Anchor Handling Tug Supply

Is there a correlation between fuel consumption and rate levels?

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AHTS, IS THERE A CORRELATION BETWEEN FUEL CONSUMPTION AND RATE LEVELS?

Abstract

The last four years have seen offshore vessel owners struggle with declining utilization and revenues from their fleet. Reducing the cost of operation have been the focus for survival, second only to securing capital expenditure runway. Where other offshore segments have seen a clear favouritism from oil companies, hiring and advocating for vessels with more fuel and cost-efficient profiles, the powerful and complex AHTS vessels have been lacking a similar seen focus. This thesis has studied the variance between consumption and rate levels for the large sized AHTS vessels. Through statistical analysis and regressions, it sought to determine a correlation between consumption profile and rate levels earned, both from an overall perspective, and during power distribution favouring either buyer or seller, in geographical specified areas of operation. Interviews with eight relevant industry professionals were in addition conducted, to strengthen the quantitative results together with evaluating and connecting relevant literature on the subject. The overall results found that the fuel consumption has played a diminutive part in determining rate levels for these vessels. Indications where found supporting a positive correlation between less fuel consuming vessels and rates, when buyer's bargaining power was strong. For the area specific research, the South American and Australian covered areas reflected to be the regions with the strongest consumption focus and rate correlation. Respondents were found to diverge in their expressed views, with oil companies more inclined to support a fuel efficient AHTS's positive influence on rates, while owners expressed little confidence in consumption significantly affecting rates.

Acknowledgments

First, I would like to show my gratitude and thank my supervisor, Marius Imset. Thank you for the guidance and helping me stay on point. The narrowing down of topic and research questions, along with the demand for theoretical connections, contributed to elevate this thesis. Secondly, I would like to thank the supportive and knowledge-sharing employees at Arctic Offshore, who have aided me along the process with both insightful views and access to data. A huge thank you also goes out to the interview participants, for taking the time out of their demanding everyday schedules and helping me make this research more solid.

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Abbreviations

AHTS – Anchor handling tug supply vessel

PSV – Platform Supply Vessel

OSV – Offshore Support Vessel

DW – Deadweight tonnage

GT – Gross tonnage

E&P – Exploration and Production

LNG – Liquified Natural Gas

FOC- Fuel Oil Consumption

IOC – International Oil & Gas Company

DP - Dynamic Positioning

DE – Diesel Electric Propulsion System

DM – Diesel Mechanic Propulsion System

Hybrid – Combined DE and DM systems

NPV – Net Present Value

PBP – Payback Period

IV- Independent Variable

DV- Dependent Variable

Table 1 Abbreviations

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1. Introduction

Described below are the developments that motivated me to conduct research within the field of consumption and rates in the AHTS segment. The introduction sheds light on the purpose of the thesis along with the research questions raised and sought answered.

1.1 Background

The AHTS vessels plays a crucial part in the offshore oil and gas industry. Together with other vessel segments, they deliver a key service to oil companies in exploration for and production of oil and gas. As Leffler, Pattarozzi & Sterling, (2011) describe, the AHTS vessels are typically used to tow oilrigs from A to B, assist in the anchor placement and securing rigs at various wells to be drilled. The vessels can also supply the oilrigs and offshore installations with containers and bulk-cargo. However, the anchor handling and towing capabilities are what makes these vessels unique. These features nevertheless, come at a price, as the vessels are highly complex and expensive to both build and operate, Myklebust & Aadnanes (2011). One significant cost of operating AHTS vessels are the fuel cost. The unique abilities to tow objects and conduct anchor handling, demand large power outputs, which results in high fuel consumption.

Tvedte & Sterud, (2016) points out that the oil companies chartering the vessels at agreed upon rates are also typically responsible for covering the fuel costs. The shipowners on the other hand are responsible for acquiring and operating the vessels. They decide on the design and propulsion-configuration when building new vessels or buying second hand assets, all of which affects the consumption of the vessel.

Fuel consumption within the AHTS segment varies and in the last decade new and modern designs are proving superior with regards to consumption. Innovative and modern tonnage is more expensive to acquire for the owners, so the question becomes; does it make economic sense to invest in vessels with efficient consumption profiles, from an owner's point of view? And is there empirical evidence supporting incentives for this from the charterers?

Research conducted by Lindstad, Eskeland & Rialland (2016) has shown that the related segment of platform supply vessels (PSVs), has experienced a higher pace when turning their attention towards fuel consumption and alternative fuels, including LNG and battery supplements. Their study makes claim for a possible payback period (PBP) of 5 years, for a battery instalment on a new-built PSV. The related PSV segment has also seen clear signs from charterers, that reducing consumption is valued. Oil major Statoil's, (2017), recent proclamation for more fuel efficiency in the offshore sector, supports the timing and relevance of this thesis, as the overall literature and research on the AHTS segment is slim.

AHTS' are more complex and fuel consuming than the related PSVs, especially in their operational modes of towing and anchor handling. I argue however, that many similarities in operational modes justifies more research on this specific segment, to optimize the efficiency and reduce fuel and cost, as seen in the related offshore support vessel (OSV) segments.

Studies show variations in the fuel consumption within the AHTS fleet, Myklebust & Aadnanes (2011). So, are the vessels with the optimal fuel consumption profile the ones being hired in today's challenging market? Are they receiving a "premium" rate, and is there evidence of variations in rates for these vessels compared to less fuel-efficient ones? These are some of the research questions this thesis will attempt to answer, in hopes that industry players can acquire insight to further conduct research studies', and use as guidance when ordering, chartering and operating AHTS vessels in the future.

The above combined with firmer global seaborne emission legislation and upcoming mandatory consumption registration, IMO, (2016), strengthen my argument for further research on the correlation between fuel consumption and rate levels in the AHTS segment.

1.2 Purpose and research problem

The purpose of this thesis has been to investigate if there is evidence for a correlation between fuel consumption and rates earned by the AHTS vessels. I wished to establish if less fuel consumption resulted in a rate premium, and if this was something that occurred on an unremitting regularity, or if it was dependent on the market's power distribution as well. This thesis also sought to research if the conceivable correlation varied across geographical areas of operations, as these vessels work worldwide under various oil companies and governmental legislations.

Research conducted on the different propulsion systems available have shown variations in consumption and these differences had a central place when investigating a possible correlation between consumption and rates, for the large type AHTS vessels. The argumentation for the choice will be described in depth, but originates from the complexity and variations of the operational modes and consumption profile for the AHTS.

Through empirical research this thesis attempted to answer the research question: *"Is there a correlation between fuel consumption and rate levels with regards to Anchor Handling Tug Supply vessels?"*

2. Literature review

2.1 The AHTS-segment and its dynamics

The literature on the collective OSV sector and more specifically the AHTS segment and its dynamics, is a field with little standardized curriculum. Although the sector is over fifty years old, we still see a superior focus on conventional shipping segments like deep-sea bulk and tank freight. Various textbooks such as; Leffler, Pattarozzi & Sterling (2011) guide on the basics of the offshore industry, but little is written on the correlation between specifications of the vessels and their utilization and rates. Reasons for the lack of literature and research could be, as argued by Stopford (2009), the relative small size that the segment adds up to in terms of gross tonnage. These vessels are not transporting goods from port to port and labelled by way of weight capacity, as is the case in deep-sea shipping. The offshore sector is more complex in terms of work scopes, which makes studying the AHTS segment more challenging, compared to the more traditional shipping sectors.

