are seasonal variations. This, however, goes beyond the boundaries of this thesis and will not be further elaborated on.

6.2.2 Challenges with possible Measures

In order for the concept to be preferred among customers and hence for the concept to be successful, it would have to meet their needs. In this context, meeting the customers´ needs means that the vessel would have to be capable of supplying what is demanded, comprising both delivery of sufficient amounts of various equipment and retrieval of adequate amounts of drilling waste generated at the various offshore sites. This is regarded as the most critical concern for the concept.

Based on these needs, the vessel may experience a challenge in terms of the vessel´s capacity. As presented in Figure 5.22, the amount of cuttings varied to a larger extent than the amounts of slop during the year 2015. Thus, the figure indicates that retrieval of the amounts of cuttings would be a greater challenge than the retrieval of the amounts of slop.

However, as in detailed in section 5.1.2, the vessel`s deck ratio could comprise additional tanks for storing cuttings, more specifically CTTs, if additionally capacity would be required. Also, the vessel´s capacity for slop and cuttings was, according to the SWOT analysis, considered to be the third greatest contributing strength of the concept, presented in Figure 5.14. However, the length of the bar size communicating the variance of this contributor is somewhat high, suggesting that there is uncertainty among those ranking regarding this contributor´s importance.

Nevertheless, the challenges would be particularly critical if activities generating great amounts of waste would occur at several locations simultaneously. Such a scenario indicates that the vessel would have to deliver equipment and retrieve waste from a number of fields within a limited schedule, i.e. the vessels frequency would be high. As presented in Figure 5.15, frequency of retrieval and delivery was according to the conducted SWOT analysis regarded as the greatest weakness contributor to the concept. However, the variance´s bar size if long, indicating that there is a significant degree of uncertainty related to this contributor´s importance among those ranking it.

As explained in more details in section 5.1.2, the vessel would operate based on the reservations made by the operators by using a booking system, meaning that each offshore installation would need to have a sufficient temporary storage capacity to store the waste until the vessel is scheduled to retrieve it. This is a critical factor related to the feasibility of the concept, i.e. the concept cannot be conducted without temporary storage capacities on the various offshore installations. According to the SWOT analysis, temporary storage capacity is considered to be the second greatest threat related to the concept, further described in Figure 5.17. However, the variance´s bar size reflects that there is disagreement among the answers regarding the threat in question.

As required storage capacities commonly varies from one rig or platform to another due to the installations generating different levels of slop and cuttings, general storage capacities were determined to be 300 tons for slop and 200 tons for cuttings. These numbers were considered appropriate, as they were regarded as obtainable for all offshore installations. Some installations could have had room for greater storage capacity, however, this was not accounted for. That is, greater capacities indicate that retrieval operations could be very time consuming, and the vessel´s flow could be disrupted if some installations had this opportunity, while others did not.

Moreover, it is crucial that the time period for storing the waste until the vessel is scheduled to retrieve it is not exceeded, as this may lead to an exceeded storage capacity. Furthermore, this could lead to the possibility of drilling and production activities having to stop, which is a very costly situation for the operators.

Basing the concept on a booking system would reduce the probability of such incidents from occurring, as the operators would have to reserve the vessel in advance for retrieval of waste and delivery of equipment. That means, the operators would have to reserve the vessel with its related services in advance, e.g. if they had drilling activities which would generate significant amounts of waste planned in the near future.

Contrary to the situation above, the vessel may experience periods of low activity and thus its services would be needed in a smaller degree. As seen in Figure 5.21, there are seasonal variations which also the vessel would have to adhere to. However, in favor of basing the concept on a booking system, the system could even out the periods with high activities and the periods of low activities to some extent due to the necessity of planning when the various sites would need retrieval and delivery.

Moreover, it should be mentioned that the vessel would have to adhere to seasonal variations as well, as it would not be prudent or desirable for the operators to carry out drilling activities in periods of bad weather, such as great wave heights. That means, HSE would not have been ensured, and the operation might have to cease due to the bad weather conditions. As indicated in Figure 5.17, weather dependence is considered to be the third greatest threat related to the concept.

That is, peaking periods would probably make the vessel have to adhere to a tight schedule, and maybe there would even be a necessity for backup solutions such as using PSVs or shuttle vessels as extra capacity in such periods. On the other hand, periods of low activities would also have to be adhered to. Hence, the vessel´s utilization rate would vary in terms of seasonality, and bad weather conditions would be one of the most critical concerns related to the concept.

It should be mentioned that such a booking system is already used on the NCS, more specifically the system applies to transportation of gas. As Gassco operates all the pipelines to Europe, the operators have to reserve capacity when the gas needs to be transported through Gassco´s Booking System. This is an online system providing information about pipeline capacity and booking opportunities.

Further on, the concept may experience additional challenges which should be particularly emphasized in peaking periods. More specifically, the time consumption related to the vessel staying at the various installations for delivery of casing and retrieval of waste, in addition to the time consumption onshore for unloading waste and loading casing, is crucial for the concept´s feasibility. In terms of the vessel staying at the offshore sites, the necessary time is based on the amounts of waste needed to be retrieved and the amount casing needed to be delivered.

However, regardless of amounts, the time consumption is sought reduced as delivery of casing and retrieval of waste is intended to occur simultaneously. Similarly, the time consumption onshore depends on the amounts, but also here a measure is thought implemented to reduce the necessary time. That is, as the concept comprises making a slurry of the various waste volumes and making use of several piston pumps simultaneously, the time related to pumping these volumes to shore can be reduced.

Nevertheless, the quality of the slurry is dependent on the amounts slop and cuttings retrieved. The evaporator will only be used when there are sufficient amounts of slop to fraction, which determines the amounts slop that can be mixed into a slurry. If inadequate amounts of slop, the solution would have been to mix the slop with the cuttings into a slurry, and not fraction the slop and solely use the sludge.

All the challenges mentioned above, could be minimized, mitigated, or even eliminated, if conducting the concept by using several vessels. That means, as there may occur situations of which there is need for the vessel´s services at several locations simultaneously, which is impossible, the option of using several vessels to conduct the concept should be considered.

Offering the customers e.g. two vessels instead of one could be regarded as beneficial in several ways. For example, less risk would be involved if one of the vessels would experience problems, as the other vessel then could have taken over. Especially in peaking periods, where several fields may need retrieval and delivery at the same time, two vessels would likely have conducted the concept better than one vessel.

Also, if expanding the concept and thus make use of e.g. two vessels, it may have been expedient to separate the fields within the NS into two clusters, North and South. Hence, one vessel could mainly have operated within the North cluster, while the other could mainly have operated within the South cluster. However, if the fields within one of the clusters were significantly busier than the fields within the other cluster, both the vessels could have operated within that cluster as long as it does not defy the other. Not only would using several vessels reduce risk related to the concept, but the concept could also be expanded in terms of area of interest. That is, the concept would then no longer be solely reserved for the NS, but the whole NCS could be included for the vessels to have greater areas to serve.

6.3 Economy

The NPV calculations are based on the cash flows of the concept, meaning that the validity of the result depends on the degree of accuracy related to the estimated yearly revenue and expenses. As there are many factors which have impact on the cash flow, it was necessary to evaluate the variables that was considered to be most crucial for the concept; the daily rate and the dollar exchange rate.

6.3.1 Daily rate and Dollar Exchange Rate variations

Based on the analyzes conducted in order to get an overview of how the concept could impact Halliburton´s profitability, some concerns are essential to discuss.