The AHTS segment varies between smaller less powerful vessels, operating in more shallow-water areas, to the large type AHTS vessels, able to deliver services in deep-sea areas. Break horse power (BHP) and bollard pull (BP) capacity are found to be the most commonly used features to divide the segment on and approximately 15,000 Bhp / 140t BP and upwards are considered as large type AHTS. The latter is the population this thesis seeks to research.

2.2 Charter contracts in the AHTS segment

Charter contracts for AHTS vessels are usually divided between spot and long-term charters. Where the spot charter period normally refers to commitments for a period less than a month. Oil companies typically use these spot charters when they need vessels for one specific rig-move or towing job.

The long-term charter periods can vary from more than a month to multiple year commitments. Long-term charters are utilized by oil companies to secure access to certain type vessels for longer periods. Both charter contracts are awarded or fixed after a tendering process. On occasion the contracts can be awarded ahead of commencement, however the trend shown in the data demonstrate a clear tendency of contracts being fixed close to the actual date of instigation, particularly for spot charter fixtures.

2.3 The AHTS Market and Geographical Areas of Operation

The AHTS sector represents a part of the supply side, selling their services to the buying oil and gas companies, putting forth the demand. Economical market theory applies to sea trade as well, and as stated by Y. H. V. Lun., et al. (2010), price will favour seller if the demand outweighs the supply, and support buyer when the opposite is true.

In recent years the latter have been most accurate, as worldwide oversupply of AHTS vessels have seen chartering rates plumage. This is no unprecedented occurrence, as prescribed by Daleel, (2017), the offshore market mirrors that of the deep-sea shipping trade in being highly cyclical. While deep-sea shipping is global in its essence, the AHTS segment diverge to a degree.

Since the core business model is supporting oil and gas exploration and production (E&P), the AHTS vessels operate in such areas around the globe that have the demand for said service and support. The largest and most significant offshore E&P areas are displayed below:

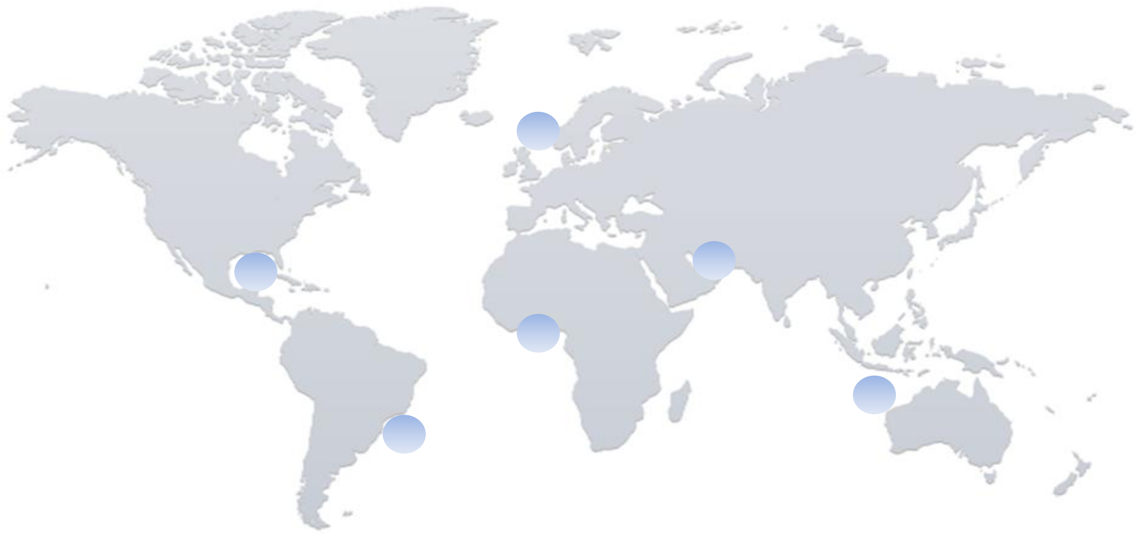

Figure 1 AHTS Main Geographical Areas of Operation, Daleel, (2017)

We find the main geographical areas for larger AHTS vessels around the deep-water and ultradeep water E&P shelfs in; the Northwest Europe (NWE), Gulf of Mexico (GOM), West Africa (WA), Americas, Brazil, Southeast Asia (SE Asia) and Australian waters, Sakar & Hwa, (2017).

These areas follow the same basic market principals and historical statistics show that declining oil prices and investments from the oil majors, affects all areas negatively. The downward spiral is felt with utilization and rates reduced for the owners. The maturity level of the areas does however wary, and younger deep-sea areas found in Brazil, Australia, and WA, have historically seen an un-synced pace of decline compared to GOM and NWE. This has generally led to owners deploying their vessels to said areas, resulting in oversupply and lower rates over time, Sakar & Hwa, (2017), OECD, (2014).

The NWE area is unique with regards to its spot market and transparency, making it much more predictable as to preferences from the chartering side. Other areas for the large

AHTS, have seen less uniform vessels operating, and preferences including propulsion system and overall consumption weighing is thought to be more uncertain.

Few AHTS specific studies can be found on areas outside NWE, but in researching more broadly when observing for correlations between consumption and rates, the expectation is that this thesis will be able to confirm or reject correlations between the variables in all areas of operations.

2.4 The rate determinations offshore

The correlation between specifications of OSVs and market appeal has seen some more attention of late, both within the PSV and AHTS segments. Dahle & Kvalsvik, (2016) investigates the microeconomic factors that ship-specifics gives in terms of charter and rates. They also explore if energy efficiency pays off by means of contracts. In their findings, they highlight that “standardized vessels” in both the PSV and AHTS segments has been shown to be preferred. For energy efficient AHTS, they argue that the market has become more sensitive to the issue, specifically for longer charter contracts awarded AHTS vessels in the NWE area. They further state that both environmental legislation and the charter dominant role in the supply chain, may impact further developments in this segment.

Grøvdal & Tomren, (2016)’s OSV lay-up research, comes at this from a different angle. Their thesis uses logistic regression to argue for the significant link between the AHTS specific bollard pull (BP) capacity and the lay-up decision by owners.

An equivalent research done by Tvedte & Sterud, (2016), look at obtaining contracts for OSV’s. For the AHTS segment, that research makes claims to the diversification between spot/long-term chartering and the vessel specifications. Elaborating on the importance of technical specifications to be able to win contracts.

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Bjørkelund, (2014) thesis on pricing in offshore shipping markets, suggest a two-regime mean reverting jump diffusion model with seasonality, to better understand the spot rate dynamics in the North Sea market.

The above-mentioned research's denominator is the influence OSV vessel's specifics have on charterer appeal, disclosed through utilization, lay-up decision and rate levels. The only AHTS specific research found, Dahle & Kvalsvik, (2016), disclosed a handful of specifications to have a significant effect on the rate levels:

AHTS specifications researched to correlate with charter rates	Correlation	Comments / indicating	Geographical Area
Bollard pull	Sig. positive	Larger BP cap. earns higher rates	NEW
Break horsepower		Argued to reflect that of BP	NEW
Deadweight t	Sig. positive	Larger cargo cap. In DWT earns higher rates	NEW
DP configuration	Sig. positive	DP class 2 vsl. earn higher rates	NEW
Age	Sig. Negative	Higher aged vsl. earn lower rates	NEW
Duration of charter	Sig. Negative	Longer charter periods earn lower rates	NEW
Average monthly rate	Sig. positive	Monthly rates reflected market and removes spikes and troughs	NEW
Areas of operation		Not found other areas researched than NWE	
Fuel consumption	Various results dependent on represented consumption variable and calculations.	Signs of FEI (bhp) variable showing a penalty for AHTS with higher relative consumption. Negative corr. in long term charters, positive in shorter charter periods.	NEW

Table 2 AHTS specifications researched to correlate with charter rates

The findings regarding consumption and rates are described as insignificant in all but one consumption variable. The consumption findings encounter some issues that arguably originates with the data and method used for analysing the various vessels consumptions. The research finds the modified Fuel Efficiency Index (FEI) variable to show significance, however, this method has certain limitations. The adaption of research from conventional shipping and geographical narrowing-on the NWE area, will be sought further explained and countered in the following sections.

2.5 The fuel consumption for AHTS

Fuel consumption theory and calculations in shipping are dependent on the displacement of the vessel and speed to power ratio. Assmann, Andersson & Eskeland, (2015), utilizes the commonly agreed upon equation for fuel consumption in their research regarding very large crude carriers (VLCC):

$$F = \left(\frac{V}{V_d}\right)^{\varepsilon} F_d \left(\frac{\nabla}{\nabla_d}\right)^{\varepsilon}$$

F - Fuel Consumption

V - Vessel speed

Vd – Vessel design speed

Fd - Fuel consumption at design speed Vd

ε - Fuel consumption exponent (depends on vessel type)

∇ - Displacement of a ship

∇d -Displacement at design draught

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The above outlined equations show the fuel consumption as dependent on vessel speed, displacement, their design calculations, and a fuel consumption exponent, varying amongst vessel segments.

Another equation utilized in researching consumption and variations in efficiency towards rates, is the fuel efficiency index equation developed by Adland et al. ,(2017).

$$FEI = \left(\frac{Consumption}{DWT \times Speed \times 24}\right) \times 10^6$$

The FEI index was originally employed in analyses conducted for researching the dry-bulk market and the probable premium obtained with improved fuel efficiency. In later researches, it has been used in research conducted on AHTS specifics and its influence vis-à-vis rate levels. When applied to researching the AHTS segment, neither the fuel consumption equation nor the FEI equation can account for the various operation modes, typical for ordinary AHTS operations.

When a cargo vessel transports goods from A to B, there are some key aspects that effects the fuel consumption of the vessel. Bialystocki & Konovessis, (2016) state that in addition to the traditionally used power to speed curve for optimal consumption during transit; draft, displacement, external conditions (waves, wind, and currents), and the design of the hull also affect the consumption. Since the core operational modes in the deep-sea segment are few, (in port loading/offloading, transit fully-loaded, transit in ballast condition, manoeuvring and waiting at anchor), and most of the operational time is spent in transit, monitoring and data collection is mainly focused on the latter mode.

The deep-sea theories and calculation methods as viewed below, encounter some limitations when adapting them to the offshore segment, as the AHTS vessels endures a wider spread over additional modes of operation.

Fuel consumption theory & calculations	Equations	Research by
Dependent on vessel speed, displacement, their design calculations, and a fuel consumption exponent, varying amongst shipping segments.	$F = \left(\frac{V}{V_d}\right)^{\varepsilon} F_d \left(\frac{\nabla}{\nabla_d}\right)^{\varepsilon}$	Assmann, Andersson & Eskeland, (2015)
Fuel efficiency index (FEI) Uses DWT (Cargo shipped in tons instead of vessels displacement. A commonly used index to research connections between consumptions and rates. Modified with bhp in lower equation.	$FEI = \left(\frac{Consumption}{DWT \times Speed \times 24}\right) \times 10^6$ $FEI_{AHTS} = \frac{Consumption}{BHP*Speed*24} * 10^6$	Adland et al. ,(2017) Dahle & Kvalsvik, (2016)
Difference from average fleet (DAF)	DAF = (Consumption-Average fleet consumption) x bunkers price	Dahle & Kvalsvik, (2016)
Divided on propulsion type	Diesel mechanical system analysed for correlation with rate levels	Dahle & Kvalsvik, (2016)

Table 3 Fuel consumption theory & calculations

The preliminary research on the AHTS segment reflects that traditional deep-sea consumption definitions and calculation of variables, viewed in *table 3*, only to some degree corresponds. Essential differences should be noted, as the following table shows, some key modes are not represented for the compared vessel segments:

Variables effecting vessels consumption performance			Deep-sea	AHTS
Power-speed ratio			x	x
DWT, Displacement and draft			x	x
Engines & Generators; type & configuration			x	x
Hull, shape and smoothness			x	x
Operational modes	Transit A-B, loaded condition		x	x
	Transit A-B, ballast condition		x	x
	In Port Loading/Unloading		x	x
	At anchor (Awaiting quay or charter)		x	x
	DP Mode	Supply		x
		Waiting on platform or weather		x
		Standby		x
	Towing			x
	Anchor Handling			x
External forces (Wind, waves & Currents)			x	x
Operational Management (decentralized). Company guidelines, routing etc.			x	x
Operational Management (local). Onboard planning and optimization from crew; Including trim of vessel, route planning, speed and engine optimizations towards logistic schedule etc.			x	x

Table 4 Consumption variables effecting vessels performance

The crucial part of station keeping using Dynamic Positioning (DP), is one variable that separates the segments. Lindstad, Eskeland & Rialland (2016), argues that for the AHTS vessels, DP mode is often a requirement, when entering the rig or platforms 500-meter safety zone. The system maintains a set position at high accuracy and is engineered around a philosophy of redundancy. This means backup systems and power sources, which in turn means potentially higher consumption, as two or more engines / generators are operating on what is conceivably far from optimal power outputs.

Myklebust, (2011) support this, and makes claim for its significance, stating in his comparison study that close to 50 % of the time was spent in DP / Standby mode. He goes on to describe that during the crucial operations of anchor handling or towing, the AHTS can use large power outputs over shorter periods of time, illustrating the vast differences between modes, these vessels can encounter. A study conducted on a AHTS mode and consumption spread, conducted by a classification society in 2012, were as viewed in *figure 2*. The internal study on 66 vessels from various owners found that over 30% of the time and 29% of the consumption were during DP Mode. The specified modes and fuel oil consumption (FOC) in said modes, are what's separating this segment from more conventional consumption theory.