As described in the analyzes, a crucial variable related to the concept is the daily rate. Table 5.18 presented that the NPV of the concept, based on the various assumed daily rates, would lie within the range of -$ 3 359 441 to $ 3 780 321, with a most likely value of $ 210 440. Within the oil and gas sector, such a most likely NPV value is relatively low. Also, the range was proved to be widely spread, indicating that there is great uncertainty related to the concept´s profitability. Thus, it was considered necessary to further analyze the daily rate´s impact by associating uncertainty related to them, by using @Risk.

Additionally, it was seen as essential to include analyzes of how the dollar exchange rate affects the NPV. Halliburton evaluates all their projects in USDs, therefore, implementing a range for the dollar exchange rate was necessary in order to evaluate the concept in realistic terms. Also, it should be mentioned that Halliburton´s expenses related to a project is paid in NOK while the revenue is received in USD, which increases the importance of the exchange rate as its value has a major impact on the NPV.

Moreover, a high dollar exchange rate would provide high expenses, which would make the difference between revenue and expenses increase as the revenue is based on NOK. Supporting this, the regression coefficients in Figure 5.47 indicated that the dollar exchange rate affects the NPV negatively, meaning that an increase in this input would provide a decrease in the output. Contrary, the daily rate affects the NPV positively, meaning that an increase in this input would provide an increase in the output. Also, it was presented that the dollar exchange rate affects the NPV to a larger extent than the daily rate affects the NPV.

Furthermore, the importance of the dollar exchange rate was indicated in Figure 5.45, presenting NPV values to describe a worst-case scenario, a best-case scenario and a most-likely scenario. Calculations showed that a worst-case scenario would provide a NPV of - $ 5 863 532 and a best-case scenario would provide a NPV of $ 18 034 218. Uncertainty related to variables, i.e. uncertainty related to the daily rate and the dollar exchange rate, are both included and reflected in these results. That means, the worst-case scenario is based on the highest possible dollar exchange rate in order to obtain as high expenses as possible, and the lowest possible daily rate to obtain as low revenues as possible.

Contrary to the worst-case scenario, the best case scenario is based on the lowest possible dollar exchange rate in order to obtain as low expenses as possible, as well as the highest possible daily rate to obtain as high revenues as possible. The intermediate scenario, i.e. the most likely scenario, is based on an average daily rate and an average dollar exchange rate, and was revealed to be $ 4 259 258.

A comparison of these NPV values to the values of the NPV which did not include uncertainty related to both the various daily rates the dollar exchange rate, can be found in Table 6.1. As presented, the range is spread to a greater extent when including uncertainty related to the dollar exchange rate, and the most likely NPV value has increased remarkably from the initial most likely NPV value, which was considered to be relatively low within the sector in question. Realistically speaking, there will be uncertainty related to the variables affecting a NPV value. Hence, uncertainty should also be taken into account when determining the various NPV values for this concept, and based on this is can be stated that the most likely value for the NPV can be determined to be $ 4 259 258.

Table 6.1: NPV - Scenarios with and without related Uncertainty

NPV – Scenarios with and without related Uncertainty			
	Worst Case [$]	**Most likely [$]**	**Best Case [$]**
Uncertainty not incl.	- 3 359 441	210 440	3 780 321
Uncertainty incl.	- 5 863 532	4 259 258	18 034 218

Nevertheless, it should be pointed out that the most likely NPV of $ 4 259 258 is based on the fictional month constructed, of which the potential route consists of fields with a significant geographical spread. Thus, if considering an area of more limited geographically spread known to have high activity, and further assuming that Halliburton would be the only performing service company within the limited area, it can be argued that this would be even more feasible for this concept, and hence the NPV could increase.

If solely considering an area such as the Utsira High, which generates great amounts of waste needed to be retrieved as well as requiring a significant amount of casing delivered, the vessel would exploit its time efficiently between the various fields. Hence, if the vessel´s primary focus was put on operating between the fields that form this area, increased and sustainable utilization of the vessel would be ensured, as it could also have the capacity of supplying various products to the fields, such as base oil, dry bulk chemicals, or drill water.

Furthermore, the time allocated for sailing between the installations would be minimal, due to the limited distances between the various fields. However, in order for the concept to be able to cover the various fields in the NS´s need for product supplies, in addition to waste retrieval and delivery of equipment, the concept would have to be expanded to include one or several additional vessels. As presented in Figure 5.14, product supply was according to the SWOT analysis regarded as the second greatest strength related to the concept. However, this is a topic which goes beyond the limits of this thesis and will therefore not be further discussed.

Moreover, the tornado chart in Figure 5.48 and the summary of the various extremities in Table 6.2, indicates that the dollar exchange rate´s impact on the NPV is greater than the daily rate´s impact if only considering one variable at a time, as the dollar exchange rate´s confidence interval is more widely spread compared to the daily rate´s confidence interval.

Table 6.2: Confidence Interval for NPV - Extremities of Outputs

Confidence Interval for NPV- Extremities for Outputs			
	Minimum Extremity	**Maximum Extremity**	**Deviation**
Dollar Exchange rate [$]	- 2 029 859	10 714 001	12 743 860
Daily rate [$]	1 615 472	7 523 217	5 907 745

Figure 5.46 indicated that there is an 83.2 % probability that the NPV of the concept is greater than zero and hence profitable for Halliburton. However, it has been shown that there is great uncertainty, and thus great risk, related to the concept´s profitability. Based on this, it can be argued that the dollar exchange rate´s impact on the NPV is great enough that Halliburton should consider to conduct the expenses related to a project in the same currency as the revenue is received in. In terms of this concept, this means that Halliburton should consider to invoice their revenues and expenses in the same currency.

Another option, that is include the risk related to the dollar exchange rate in the yearly increase rate, could also be considered as a risk reducing measure.

Holistically, a number of other inputs that affects the NPV could be discussed. However, disregarding the variables spoken of above, those that affect the concept´s profitability to the greatest extent can be argued to be the number of operating days during a year and the yearly allotted assets for potentially buying the vessel from the ship-owner after the contract´s period of validity.

With regards to the number of operating days´ impact on the NPV, it would be the degree of offshore activities that would imply how busy the vessel would be. Moreover, this would determine how many days during the year the vessel would have income in terms of daily rate paid by the customers, i.e. the operators. As this number was set to be a fixed ratio of 355 days per year, it was assumed that the vessel would be non-operational for ten days during a year due to such as planned class surveys that must be conducted in year three, five and eight in order to make the vessel certified by DNV GL[37]. As it is difficult to anticipate what may occur, it is challenging to tell if this number is appropriate. However, the number is based on Halliburton personnel´s experiences concerning commonly estimated non-operational days and thus believed to be credible.

[37] Merged of Det Norske Veritas (DNV) and Germanischer Lloyd (GL). The world`s largest ship classification society, with operations in ship classification, certification, and inspection, among other.

Other contributors to the non-operational days is repairs of the vessel, or unexpected events such as engine failure which would cause down-time for the vessel. However, down-time for the vessel due to engine failure is considered highly unlikely, and such incidents are covered by the insurance. Hence, it would not affect the NPV value, but rather weaken the customers´ confidence in the concept.

Also, incidents such as pump failures leading to difficulties regarding pumping the volumes to shore would not cause down-time for the vessel, as it would possess four specialized centrifugal mud pumps with 6” hoses connected to carry out this activity. Thus, the process would be rapid and it would not make a significant difference if one pump would experience problems, as the other pumps would work as back-up solutions.