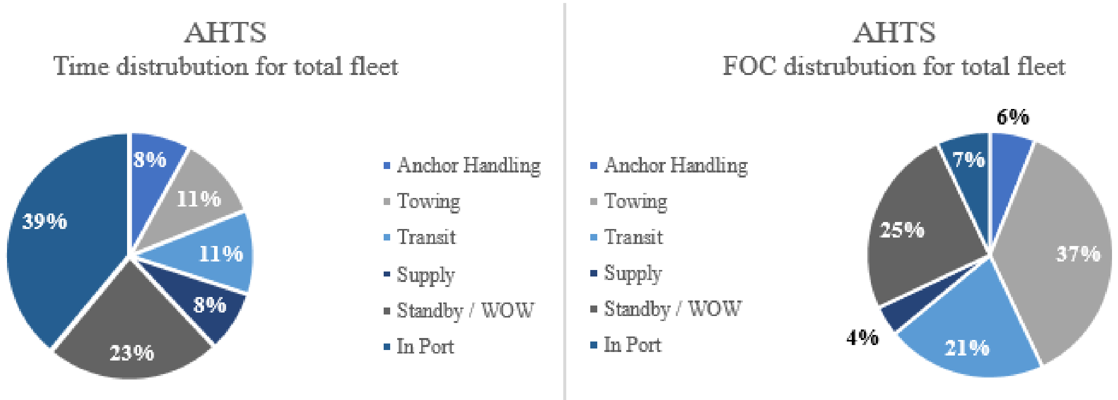
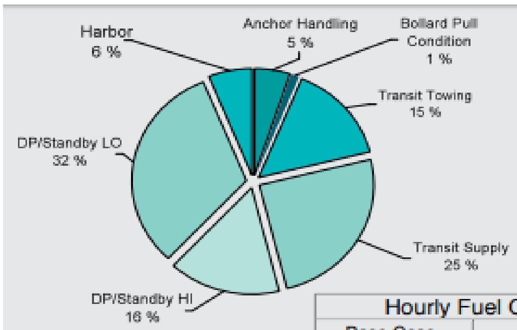


Figure 2 Distribution for Time & FOC (Internal Class society survey, 2012)

Time spent in different modes vary with scope of work, area of operation and external forces like weather. A case study by Myklebust, (2011) on a 200t BP AHTS, *figure 3.* Shows time spent in different modes, and how the difference in consumption for the diesel-mechanic and diesel-electric propulsion systems vary. The variation in consumption between propulsion systems will be utilized when dividing the vessels consumption profile in coming research, as they arguably offer a more precise segregation than conventional consumption theory, and lay the foundation for a more segment specific research of the AHTS vessels.

2.6 Propulsion systems and developments in AHTS

Myklebust & Aadnanes (2011) explain that a potential reduction in consumption of 16.8% is credible to favour a DE propulsion system, given *figure 3'*s used spread over modes, during a year in operation. They also state that in certain modes demanding higher power outputs, the DM systems are superior to the DE ones. Wartsila (2015), also support this and state that the optimal fuel consumption profile available today is gained with a Hybrid system. For the large type AHTS's, the hybrid system incorporates the advantages from both DE and DM systems and can be optimized according to each mode. Still maintaining high capabilities needed for anchor handling and towing scopes.



	Hourly Fuel Oil Comsuption kg/h		
	Base Case D-Mech	Electric Propulsion	Operation Profile
Anchor handling	2280	2295	438
Bollard Pull Condition	2451	2795	88
Transit Towing	1898	2053	1314
Transit Supply	1276	1036	2190
DP/Standby HI	1377	1020	1402
DP/Standby LO	1015	620	2803
Harbor	26	25	526

Total FOC kr//year	11 293 005	9 396 661	
Total FOC m.t./year	11293	9 397	
Difference, m.t./year	0	1896	

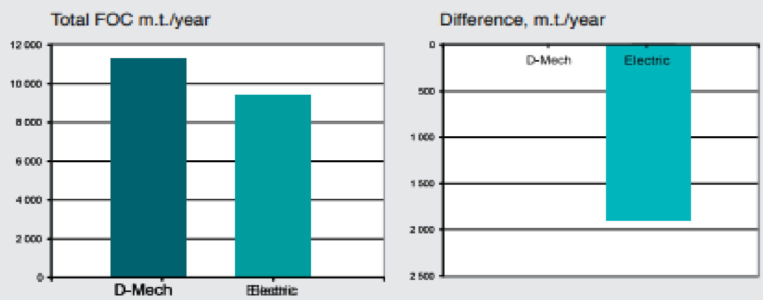


Figure 3 Myklebust & Aadnanes (2011).

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In the coming research, the different consumption profiles obtained through DE and hybrid engine configurations versus the more traditional DM, will be used as independent variables, when researching if there is a correlation between consumption and rates. The argument supporting this variable selection is split between the unprecise methods of analysis adapted from deep-sea theory and the current lack of precise consumption data from the AHTS vessels, reflecting their spread over operational modes.

Up until the mid-1990ies, the majority of OSVs' were using diesel mechanical propulsion systems. Rapidly, the PSV segment started adapting the DE solution, and today the clear majority of PSVs are configurated with this type of setup.

Some of the first AHTS vessels with DE and later Hybrid arrangement were built from around 2005, and this segment has also seen a percentage gain away from pure DM. Though not to the same extent as the PSV segment, as bollard pull demands, which are technically favoured in DM configurations, have surpassed the overall benefits and consumption gains from configurating with pure DE, Myklebust & Aadnanes (2011).

The current OSV market recession is well in to its consecutive forth year, and few orders for new AHTS vessels were found placed prior to 2014. The perceiving cases prior to the collapse can be viewed to support a hypothesis in ways of HB system preference. The latest major order came in October 2014, when the large Danish OSV owner, Maersk Supply Service inked a deal for six hybrid AHTS vessels, from the Norwegian yard Kleven, Offshore Energy Daily, (2014).

Most recent orders of AHTS vessels as viewed below, supports the argument for assumed movement away from DM.