Lastly, the yearly sum of $ 1 000 000´s impact on the NPV value, which was included in the expenses applicable to Halliburton in order to reflect allotted assets that potentially could buy the vessel from the ship-owner when the validity period of the contract has ended, should be discussed. Including this number neglects the possibility of renewing the contract, which should be considered a real opportunity. That is, if the concept would turn out to be successful, those allotted sums would be redundant and the NPV value would have increased if removed. Potentially, if not removed, the yearly sum could have been negotiated down if the ship-owner wanted to still be a part of the concept, and thus the NPV would also increase.

6.4 Overall Discussion

As the organizations within the oil and gas industry currently find themselves in a challenging market situation, it is regarded as more important than ever to seek new ideas to ensure competitiveness. According to the conducted SWOT analysis, the greatest threat related to the concept is considered to be competition from new technology, as presented in Figure 5.17. Supporting this, the variance of the specific contribution is low, indicating that there is consensus among those rating the various contributors regarding the importance of this contribution.

It can be stated that if the concept is to be initiated in the future, it would be a game changer within new technology and developments. Not only would the concept cause major changes to the value chain, but it would also liberate the work that a number of PSVs are currently conducting. A convenient question to ask is how many PSVs that potentially could have been replaced by the vessel.

Also, the concept is solely analyzed in terms of being implemented in the NS. That means, it is evaluated on a local basis. However, it should also be regarded as interesting to evaluate how extensively the concept could have worked. That is, to evaluate if the concept could have worked nationally, or even globally. Further on, this leads to the question regarding what changes such an expansion could have resulted in in terms of Halliburton´s market share. Prominent results were provided regarding the market share currently possesses in terms of retrieval of drilling waste, compared to what they could have obtained by implementing the project locally. More specifically, their current market share was calculated to be approximately 20 % in 2015, while a time period considered to be similar to the fictional month could have increased the market share to approximately 80 %.

Seeking to increase this even more, aspects such as Halliburton emphasizing recycling and reuse of the waste retrieved could be considered implemented in the analyzes. Even though this thesis is limited to activities occurring offshore, it should be mentioned that including such activities occurring onshore may have increased Halliburton´s market share even more.

Also, as all companies within the oil and gas sector constantly have to adhere to stricter rules and regulations, emphasizing recycling and reuse of the waste retrieved should be considered implemented as it describes a likely situation that Halliburton will face in the near future. Hence, emphasizing such activities could make Halliburton a good role model for other service companies within the oil and gas sector.

7 Conclusion

The results arrived at through the qualitative and quantitative analyzes carried out together form the main decision criteria regarding whether the concept should be introduced to the market, based on the concept`s evaluated feasibility.

Results proved that the way the operations of interest are currently handled, are inefficient, supported by the example regarding how the field Krafla was operated during April 2016. More specifically, it was revealed that the PSV sailing between the specific field´s base and the rig operating the field, spent 51 % of the time during the month in question at the rig, waiting for its next operation. Based on this, it can be argued that a new and more efficient concept for how the activities of interest are conducted would be desirable among the operators.

Further analyzes provided information regarding the concept´s feasibility – both technically and in terms of amounts equipment needed to be supplied and waste needed to be retrieved. A good technical solution was arrived at, together with a potential vessel to conduct the concept. Moreover, it was revealed that the vessel would have been able to satisfactorily operate the month considered as most crucial during 2015, i.e. April, and still have 45 % available time within that month.

It was further constructed a fictional month in order to challenge the vessel`s capacity limits, of which Halliburton would possess 80 % market share if realized. The results proved that one vessel operating during such a month would have been sufficient, while it would still have 27 % available time.

Based on the results it can be concluded that the concept would be feasible, and that it would have a good opportunity of being the preferred solution among customers. If so, Halliburton could maintain, and even improve, their competitiveness in the long run by introducing the concept to the market.

Moreover, the concept could reduce customers´ costs related to conducting the operations of interest significantly, based on results indicating that the vessel could replace a number of the PSVs currently used and operate in a more efficient manner. The concept would additionally have contributed to innovation within the oil and gas sector, due to the vessel´s possibility of preparing waste retrieved for a potential future treatment process onshore by fractioning during transportation.

Further on, it can be stated that the concept would be a somewhat groundbreaking addition to the offered services within the sector of interest. Thus, it should initially be introduced as a pilot project in order to determine how many PSVs the vessel potentially could have replaced. Initiating the concept as a pilot project would also be essential in order to safeguard important risk aspects.

For example, if the vessel would experience challenges related to frequency of retrieval or delivery, one avoids adverse situations such as drilling operations having to stop due to having exceeded the limits for temporary storage capacity.

Conclusively, the concept can be considered to be a game changer if initiated. Hence, Halliburton would offer the operators within the oil and gas sector in the NS a complete service that no other service company offers today. Also, it would provide environmental benefits as well as economic benefits, both for the operators and most certainly for Halliburton.

The probability of the concept being profitable is 83.2 %, with a most likely NPV of $ 4 259 258.

Furthermore, following these conclusions, the question becomes how the concept could have been globalized.

8 Suggestions for Future Work

As a continuation of this thesis, suggestions for future work related to the concept will be presented.

The topics considered most pertinent to recommend Halliburton for further work on the concept assessed in this thesis, are related to further development of it. More specifically, expansion of the concept and treatment of retrieved waste was regarded as essential suggestions.

Perhaps the most important aspect to safeguard within the oil and gas sector, is risk. In order to safeguard risk related to the concept to the greatest possible extent, it should be considered particularly interesting to look into how several specialized vessels could have cooperated to conduct the activities of interest. This would reduce the possibility of undesirable events, such as drilling operations having to cease due to one vessel experiencing frequency challenges, resulting in exceeding the limits for temporary storage capacity.

Furthermore, using several vessels could optimize the concept in two ways:

1) The economic benefits could increase, based on limiting each vessel´s area of operation. Thus, the concept would enable product supply in addition to delivery of equipment and retrieval of waste, as explained in section 6.3.1.

2) It would enable the possibility of expanding the concept to not solely be a service offered in the NS. That is, the entire NCS and perhaps also fields located in Danish and British waters could be offered the service. If so, Halliburton could have increased their market share not only in Norwegian waters, but also in foreign waters. Expanding the concept beyond Norwegian waters would mean that the concept would have to adhere to foreign laws and regulations.

In addition to safeguard risk related to HSE, Halliburton should also consider to implement risk reducing measures in terms of economy. That is, Halliburton should consider to invoice their revenues and expenses in the same currency, in order to reduce economic risk to a level as low as possible.

Subsequently, ensuring sufficient capacity for downstream solutions, together with streamlined treatment methods for the waste retrieved, are regarded as topics that can advantageously be looked further into. The downstream solution in Risavika may not be of sufficient capacity if the concept would expand to a larger extent. Thus, an evaluation of the capacity limit in Risavika and possible backup locations should be carried out before initiating the concept. Additionally, optimizing the value of such volumes through recycling and reuse should be emphasized.

V

ENDING

9 Bibliography

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10 Appendix

A memory stick is enclosed, containing complete analytical work on the various analyzes presented in short within this chapter.

10.1 Appendix A: SWOT Analysis

To clarify the roles of the respondents to the SWOT analysis, reference is made to Figure 4.1.

		Priority							Average	Importance	Variance
S	Strengths (Internal factors)										
		Knut Are Strøm	Roger Iversen	Martin Toft	Henry Magne Håkstad	Per Magnus Skretting	Kristian Evjen	Aage Andreassen			
1	Capasity of slop and cuttings	17	2	5	11	3	2	5	6,4	1,6	26,8
2	Casing delivery to rig	11	11	6	9	15	3	4	8,4	1,2	16,0
3	Dry bulk	10	10	4	10	10	4	18	9,4	1,1	19,1
4	Product supply: fluids , baseoil, mud, produced water etc.	4	3	3	2	4	5	14	5,0	2,0	14,3
5	Flexibility and adaptability in relation to pick up and deliv	12	5	7	7	11	6	19	9,6	1,0	20,5
6	Closed loop system - HSE	3	20	14	12	5	7	11	10,3	1,0	29,1
7	Reduce crane lifts on rig - HSE	5	18	13	5	6	8	12	9,6	1,0	20,8
8	Unloading rate onshore	15	15	12	4	16	9	3	10,6	0,9	24,8
9	Versatility and innovative	16	6	15	14	14	17	2	12,0	0,8	27,7
10	Backup CTT on deck	8	17	20	8	12	18	6	12,7	0,8	27,1
11	Backup pumps	18	16	19	13	20	19	10	16,4	0,6	11,7
12	Halliburton suggests drilling campaign schedule	13	9	16	19	13	10	13	13,3	0,8	9,9
13	Automation of core equipment	6	12	10	16	17	11	9	11,6	0,9	12,8
14	Floating screen hotel	9	19	17	20	18	20	20	17,6	0,6	13,4
15	New buisness	19	4	18	15	9	12	17	13,4	0,7	25,4
16	Increased/secured market share products and waste	1	7	9	3	7	13	15	7,9	1,3	21,6
17	Increase sales of HCB on rigs	7	14	11	6	8	14	7	9,6	1,0	10,0
18	Lowest cost in market	2	1	8	1	1	1	1	2,1	4,7	5,8
19	Several vessels		8	1	17	19	15	16	12,7	0,8	38,9
20	Potential outside the NS		13	2	18	2	16	8	9,8	1,0	40,1

	W Weaknesses (Internal factors)	Priority: Knut Are Strøm	Roger Iversen	Martin Toft	Henry Magne Håkstad	Per Magnus Skretting	Kristian Evjen	Aage Andreassen	Average	Importance	Variance
1	Storage Capacity at vessel	6	4	14	3	15	12	2	8,0	1,3	26,0
2	Frequency of retrieval and delivery	1	1	16	2	1	2	1	3,4	2,9	26,5
3	BSS core services CTT reduced	17	9	17	8	7	13	8	11,3	0,9	16,2
4	Vessel Stability	5	6	1	1	5	17	4	5,6	1,8	25,1
5	Availability of Downstream solution	16	12	3	4	12	3	10	8,6	1,2	23,4
6	Declarations	2	13	13	14	11	4	14	10,1	1,0	21,6
7	Capacity hold loop	11	8	4	15	13	5	16	10,3	1,0	19,3
8	Connectivity on rig	12	17	5	16	8	6	15	11,3	0,9	21,1
9	Transfer rate/time from rig to vessel	7	10	2	7	9	10	9	7,7	1,3	6,8
10	Time emptying waste from vessel	8	11	6	13	10	11	12	10,1	1,0	5,0
11	Evaporator capacity	9	14	8	12	6	7	7	9,0	1,1	7,4
12	Homogenizing waste	13	15	7	6	14	8	6	9,9	1,0	13,6
13	Cleaning tanks	14	16	12	17	17	14	17	15,3	0,7	3,3
14	Increased personnel on board (rig)	10	7	15	5	16	15	13	11,6	0,9	16,0
15	Increased personnel on vessel	4	3	10	9	3	9	11	7,0	1,4	10,6
16	Investment cost vessel	15	5	11	11	4	16	3	9,3	1,1	24,2
17	Long term contract for vessel	3	2	9	10	2	1	5	4,6	2,2	11,1

	O Opportunities (External factors)	Priority: Knut Are Strøm	Roger Iversen	Martin Toft	Henry Magne Håkstad	Per Magnus Skretting	Kristian Evjen	Aage Andreassen	Average	Importance	Variance
1	Reduced Environmental footprint (transportation emission	3	4	4	3	2	4	4	3,4	2,9	0,5
2	Cost reduction for customer	1	1	1	1	1	1	1	1,0	10,0	0,0
3	Reduced inventory onshore	2	3	2	4	4	2	3	2,9	3,5	0,7
4	Game changer on re-injection	4	2	3	2	3	3	2	2,7	3,7	0,5

	T Threats (External factors)	Priority: Knut Are Strøm	Roger Iversen	Martin Toft	Henry Magne Håkstad	Per Magnus Skretting	Kristian Evjen	Aage Andreassen	Average	Importance	Variance
1	Changing regulations	2	8	3	4	5	9	5	5,7	1,8	4,6
2	Competition from new technology	4	2	1	2	4	1	4	2,3	4,3	1,6
3	TemporaryStorage Capacity at rig	8	3	2	3	1	2	9	3,3	3,0	6,9
4	Weather dependent	6	1	6	1	3	5	7	3,8	2,6	5,5
5	Market ready for innovation	3	4	7	8	8	3	2	5,3	1,9	5,9
6	Market affecting possible daily rate of Vessel	7	5	8	7	7	7	3	6,2	1,6	2,8
7	Dollar Exchange rate	9	7	9	9	9	8	6	8,0	1,3	1,3
8	Increased use of WBM - slim hole drilling	5	6	5	6	2	4	8	5,2	1,9	3,5
9	Less intermediate sections drilled	1	9	4	5	6	6	1	5,2	1,9	5,8

10.2 Appendix B: Waste and Casing Analyzes

Appendix B.1: Waste Analyzes 2015

As presented, the total weight of slop and cuttings delivered to Halliburton´s facilities from the NS during 2015 was 24 560 and 29 150 tons, respectively. Summarized, the weight was 53 710 tons.

TOTAL WEIGHT OF SLOP RECEIVED BY HALLIBURTON PER MONTH IN 2015													
Rig/Platform	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**Total**
Borgland Dolphin	-	-	154	140	508	580	459	43	591	483	484	948	**4 390**
Brage	-	51	464	523	18	136	8	111	54	123	-	264	**1 753**
Grane	261	287	74	-	62	1 341	77	441	174	391	182	175	**3 465**
Heimdal	341	154	62	93	178	240	224	257	230	169	193	257	**2 398**
Maersk Gallant	536	545	162	358	427	183	396	603	721	256	-	-	**4 186**
Maersk Giant	-	-	-	-	36	49	40	3	43	36	-	-	**207**
Maersk Integrator	-	-	-	-	-	-	61	63	270	606	1 044	650	**2 694**
Songa Dee	-	-	9	-	-	19	-	-	-	-	-	-	**28**
Songa Trym	3	-	52	133	127	394	57	83	211	17	-	-	**1 077**
Transocean Arctic	66	-	-	-	220	259	3	-	-	-	-	-	**549**
West Alpha	9	9	-	-	5	5	-	-	-	-	-	-	**28**
West Epsilon	447	427	336	772	321	576	144	474	234	19	35	-	**3 784**
Total slop [ton]	**1 663**	**1 473**	**1 313**	**2 019**	**1 902**	**3 781**	**1 470**	**2 078**	**2 528**	**2 100**	**1 938**	**2 294**	**24 560**
Average slop [ton]	2 047	2 047	2 047	2 047	2 047	2 047	2 047	2 047	2 047	2 047	2 047	2 047	