Vessel Name	Status	Propulsion System	DWT	BP	BHP	Delivered	Design
Maersk AHTS SALT 200 TBN06	Under Construction	HB	4,500	230	23,000	2019	SALT 200
CBO AHTS OCEANA 05	Under Construction	DM	3,000	200	16,316	2018	Haryard 843
CBO Iguacu	In Service	DM	3,000	200	16,316	2018	Haryard 843
ECO Ice Class AHTS TBN01	Newbuild Cancelled	DE	5,000	180	27,520		na
ECO Ice Class AHTS TBN02	Newbuild Cancelled	DE	5,000	180	25,000		na
Island Victory	Under Construction	HB	8,000	400	26,000	2018	UT 797 CX
Maersk AHTS SALT 200 TBN04	Under Construction	HB	4,500	230	23,000	2018	SALT 200
Maersk AHTS SALT 200 TBN05	Under Construction	HB	4,500	230	23,000	2018	SALT 200
Maersk Mover	In Service	HB	4,500	230	23,000	2018	SALT 200
Sayan Prince	Under Construction	DM	4,000	220	21,700	2018	MOSS 919
Varada AHTS H842 TBN03	Under Construction	DM	3,000	200	16,092	2018	Havyard 842
Varada AHTS H842 TBN04	Under Construction	DM	3,000	200	16,092	2018	Havyard 842
Varada AHTS H842 TBN05	Under Construction	DM	3,000	200	16,092	2018	Havyard 842
Varada Grace	Under Construction	DM	3,000	200	16,092	2018	Havyard 842
Varada Shark	Under Construction	DM	3,000	200	16,092	2018	Havyard 842
Bram Force	In Service	HB	4,891	260	27,360	2017	na
Bram Power	In Service	HB	4,917	260	27,256	2017	na
CBO Bossa Nova	In Service	DM	3,000	200	16,316	2017	Havyard 843
Maersk Mariner	In Service	HB	4,500	252	24,018	2017	SALT 200
Maersk Master	In Service	HB	4,500	252	23,000	2017	SALT 200
Bourbon Arctic	In Service	HB	4,000	280	26,000	2016	VARD 2 12 Arctic
Skandi Paraty	In Service	DM	4,200	250	23,112	2016	STX AH11
Boa Jarl	In Service	HB	4,250	285	27,000	2015	VS491CD
Bram Titan	In Service	HB	4,742	310	23,392	2015	na
Go Perseus	In Service	HB	4,500	250	24,000	2015	VS491CD
Hai Yang Shi You 684	In Service	DM	3,293	190	15,000	2015	na
Hai Yang Shi You 685	In Service	DM	3,293	190	15,000	2015	na
Maersk Cutter	In Service	DE	4,000	180	15,000	2015	VS482
Pacific Centurion	In Service	DM	3,600	200	16,100	2015	UT786CD
Skandi Angra	In Service	HB	4,299	250	19,646	2015	STX AH11

Table 5 Overview of most recent AHTS orders and deliveries

Recent years orders and delivery's show owners' slight lean towards Hybrid solutions, with 15 HB systems under construction or delivered since 2015. 14 of the more traditional DM configuration can be seen in the same period, while only 3 diesel electric system were found to have been ordered, with two of these cancelled by buyers, prior to completion.

The trend in ordering more hybrid propulsion systems supported an initial hypothesis favouring a negative correlation between rates earned and AHTS vessels with DM systems. It also perceived the possibility of detecting a significant positive correlation between hybrid and diesel electric systems and rate levels, as a negative or non-existent correlation, could be argued to make diminutive economic sense, as the next section will highlight.

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2.7 Investment Theory for Projects

Berk & DeMarzo, (2014) supports an initially higher project investment, given that the net present value (NPV) exceeds an initially cheaper project. The NPV calculation requires a certain amount of knowledge and credible assumptions, to be able to be viable. In short, the calculations seek to show the relationship between the cash outflows and the cash inflows of a given investment project, and uses compounded interest rate to illustrate what NPV an investment is expected to create.

A similar more simplistic investment appraisal, often used to support a preliminary project or configuration investment, is known as the payback period (PBP). Berk & DeMarzo, (2014) argues that the NPV method is preferred for accuracy, but state that a PBP calculation can be used as decent guidance at an initial decision stage. The PBP method is often used in both shipping and offshore circles, due to its simplicity and suitability for the volatile business models. The PBP shows the time it will take for an initial cash outflow to be repaid, without considering the time value of money and interest rate. Both methods are based on the principle of obtaining the highest possible value when deciding amongst different investments.

Keeping in mind the initial higher cost for selecting DE or HB as appose to a DM configuration, one could argue, based on these theories that the owners expect higher revenues (rates) for the DE or HB vessels, as this configuration is proving to be increasingly preferred, shown through historically placed orders.

2.8 Competitive Forces

According to Porter, M. E. (2008)'s Five Competitive Forces, applied to analyse markets and business strategies, the bargaining power rests with buyer or seller dependent on various factors. Olesen, (2016) Points to the supplier's strength to be dominant when demand is high and there is no substitute for the product or service provided. A strong group of suppliers can then charge high prices despite limited quality and services, since the buyer's position is weak. A contrary scenario will see buyers position strengthened, as the oversupply would lead them to force down prices and request more for less, in terms of quality and performance.

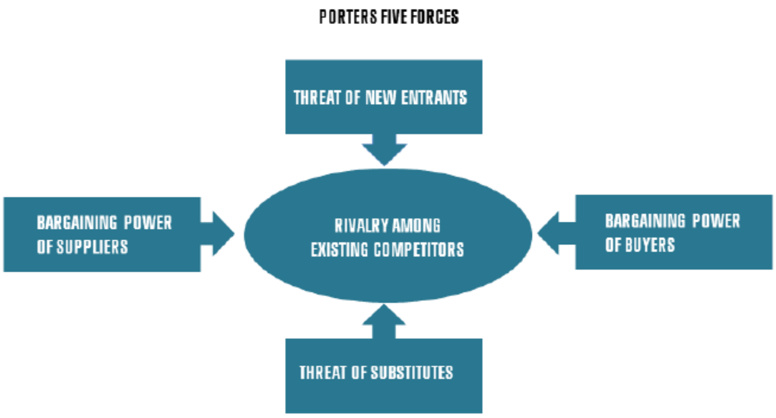

Figure 4 Porter, M. E. (2008). The five forces that shape strategy

Viewed through the lenses of the upstream offshore E&P chain, the supply/demand and power ratio theories could be adapted, and help reject or confirm the hypotheses put forth in the coming section.

2.9 Refined research questions and hypotheses

To answer the research questions in *table 7*, I utilized the three different propulsion systems available for the AHTS's, searching for a correlation between consumption and the dependent variable, daily rate. The independent control variable, average monthly rate, was added to divide the market, and test for correlations in both sellers and buyers' market.

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Dependent Variable	Unit	Type	Interpretation
Daily rate	USD /d	Numeric	Continuous
Independent Variable			
Hybrid Propulsion System		Categorical	Dummy variable created to analyse variable in the methods conducted
Diesel Electric System		Categorical	Dummy variable created to analyse variable in the methods conducted
Diesel Mechanic System		Categorical	Dummy variable created to analyse variable in the methods conducted
Average monthly rate	USD/d	Numeric	Continuous. Monthly avg. day-rate (manually calculated) to reflect a buyers' market.

Table 6 Variables and definitions

The variables listed in *table 6* were used to analyse and answer 2.9.1, 2.9.2.1, 2.9.2.2 and within each of the main areas isolated, for research question 2.9.3.

No	**Research question**	**Market**	**Area**	**HB**	**DE**	**DM**	**Hypotheses**
2.9.1	Are there variations in rate levels earned for AHTS's with different consumption systems?	Overall	All	x +	x +	x -	Yes, superior consumption systems in AHTS vessels are believed to earn an average higher rate. Also, a variance between the three is believed to exist
2.9.2.1	Is there a positive correlation between consumption-efficient AHTS's and rate levels?	Strong seller power	All	-	-	+	No, DM systems are believed to have a positive correlation with rates, when sellers power is strong, and buyer lack options. HB and DE predicted to show negative or no correlation with rates.
2.9.2.2		Strong buyer power	All	+	+	-	Yes, HB and DE systems are believed to have a positive correlation with rates, when buyer power is strong, and options are vast. DM systems believed to correlate negatively.
2.9.3	Are the stated research questions in 2.9.2.1-2 true for all main areas of operations?	Both	Individually	x	x	x	Various levels of maturity and development might separate areas with regards to propulsion system and rate correlation. I lean towards the research showing variations between areas.