TOTAL WEIGHT OF CUTTINGS RECEIVED BY HALLIBURTON PER MONTH IN 2015													
Rig/Platform	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**Total**
Borgland Dolphin	-	-	-	1 310	46	347	400	51	770	308	14	21	**3 268**
Brage	135	80	44	263	560	36	53	76	14	-	29	5	**1 296**
Grane	78	39	729	113	39	925	388	1 119	463	68	389	198	**4 546**
Heimdal	-	-	-	-	2	-	16	6	-	-	-	32	**56**
Maersk Gallant	88	179	584	1 780	115	197	83	45	28	55	-	-	**3 153**
Maersk Giant	-	-	-	-	453	19	12	65	7	-	-	-	**555**
Maersk Integrator	-	-	-	-	-	-	-	-	1 126	1 402	1 699	284	**4 511**
Songa Trym	-	-	-	-	642	552	-	-	317	-	-	-	**1 511**
Transocean Arctic	-	-	-	-	442	70	6	-	-	-	-	-	**518**
West Alpha	1 290	200	225	214	1 316	133	24	9	-	504	39	1 029	**4 981**
West Epsilon	63	1 311	1 091	1 310	253	505	122	52	43	-	6	-	**4 756**
Total cuttings [ton]	**1 654**	**1 809**	**2 672**	**4 990**	**3 867**	**2 784**	**1 102**	**1 421**	**2 769**	**2 336**	**2 176**	**1 569**	**29 150**
Average cuttings [ton]	2 429	2 429	2 429	2 429	2 429	2 429	2 429	2 429	2 429	2 429	2 429	2 429	

Total weight of Slop and Cuttings 2015	
Month	**Weight [ton]**
January	3 317
February	3 282
March	3 986
April	7 009
May	5 769
June	6 565
July	2 571
August	3 499
September	5 297
October	4 437
November	4 114
December	3 863
Total	**53 710**

Appendix B.2: Waste and Casing Analyzes April 2015

Waste Retrieval per field

The total weight of slop and cuttings delivered to Halliburton´s facilities from the NS during April 2015 was 2 019 and 4 990 tons, respectively.

Weight of Slop and Cuttings - April 2015				
Rig/platform	**Field**	**Slop [ton]**	**Cuttings [ton]**	**Total [ton]**
Borgland Dolphin	Snorre	140	1 310	1 450
Brage	Brage	523	263	786
Grane	Grane	-	113	113
Heimdal	Heimdal	93	-	93
Maersk Gallant	King Lear	358	1 780	2 138
Songa Trym	Sleipner East	133	-	133
Songa Trym	Gina Krog			
West Alpha	Balder	-	214	214
West Epsilon	Gudrun	772	1 310	2 082
Total		**2 019**	**4 990**	**7 009**

Casing Delivery per field

The upper table indicates that the amount of waste delivered to Halliburton´s facilities from various fields located in the NS during April 2015, contributed in determining the number of meters drilled at the fields and thus the number of meters casing required. A summary is provided in the lower table.

Rigs which delivered waste from the North Sea to Halliburton in April 2015, with meters drilled

Rig	Field	Waste Delivered [tons]	Total Waste delivered	% of Total Waste delivered	Drilled per rig [m]	Drilled per field [m]	Casing needed [m]	# Visits	Casing deliverd per time [m]
Borgland Dolphin	Snorre	1 450	1 450	100,0 %	3 097	3 097	3 716	2	1 858
Brage	Brage	786	786	100,0 %	71	71	85	1	85
Grane	Grane	113	113	100,0 %	4 326	4 326	5 191	2	2 596
Songa Trym	Sleipner East	93	133	69,8 %	2 796	1 951	2 341	1	2 341
Songa Trym	Gina Krog	40		30,2 %		845	1 014	1	1 014
West Alpha	Balder	214	214	100,0 %	2 796	2 796	3 355	2	1 678
West Epsilon	Gudrun	2 082	2 082	100,0 %	2 104	2 104	2 525	2	1 262
Total		4 778	4 778		**15 190**	**15 190**	**18 228**		

Summary, Casing requirement per field - April 2015

Rig	Field	Drilled per rig [m]	Drilled per field [m]	Casing needed [m]
Borgland Dolphin	Snorre	3 097	3 097	3 716
Brage	Brage	71	71	85
Grane	Grane	4 326	4 326	5 191
Songa Trym	Sleipner East	2 796	1 951	2 341
Songa Trym	Gina Krog		845	1 014
West Alpha	Balder	2 796	2 796	3 355
West Epsilon	Gudrun	2 104	2 104	2 525
Total		**15 190**	**15 190**	**18 228**

Retrieval of Waste and Delivery of Casing within various Routes

The upper table presents the amount of waste that would have been necessary to retrieve from the various fields located in the NS during April 2015, separated into three main tours. Furthermore, the lower table presents the amount of casing that would have been needed to deliver to the fields.

WASTE RETRIEVAL AND WASTE UNLOADING - APRIL 2015

	Tour Index	From	To	Vessel present from	Vessel present to	Waste Mission	Total Waste [tons]	True Retrieval/Unloading time [h, min]	
1st tour	0	Risavika	Grane	06/04/15	06/04/15	-	0	0	0
	1	Grane	Gudrun	06/04/15	07/04/15	Retrieval	433	3	18
	2	Gudrun	King Lear	07/04/15	09/04/15	Retrieval	522	5	0
	3	King Lear	Gudrun	09/04/15	11/04/15	Retrieval	511	2	36
	4	Gudrun	Brage	11/04/15	11/04/15	Retrieval	149	0	54
	5	Brage	Risavika	12/04/15	12/04/15	Unload	1614	3	35
2nd tour	6	Risavika	King Lear	13/04/15	13/04/15	Retrieval	799	6	48
	7	King Lear	Sleipner East	16/04/15	16/04/15	Retrieval	66	0	24
	8	Sleipner East	Gina Krog	-	-	-	0	0	0
	9	Gina Krog	Grane	16/04/15	16/04/15	Retrieval	71	0	42
	10	Grane	Balder	-	-	-	0	0	0
	11	Balder	Heimdal	16/04/15	16/04/15	Retrieval	83	0	36
	12	Heimdal	Brage	18/04/15	18/04/15	Retrieval	320	1	42
	13	Brage	Snorre	19/04/15	20/04/15	Retrieval	1182	10	48
	14	Snorre	Florø	21/04/15	21/04/15	-	0	0	0
3rd tour	15	Florø	Gudrun	22/04/14	22/04/14	Retrieval	158	0	54
	16	Gudrun	King Lear	23/04/14	23/04/14	Retrieval	210	1	24
	17	King Lear	Snorre	26/04/15	26/04/15	Retrieval	318	1	36
	18	Snorre	Gudrun	27/04/15	27/04/15	Retrieval	756	4	54
	19	Gudrun	King Lear	27/04/15	27/04/15	Retrieval	537	5	24
	20	King Lear	Snorre	28/04/15	28/04/15	Retrieval	196	2	0
	21	Snorre	Gudrun	30/04/15	30/04/15	Retrieval	176	1	48
	22	Gudrun	Balder	30/04/15	30/04/15	Retrieval	214	2	6
	23	Balder	Risavika	01/05/15	01/05/15	Unload	2564	5	42

CASING DELIVERY AND RETRIEVAL - APRIL 2015

	Tour Index	From	To	Vessel present from	Vessel present to	Casing Mission	Casing Delivery/Retrieval [m]	True deliver/Retrieval casing time [h, min]	
1st tour	0	Risavika	Grane	06/04/15	06/04/15	Deliver	2596	0	48
	1	Grane	Gudrun	06/04/15	07/04/15	Deliver	0	0	0
	2	Gudrun	King Lear	07/04/15	09/04/15	Deliver	0	0	0
	3	King Lear	Gudrun	09/04/15	11/04/15	Deliver	1262	0	30
	4	Gudrun	Brage	11/04/15	11/04/15	Deliver	85	0	12
	5	Brage	Risavika	12/04/15	12/04/15	Retrieval	9487	3	12
2nd tour	6	Risavika	King Lear	13/04/15	13/04/15	Deliver	0	0	0
	7	King Lear	Sleipner East	16/04/15	16/04/15	Deliver	2341	0	48
	8	Sleipner East	Gina Krog	-	-	Deliver	1014	0	18
	9	Gina Krog	Grane	16/04/15	16/04/15	Deliver	2596	0	48
	10	Grane	Balder	-	-	Deliver	1678	0	42
	11	Balder	Heimdal	16/04/15	16/04/15	Deliver	0	0	0
	12	Heimdal	Brage	18/04/15	18/04/15	Deliver	0	0	0
	13	Brage	Snorre	19/04/15	20/04/15	Deliver	1858	0	42
	14	Snorre	Florø	21/04/15	21/04/15	Retrieval	4798	1	42
3rd tour	15	Florø	Gudrun	22/04/14	22/04/14	Deliver	1262	0	30
	16	Gudrun	King Lear	23/04/14	23/04/14	Deliver	0	0	0
	17	King Lear	Snorre	26/04/15	26/04/15	Deliver	1858	0	42
	18	Snorre	Gudrun	27/04/15	27/04/15	Deliver	0	0	0
	19	Gudrun	King Lear	27/04/15	27/04/15	Deliver	0	0	0
	20	King Lear	Snorre	28/04/15	28/04/15	Deliver	0	0	0
	21	Snorre	Gudrun	30/04/15	30/04/15	Deliver	0	0	0
	22	Gudrun	Balder	30/04/15	30/04/15	Deliver	1678	0	42
	23	Balder	Risavika	01/05/15	01/05/15	-	-	-	-

Utilized time

The table presents how the vessel would have utilized its time during the month of April 2015, separated into sailing time, operating time offshore, and operating time onshore.

	UTILIZED VS. AVAILABLE TIME - APRIL 2015								
	Tour Index	**From**	**To**	**Sailing time [h]**	**Operating time offshore [h]**	**Operating time onshore [h]**	**Total Utilized time [h]**	**True utilized time [h]**	
1st tour	0	Risavika	Grane	6,5	0,8	0,0	7,63	7,0	38
	1	Grane	Gudrun	2,2	3,3	0,0	5,83	5,0	50
	2	Gudrun	King Lear	9,4	5,0	0,0	14,73	14,0	44
	3	King Lear	Gudrun	9,4	2,6	0,0	12,33	12,0	20
	4	Gudrun	Brage	7,9	0,9	0,0	9,13	9,0	8
	5	Brage	Risavika	8,7	-	3,6	12,62	12,0	37
2nd tour	6	Risavika	King Lear	10,9	6,8	0,0	18,03	18,0	2
	7	King Lear	Sleipner East	7,4	0,8	0,0	8,53	8,0	32
	8	Sleipner East	Gina Krog	0,9	0,3	0,0	1,53	1,0	32
	9	Gina Krog	Grane	3,1	0,8	0,0	4,23	4,0	14
	10	Grane	Balder	0,3	0,7	0,0	1,33	1,0	20
	11	Balder	Heimdal	1,7	0,6	0,0	2,63	2,0	38
	12	Heimdal	Brage	4,4	1,7	0,0	6,43	6,0	26
	13	Brage	Snorre	5,4	10,8	0,0	16,53	16,0	32
	14	Snorre	Florø	5,8	-	1,7	7,83	7,0	50
3rd tour	15	Florø	Gudrun	14,4	0,9	0,0	15,63	15,0	38
	16	Gudrun	King Lear	9,4	1,4	0,0	11,13	11,0	8
	17	King Lear	Snorre	21,6	1,6	0,0	23,53	23,0	32
	18	Snorre	Gudrun	12,6	4,9	0,0	17,83	17,0	50
	19	Gudrun	King Lear	9,4	5,4	0,0	15,13	15,0	8
	20	King Lear	Snorre	21,6	2,0	0,0	23,93	23,0	56
	21	Snorre	Gudrun	12,6	1,8	0,0	14,73	14,0	44
	22	Gudrun	Balder	2,1	2,1	0,0	4,53	4,0	32
	23	Balder	Risavika	7,1	-	5,7	13,13	13,0	8

Appendix B.3: Waste and Casing Analyzes Fictional Month 2015

Waste Retrieval and Casing Delivery per field

The table presents the average amounts of slop and cuttings that would have been necessary to retrieve from the various fields during the fictional month, separated into fields that delivered waste to Halliburton during 2015, fields that previously have contributed to the waste received by Halliburton and thus are likely to use their services in the near future, and newly developed fields.

Also, it presents the number of meters casing required at the various fields.

Total Waste and Casing - Fictional month 2015			
Field	**Average Slop delivered per month [ton]**	**Average Cuttings delivered per month [ton]**	**Casing needed [m]**
Balder	44	446	1 858
Snorre	70	114	694
Vega	212	97	1 454
Yme	53	31	253
Brage	146	108	731
Grane	303	391	9 530
Heimdal	200	5	109
King Lear	349	263	1 150
Varg	17	46	650
Gullfaks South	1	-	446
Sleipner East	24	14	401
Gjøa	40	43	3 035
Gudrun	309	396	1 710
Tordis/Vigdis	337	95	849
Fram	168	114	1 199
Visund	358	111	902
Troll	1 557	475	7 060
Oseberg	667	204	5 336
Statfjord	334	102	2 603
Johan Sverdrup	580	490	185
Ivar Aasen	580	618	1 849
Gina Krog	580	618	1 849
Edvard Grieg	483	617	1 254
	7 412	**5 397**	**45 106**

Halliburton´s Proportion of Total Waste sent onshore during 2015

It is presented that Halliburton´s proportion of the total waste delivered onshore from the NS in 2015, was 28 %.

Summary of Yearly NFFA Waste			
Year	**2014**	**Estimated 2015**	**Estimated 2015 North Sea**
Cuttings [ton]	90 580	72 464	55 797
Slop to shore [ton]	220 769	176 615	135 994
Total waste to shore [ton]	311 349	249 079	191 791

NFFA Waste - Average Month			
Average month in year	**2014**	**Estimated 2015**	**Estimated 2015 North Sea**
Cuttings [ton]	7 548	6 039	4 650
Slop to shore [ton]	18 397	14 718	11 333
Total waste to shore [ton]	25 946	20 757	15 983

Summary Halliburton Waste	
NS Average Values 2015 [ton]	
Slop	2 047
Cuttings	2 429
Average amount of Slop and Cuttings	**4 476**

Average Proportion of Total NFFA Slop Received by Halliburton	18 %
Average Proportion of Total NFFA Cuttings Received by Halliburton	52 %
Average Proportion of Total NFFA Slop and Cuttings Received by Halliburton 2015	28 %

Retrieval and Delivery of various Routes

The table presents the amount of waste that would have needed to be retrieved from the various fields in the fictional month 2015, separated into six main tours.