Table 7 Research Question and Hypotheses

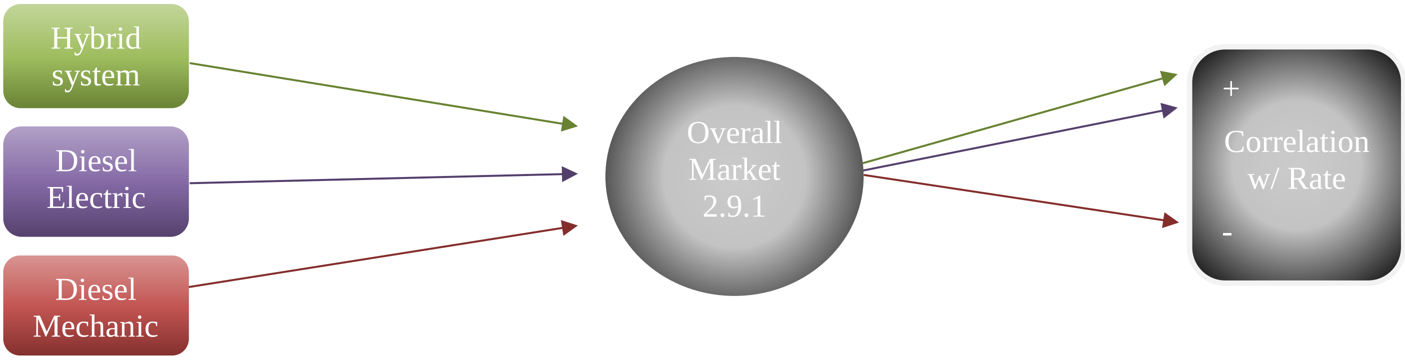

Figure 5 Conceptual model for 2.9.1

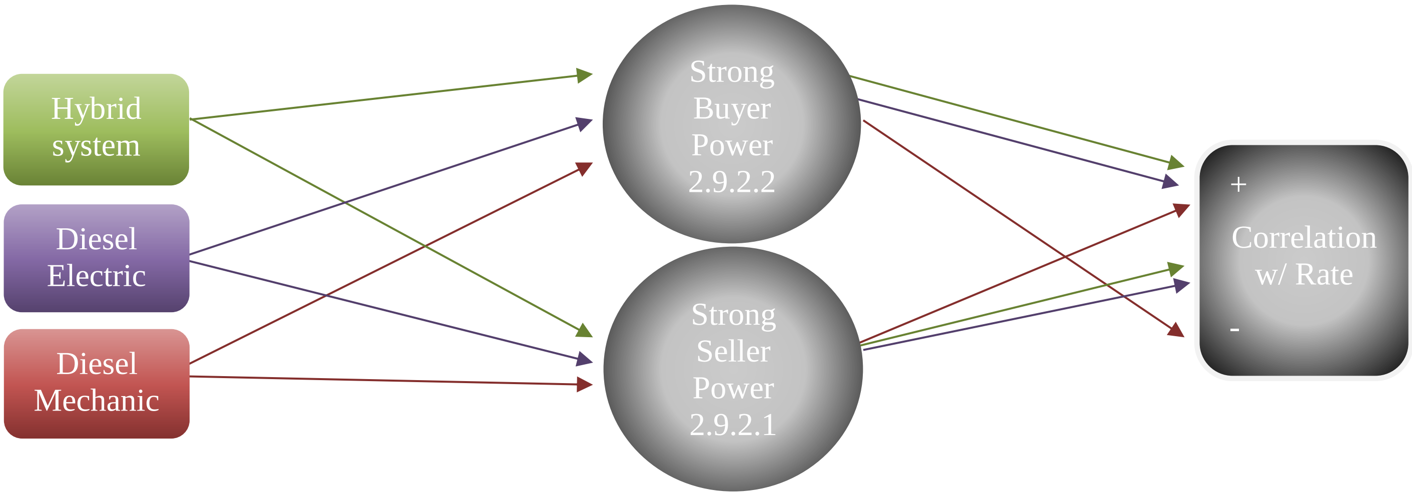

Figure 6 Conceptual model for 2.9.2.1-2

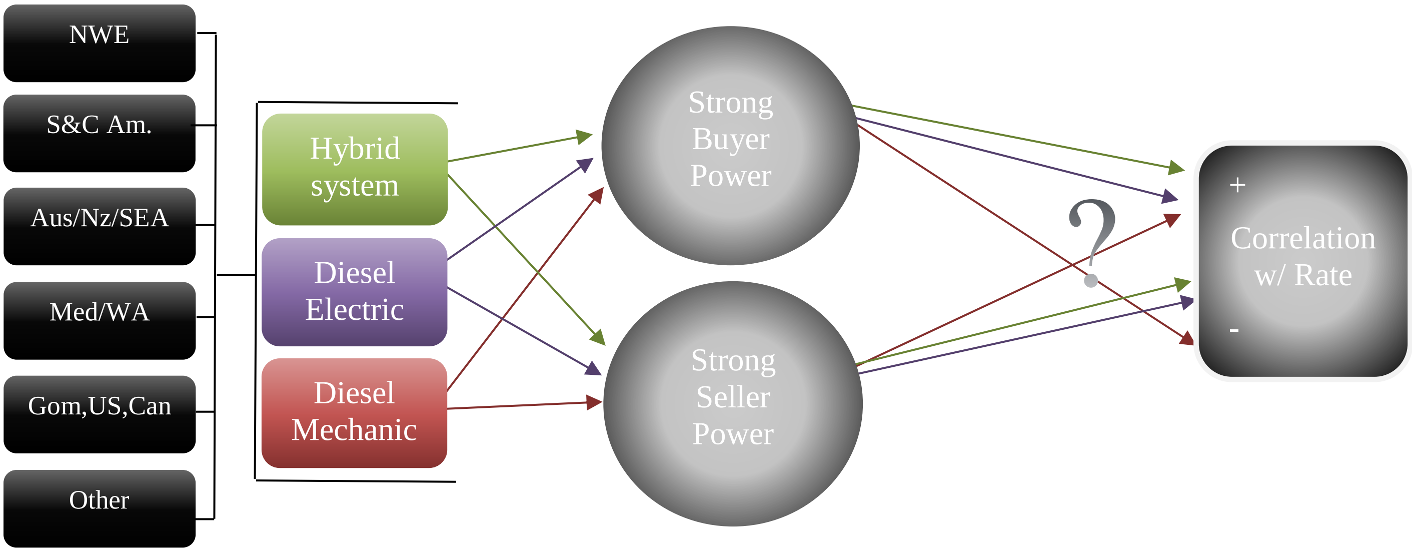

Figure 7 Conceptual model for 2.9.3

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3. Methodology

3.1 Research strategy and design

The research strategy is an overall approach to how the research is intended to be examined, and set out to explain what type of tools the researcher will apply to obtain validity for the probable answers and assumptions. A research design can be viewed as a bridge connecting research questions with data, showing their relationship in depth and the process used to answer the question(s). Frankfort-Nachmias & Nachmias, (2008).