WASTE RETRIEVAL AND UNLOADING - FICTIONAL MONTH 2015								
Tour	Tour Index	From	To	Present from - to	Waste Mission	Total waste [ton]	True retrieval time [h, min]	
1st tour	0	Risavika	Sleipner East	01.-01.	Retrieval	38	0	12
	1	Sleipner East	Gina Krog	01.-02.	Retrieval	399	2	6
	2	Gina Krog	Gudrun	02.-03.	Retrieval	706	4	0
	3	Gudrun	Ivar Aasen	03.-03.	Retrieval	599	3	6
	4	Ivar Aasen	Edvard Grieg	03.-04.	Retrieval	550	3	6
	5	Edvard Grieg	Johan Sverdrup	04.-04.	Retrieval	535	2	24
	6	Johan Sverdrup	Risavika	04.-05.	Unload	**2826**	-	-
2nd tour	7	Risavika	Grane	05.-05.	Retrieval	347	2	0
	8	Grane	Balder	05.-06.	Retrieval	490	4	30
	9	Balder	Heimdal	06.-06.	Retrieval	204	1	18
	10	Heimdal	Brage	06.-07.	Retrieval	254	1	6
	11	Brage	Oseberg	07.-07.	Retrieval	436	2	12
	12	Oseberg	Fram	07.-08.	Retrieval	282	1	6
	13	Fram	Vega	08.-08.	Retrieval	310	1	24
	14	Vega	Florø	08.-09.	-	-	-	-
3rd tour	15	Florø	Snorre	09.-09.	Retrieval	184	1	6
	16	Snorre	Visund	09.-10.	Retrieval	469	2	24
	17	Visund	Tordis/Vigdis	10.-10.	Retrieval	432	2	12
	18	Tordis/Vigdis	Statfjord	10.-11.	Retrieval	218	1	6
	19	Statfjord	Gullfaks South	11.-11.	Retrieval	1	0	0
	20	Gullfaks South	Risavika	11.-12.	Unload	**3626**	-	-
4th tour	21	Risavika	Gina Krog	12.-12.	Retrieval	399	2	6
	22	Gina Krog	Edvard Grieg	12.-13.	Retrieval	0	0	0
	23	Edvard Grieg	Johan Sverdrup	13.-13.	Retrieval	535	2	24
	24	Johan Sverdrup	Ivar Aasen	13.-14.	Retrieval	599	3	6
	25	Ivar Aasen	Oseberg	14.-14.	Retrieval	436	2	12
	26	Oseberg	Gjøa	14.-15.	Retrieval	83	0	24
	27	Gjøa	Statfjord	15.-15.	Retrieval	218	1	6
	28	Statfjord	Florø	15.-16.	-	-	-	-
5th tour	29	Florø	Grane	16.-16.	Retrieval	347	2	0
	30	Grane	Risavika	16.-17.	Unload	**2616**	-	-
6th tour	31	Risavika	Troll	17.-17.	Retrieval	2032	10	24
	32	Troll	Gina Krog	17.-18.	Retrieval	399	2	6
	33	Gina Krog	Varg	18.-18.	Retrieval	64	0	30
	34	Varg	King Lear	18.-19.	Retrieval	612	2	36
	35	King Lear	Yme	19.-20.	Retrieval	84	0	24
	36	Yme	Risavika	20.-20.	Unload	**3190**	-	-

Retrieval and Delivery of various Routes

The table presents the amount of casing that would have been needed to deliver to the various fields in the fictional month 2015, separated into six main tours.

CASING DELIVERY AND RETRIEVAL - FICTIONAL MONTH 2015

Tour	Tour Index	From	To	Present from - to	Casing Mission	Casing delivery/Retrieval [m]	Needed # Flat racks	True deliver/Retrieval casing time [h, min]	
1st tour	0	Risavika	Sleipner East	01.-01.	Deliver	401	1	0	12
	1	Sleipner East	Gina Krog	01.-02.	Deliver	616	2	0	18
	2	Gina Krog	Gudrun	02.-03.	Deliver	1 710	4	0	42
	3	Gudrun	Ivar Aasen	03.-03.	Deliver	925	2	0	18
	4	Ivar Aasen	Edvard Grieg	03.-04.	Deliver	627	2	0	18
	5	Edvard Grieg	Johan Sverdrup	04.-04.	Deliver	93	1	0	12
	6	Johan Sverdrup	Risavika	04.-05.	Retrieval	12 783	29	4	48
2nd tour	7	Risavika	Grane	05.-05.	Deliver	4 765	10	1	42
	8	Grane	Balder	05.-06.	Deliver	1 858	4	0	42
	9	Balder	Heimdal	06.-06.	Deliver	109	1	0	12
	10	Heimdal	Brage	06.-07.	Deliver	731	2	0	18
	11	Brage	Oseberg	07.-07.	Deliver	2 668	6	1	0
	12	Oseberg	Fram	07.-08.	Deliver	1 199	3	0	30
	13	Fram	Vega	08.-08.	Deliver	1 454	3	0	30
	14	Vega	Florø	08.-09.	Retrieval	4 193	10	1	42
3rd tour	15	Florø	Snorre	09.-09.	Deliver	694	2	0	18
	16	Snorre	Visund	09.-10.	Deliver	902	2	0	18
	17	Visund	Tordis/Vigdis	10.-10.	Deliver	849	2	0	18
	18	Tordis/Vigdis	Statfjord	10.-11.	Deliver	1 302	3	0	30
	19	Statfjord	Gullfaks South	11.-11.	Deliver	446	1	0	12
	20	Gullfaks South	Risavika	11.-12.	Retrieval	9 264	22	3	42
4th tour	21	Risavika	Gina Krog	12.-12.	Deliver	616	2	0	18
	22	Gina Krog	Edvard Grieg	12.-13.	Deliver	627	2	0	18
	23	Edvard Grieg	Johan Sverdrup	13.-13.	Deliver	93	1	0	12
	24	Johan Sverdrup	Ivar Aasen	*13.-14.*	*Deliver*	925	2	0	18
	25	Ivar Aasen	Oseberg	14.-14.	Deliver	2 668	6	1	0
	26	Oseberg	Gjøa	14.-15.	Deliver	3 035	6	1	0
	27	Gjøa	Statfjord	15.-15.	Deliver	1 302	3	0	30
	28	Statfjord	Florø	15.-16.	Retrieval	4 765	10	1	42
5th tour	29	Florø	Grane	16.-16.	Deliver	4 765	10	1	42
	30	Grane	Risavika	16.-17.	Retrieval	9 729	22	3	42
6th tour	31	Risavika	Troll	17.-17.	Deliver	7 060	14	2	18
	32	Troll	Gina Krog	17.-18.	Deliver	616	2	0	18
	33	Gina Krog	Varg	18.-18.	Deliver	650	2	0	18
	34	Varg	King Lear	18.-19.	Deliver	1 150	3	0	30
	35	King Lear	Yme	19.-20.	Deliver	253	1	0	12
	36	Yme	Risavika	20.-20.	-	-	0	0	0

Pumping Slurry to Shore

The table presents the various amounts of slurry, with related SGs, which would have been mixed by the retrieved cuttings and the sludge fractioned from the slop. Also, it presents the time it would take to pump the slurry to shore.