This thesis has its basis in research and results from a combination of qualitative and quantitative data collection. The quantitative data gathered assisted in building empirical evidence, supporting, or rejecting a correlation between consumption and rates. The qualitative interviews strengthen the research and helped produce a contemporary understanding of the underlying variables, from key industry-player's perspective. The decision to use a mixed method approach originated from the complexity of the business and the lack of easily accessible data, concerning fuel consumption and rates.

From an early stage of the process, it was evident that a combination of quantitative and qualitative methods would suit the task and have the potential of gaining the most useful result. This methodology chapter describes the methods used, first through a wide-ranging interpretation, followed by a thesis attentive description.

3.2 Quantitative research

Quantitative research uses objective measurement of extensive data sets collected, to attempt explaining a phenomenon. Mathematical, statistical, and numerical tools are utilized to produce empirical evidence from the data sets, which in turn give potential for generalization. Typical forms of data collection can be questionnaire's or secondary data from previous conducted studies. The goal of the research is often to be able to gain support for a relationship between one dependent and one or more independent variables. Creswell & Creswell (2018).

Strengths of quantitative approaches as argued by USC, (2018), includes the ability to take on broader studies and enhancing the generalization of the results, objectively and accurate. They go on to state that such methods can be replicable and earn the study more validity. Other pros include utilizing computerized tools, cover larger data amounts and avoid bias from interacting directly with subjects. The negative characteristics can entail a lack of circumstantial elements, little flexibility, diminutive knowledge of surrounding variables and a large error risk, if the population and sample data is incorrect.

A research covering an entire population is challenging, so a common approach is to select a representative sample of the population and thus provide supportive evidence from the sample researched. One important feature for this type of study is the correct selection and collection of sample data. As an example, investigating and analysing a parameter, such as consumption data gathered from 500 random vessels (sample), does not automatically provide any consistent empirical resilience, if the researchers objective is to collect and process data reflecting vessels defined as AHTS (population).

This thesis used a deductive research approach in attempting to reject or confirm the stated hypotheses in section 2.9, through the quantitative data analysis and qualitative interviews with key individuals. The quantitative data was used in a one-way ANOVA analysis to examine the difference in average mean between the three propulsion systems on the dependent variable.

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To detect magnitude and direction of correlation, a multiple linear regression analysis was conducted. For answering 2.9.2.1, a model with the three independent variables for propulsion systems were tested against the dependent variable, rate.

Researching if the market-power affected the outcome, and answering 2.9.2.2, the independent variable, avg. monthly rate was added to the model. I defined this variable as a moderator for the market, rejecting single high and low rates and reflecting a more balanced market climate, argued to favour the buyer side. The background for the method choice stems from similar theses referred to in the literature review, researching vessel specifics and there influence on the rate earned, for PSVs and AHTS vessels.

3.2.1 Data Collection

The data set used in the analysis were collected as second-hand data from an oil and gas consultant and analysis firm, IHS Markit. Access to the database was provided for a period by the collaborating brokerage company. IHS provides a wide range of analysis and expert consultation to oil and gas companies and brokerage firms. The IHS Petrodata Marinebase was used to collect data concerning the vessels specifications and the contracts fixed for each vessel, from 2006 until 2018.

3.2.2 Population and Sample

The thesis researched large type AHTS vessels, able to conduct services in deep-sea areas. Accordingly, the break horsepower limit was set to 15,000 Bhp in the search. The total number of vessels with this specification were defined as the large AHTS population. To research the data in the SPSS program, some data editing and cleaning was required. The following section describes how the process accumulated in to the end set for analysis of retained samples.

3.2.3 Data editing

On the 14th of March 2018 a total of 14359 samples were found and downloaded from IHS Petrodata. Unfortunately, not all contract rates were given, so an initial 3627 fixtures were deleted from the data set, as other sources for rates, proved challenging to acquire. The removal of unidentified contracts samples was not ideal for the accuracy of the research. However, samples deprived of rates were evenly spread over the period researched, and amongst the different types of propulsion systems, resulting in an insignificant effect for the end result. Contract rates are sensitive information to each involved member of the cycle, and hence not always made available or public.

The period chosen for the research was set to cover contracts between Jan 2006 and Feb 2018. The selection was based on the absence of DE and HB vessels of size, found to be delivered prior to 2006.

In all 2472 samples were deleted from the dataset for reasons related to the fixture dates falling outside the period set. This left a total of 8260 samples for analysis in the SPSS software program.

Columns containing irrelevant data for the analysis were deleted prior to entry; client, manager, class etc. Although the data set was extensive, some specifications and figures were absent, and needed to be supplemented from other sources. Predominantly shipowner’s homepage and vessel specification sheets were used to fill in missing data. To maintain certainty in the matching of data and vessels, the ship specific IMO number was used. The IMO number follows the vessel its entire life, and does not vary if sold, converted, or changed in any way.

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The main independent variables for the correlation test, the propulsion systems, needed to be acquired from vessel specific sheets. 323 fixture dates were absent in the data set, and subsequently set manually to the same date as when the contract started.

3.2.4 One-way ANOVA

To research for a significant difference in average mean rate between the diverse propulsion systems, and answer research questions 2.9.1, a one-way ANOVA analysis was conducted. It was deemed crucial to establish significant variance between the propulsion systems and rate levels, to justifying further research.

Martin & Bridgmon, (2012), explain how the one-way ANOVA analysis can be used to research variance between and within categorical groups as the independent variables on a continuous dependent variable.

This method was predicted to reveal differences in average mean rates for the various propulsion systems, and support further analysis if found to be of significance. It was not predicted to help foresee variance between areas or buyer and seller power.

To be able to conduct a one-way ANOVA test in the SPSS software, the propulsion systems were edited and labelled numeric values 1, 2 and 3 for the DM, DE, and Hybrid systems. The daily rate was set as the dependent variable.

3.2.5 Multiple linear regression

Multiple regression analysis can be used to evaluate the extent that two or more independent variables (IV) relate to a continuous dependent variable (DV), Martin & Bridgmon, (2012). The multiple linear regression equation;

$$\hat{Y} = b_0 + b_1X_1 + b_2X_2 + ... + b_pX_p$$

Sees $\hat{Y}$ as the predicted value of the dependent variable. X_1 through X_p are p mutually exclusive independent variables, b_0 is the value of Y when all independent variables, X_1 through X_p are equal to zero, and b_1 through b_p are the estimated regression coefficients. The regression coefficients represent the change in Y relative to a one-unit change in the independent variable. In a multiple regression, b_1 can be interpreted as the change in Y relative to a one-unit change in X_1, holding all other independent variables constant.

Statistical tests can be performed to assess whether each regression coefficient is significantly different from zero. Multiple regression analysis can also be used to measure whether confounding exists, since the analysis allows for estimating the relationship between an IV and the result, all other variables constant. This allows for a possible control for added variables, encompassed in the model. Boston University, (2013).