Tour	Tour Index	From	To	Slop [ton]	Produced Water [ton]	Sludge [ton]	Cuttings [ton]	Proportion sludge to slurry	Proportion Cuttings to slurry	Total SG [ton/m3]	Slurry [ton]	Pumping Slurry to Shore [h]
					FRACTIONING - FICTIONAL MONTH 2015							
1st tour	0	Risavika	Sleipner East	24	12	12	14	52 %	48 %	1,60	26	-
	1	Sleipner East	Gina Krog	193	97	97	206	39 %	61 %	1,67	303	-
	2	Gina Krog	Gudrun	309	155	155	396	34 %	66 %	1,69	551	-
	3	Gudrun	Ivar Aasen	290	145	145	309	39 %	61 %	1,67	454	-
	4	Ivar Aasen	Edvard Grieg	241	121	121	308	34 %	66 %	1,69	429	-
	5	Edvard Grieg	Johan Sverdrup	290	145	145	245	44 %	56 %	1,64	390	-
	6	Johan Sverdrup	Risavika	1347	674	674	1479	38 %	62 %	1,67	2152	4,8
2nd tour	7	Risavika	Grane	152	76	76	195	34 %	66 %	1,69	271	-
	8	Grane	Balder	44	22	22	446	6 %	94 %	1,82	468	-
	9	Balder	Heimdal	200	100	100	5	97 %	3 %	1,39	105	-
	10	Heimdal	Brage	146	73	73	108	48 %	52 %	1,63	181	-
	11	Brage	Oseberg	334	167	167	102	69 %	31 %	1,53	269	-
	12	Oseberg	Fram	168	84	84	114	50 %	50 %	1,61	198	-
	13	Fram	Vega	212	106	106	97	59 %	41 %	1,57	203	-
	14	Vega	Florø	-	-	-	-	-	-	-	-	-
3rd tour	15	Florø	Snorre	70	35	35	114	29 %	71 %	1,71	149	-
	16	Snorre	Visund	358	179	179	111	68 %	32 %	1,53	290	-
	17	Visund	Tordis	337	169	169	95	70 %	30 %	1,52	264	-
	18	Tordis	Statfjord	167	83	83	51	69 %	31 %	1,53	134	-
	19	Statfjord	Gullfaks South	1	0	0	0	100 %	0 %	1,38	0	-
	20	Gullfaks South	Risavika	2189	1095	1095	1437	51 %	49 %	1,61	2532	5,6
4th tour	21	Risavika	Gina Krog	193	97	97	206	39 %	61 %	1,67	303	-
	22	Gina Krog	Edvard Grieg	-	-	-	-	-	-	-	-	-
	23	Edvard Grieg	Johan Sverdrup	290	145	145	245	44 %	56 %	1,64	390	-
	24	Johan Sverdrup	Ivar Aasen	290	145	145	309	39 %	61 %	1,67	454	-
	25	Ivar Aasen	Oseberg	334	167	167	102	69 %	31 %	1,53	269	-
	26	Oseberg	Gjøa	40	20	20	43	39 %	61 %	1,67	63	-
	27	Gjøa	Statfjord	167	83	83	51	69 %	31 %	1,53	134	-
	28	Statfjord	Florø	-	-	-	-	-	-	-	-	-
5th tour	29	Florø	Grane	152	76	76	195	34 %	66 %	1,69	271	-
	30	Grane	Risavika	1465	732	732	1151	46 %	54 %	1,63	1884	4,2
6th tour	31	Risavika	Troll	1557	778	778	475	69 %	31 %	1,53	1254	-
	32	Troll	Gina Krog	193	97	97	206	39 %	61 %	1,67	303	-
	33	Gina Krog	Varg	17	9	9	46	20 %	80 %	1,76	55	-
	34	Varg	King Lear	349	174	174	263	47 %	53 %	1,63	437	-
	35	King Lear	Yme	53	26	26	31	53 %	47 %	1,60	57	-
	36	Yme	Risavika	2169	1084	1084	1021	59 %	41 %	1,57	2106	4,7

Utilized time

The table presents how the vessel would have utilized its time during the fictional month, separated into sailing time, operating time offshore, and operating time onshore.

UTILIZED VS. AVAILABLE TIME - FICTIONAL MONTH 2015										
Tour	Tour Index	From	To	Sailing time [h]	Operating time offshore [h]	Pumping Slurry to Shore [h]	Operating time onshore [h]	Total Utilized time [h]	True utilized time [h]	
1st tour	0	Risavika	Sleipner East	11,5	0,2	-	0,0	12,0	12,0	2
	1	Sleipner East	Gina Krog	1,2	2,1	-	0,0	3,6	3,0	38
	2	Gina Krog	Gudrun	1,5	4,0	-	0,0	5,8	5,0	50
	3	Gudrun	Ivar Aasen	1,6	3,1	-	0,0	5,0	5,0	2
	4	Ivar Aasen	Edvard Grieg	0,5	3,1	-	0,0	3,9	3,0	56
	5	Edvard Grieg	Johan Sverdrup	0,9	2,4	-	0,0	3,6	3,0	38
	6	Johan Sverdrup	Risavika	8,9	4,8	4,8	4,8	18,8	18,0	50
2nd tour	7	Risavika	Grane	9,1	2,0	-	0,0	11,4	11,0	26
	8	Grane	Balder	0,4	4,5	-	0,0	5,2	5,0	14
	9	Balder	Heimdal	2,4	1,3	-	0,0	4,0	4,0	2
	10	Heimdal	Brage	6,1	1,1	-	0,0	7,5	7,0	32
	11	Brage	Oseberg	0,9	2,2	-	0,0	3,4	3,0	26
	12	Oseberg	Fram	3,9	1,1	-	0,0	5,3	5,0	20
	13	Fram	Vega	1	1,4	-	0,0	2,7	2,0	44
	14	Vega	Florø	5	1,7	-	1,7	8,7	8,0	44
3rd tour	15	Florø	Snorre	8,1	1,1	-	0,0	9,5	9,0	32
	16	Snorre	Visund	2,2	2,4	-	0,0	4,9	4,0	56
	17	Visund	Tordis	1,1	2,2	-	0,0	3,6	3,0	38
	18	Tordis	Statfjord	0,8	1,1	-	0,0	2,2	2,0	14
	19	Statfjord	Gullfaks South	1,4	0,2	-	0,0	1,9	1,0	56
	20	Gullfaks South	Risavika	17	3,7	5,6	5,6	26,7	26,0	40
4th tour	21	Risavika	Gina Krog	11,7	2,1	-	0,0	14,1	14,0	8
	22	Gina Krog	Edvard Grieg	2,3	0,3	-	0,0	2,9	2,0	56
	23	Edvard Grieg	Johan Sverdrup	0,9	2,4	-	0,0	3,6	3,0	38
	24	Johan Sverdrup	Ivar Aasen	1,3	3,1	-	0,0	4,7	4,0	44
	25	Ivar Aasen	Oseberg	9,9	2,2	-	0,0	12,4	12,0	26
	26	Oseberg	Gjøa	5,2	1,0	-	0,0	6,5	6,0	32
	27	Gjøa	Statfjord	5,7	1,1	-	0,0	7,1	7,0	8
	28	Statfjord	Florø	8,7	1,7	-	1,7	12,4	12,0	26
5th tour	29	Florø	Grane	17,3	2,0	-	0,0	19,6	19,0	38
	30	Grane	Risavika	9,1	3,7	4,2	4,2	17,3	17,0	19
6th tour	31	Risavika	Troll	14,5	10,4	-	0,0	25,2	25,0	14
	32	Troll	Gina Krog	14,7	2,1	-	0,0	17,1	17,0	8
	33	Gina Krog	Varg	3,2	0,5	-	0,0	4,0	4,0	2
	34	Varg	King Lear	8,8	2,6	-	0,0	11,7	11,0	44
	35	King Lear	Yme	8,9	0,4	-	0,0	9,6	9,0	38
	36	Yme	Risavika	8,7	0,0	4,7	4,7	13,7	13,0	43

10.3 Appendix C: Vessel Specifications

The figure presents the vessel, with related capacities.