Cohen, J. et al, (2003) describes the method of labelling categorical variables in to dummies, coded with 0 and 1's. This method of using dummies in a regression allows for two categorical variables to be compared to a constant (third categorical), on the dependent variable.

A multiple linear regression analysis was applied to measure the effects the IV had on the DV, and how the correlation varied in a buyer or sellers' market. The regression model was first set to research 2.9.2.1, investigating for a correlation between propulsion systems and rate levels in an unlevered market. For the second model the market variable, average monthly rate was added, in an attempt for confirming the hypothesis stated in 2.9.2.2

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3.3 Area specific analysis

For the research of 2.9.3, the multiple linear regression methods stated above, were conducted on the five segregated areas of interest. In the isolated analysis of the geographical areas, the decision was taken to compound closely connected areas to get sufficient frequencies and research the data at an elevated level. The areas were set to;

- NWE (Northwest Europe)
- S&C Am (South America and Central America)
- Aus/NZ & SE Asia (Australia, New Zealand and South-East Asia)
- MED/WA (Mediterranean, Black Sea and West Africa
- GOM, US, CAN (Gulf of Mexico, US areas and Canada)
- Others (All other; Far East, Indian Ocean, Middle East and Russian Arctic)

3.4 Qualitative research

The qualitative research approaches can in general be described to research more in depth within a topic. The QUAL methods can detect more of the underlying causes for the associations researched and help reject or confirm developed hypotheses. A common method of qualitative research, is the interview method. Conducted in various structurally forms, personal interviews with participants can produce otherwise overlooked data, and function as an elastic approach to answering a research problem. Welch et al, (2002).

For this thesis to gain sufficient data support and confirm or reject the hypotheses in *table 7*, it was deemed crucial to acquire first hand data. In hopes that such data would help explain the complexity of the business and support the QUAN data findings. Where the second-hand data analysis exploited the numbers, the interviews with top level individuals, defined as “elite informants”, Welch et al, (2002), collected first hand data, not easily extracted otherwise.

Initially one can argue that the main strengths of interviews are the collecting of supplementary information, however there are other benefits as argued by Frankfort-Nachmias & Nachmias, (2008). The flexibility in structure and process, more control over the data gathered and prone to high response rate. Disadvantages are described to include relatively high cost to conduct the research, bias exposure, and the lack of anonymity. Response and availability of elite informants could prove more challenging, as these individuals often have tight schedules and are engaged with running their businesses, Welch et al, (2002).

3.4.1 Data Collection and Approval of Research

To balance cost and time, the decision was made to conduct the interviews via mail and telephone correspondence. As stated by Keats, (2000), this can assist in lowering the cost and time consumed, but runs the risk of missing face to face interactions, and the non-verbal communication expressed by interview objects.

The questions and research methods were registered with the Norwegian Centre for Research Data (NSD) and given approval. Gathering of consent and conducting the interviews then followed. To be able acquire candid feedback and data material from the participants, I choose to analyse and present the data confidentially. This opened for more sensitive data being shared, as the questions sought answered could be argued to have negative impact on the persons and companies participating.

The depth of the elaborations was given priority over the openness regarding each object, as previous conducted research has utilized said method, it supported the decision for this thesis as well. This resulted in a presentation of participants though segment affiliation and main area of operations, instead of full name of person and company.

3.4.2 Objects of interest

To be able to gain as much relevant and geographically spread data, corresponding with the correlation analysis conducted, the decision was taken to interview key individuals at the highest levels of influence. The interview objects were sought gathered from the significant areas of operation, described in section 2.3. Preliminary research and literature on the segment suggested that the main decisionmakers would include lead chartering personnel from the oil and gas companies, vessel owners and their chartering departments, and offshore brokers, argued to possess market information and situational awareness.

The decision was also made to reach out to designers and yards, designing and building the vessels being researched. Their expertise was thought to assist in supporting or rejecting the hypothesis stated in *table 7*, as these institutions enjoy hands on experience with the types of vessels being ordered and built.

3.4.3 Participants

Initially a total of twenty-three companies and persons were approached in order to get a sufficient participation volume, able to represent the various sides of the business, and the geographical diversified areas. Out of the initial twenty-three, thirteen did not respond, despite numerous attempts to establish contact. Two responded, but declined to participate, not viewing their companies as relevant for the research. This left a total of eight respondents willing to contribute in the study.

Keats, (2000), claims non-respondents have various reasons for not partaking in research regarding their business of operation. Lack of time, overall willingness, belief in the relevance or unwillingness to share, may be possible reasons for avoiding participation. To counter the likelihood of non-respondents, initial distribution to a larger number of objects was carried out. The goal was at least one relevant company or person from each part of the industry and geographical area. A weakness in the interview method origin from lack of response, as the research sufferers both in terms of less data, but also grasping the type off data lost and the underlying reasons. The diverse types of respondents obtained are argued to diminish some of this negative effect.

3.4.4 Interview method

To be able to obtain qualitative data seeking to reject or confirm my initial hypothesis in *table 7*, a deductive approach through semi structured interviews, with open ended questions was utilized. The questions were focused on gaining background information to strengthen and explain the tendencies and correlations. The interviews were conducted through telephone and mail correspondence, and sorted by question and participant. Each answer was analysed and compared amongst respondents. By following the theory of Bogdan & Biklen, (1992), the main goal was to try and detect patterns and regularities in the responses, able to assist in confirming or rejecting the hypothesises in *table 7*.

The first question in the interview guide was edited and used to reference segment affiliation and main geographical area of operation. The last question in the interview guide was cut due to this question having more of a logistical purpose. In the interview analysis found in the result section, edits were made to revealing names to harmonize with the anonymity of each participant.

3.4.5 Interview Guide

The letter of information distributed along with the consent form can be view in the appendices of the thesis. The open-ended questions asked were as viewed below. The section with reference to each question was not initially distributed, but was added to display connections to the research questions and hypothesis in *table 7*.

	Interview Guide – Questions with regards to large AHTS vessels (140BP<, 15.000 BHP <)	Purpose and connection
	Please state your job title.	-
1	In your opinion, what are the main elements driving forth less fuel consuming vessels?	Background data
2	Do you think that the AHTS segment has seen focus on fuel consumption in the past?	2.9.1-2.9.3
3	To what extent do you think the rate obtained by a AHTS is dependent on its fuel consumption?	2.9.1-2.9.3
4	Has there been any change in the correlation between fuel consumption and rates earned by AHTS in the past three decades?	2.9.1-2.9.3
5	In your opinion, how has the cyclic market for AHTS influenced the fuel consumption correlation to rates earned?	2.9.2.1-2.9.2.2
6	Do you believe that fuel consumption will have a significant influence on AHTS rates going forward?	Expectations
7	Would you say that your answers reflect the global AHTS industry? If no, what geographical variations do you see with regards to the connection between consumptions and rates?	2.9.3
8	Apart from what we have discussed so far, is there anything relevant to the topic you would like to add?	Additional data
	Could I contact you by e-mail or telephone if further questions or clarifications are needed?	-

Table 8 Interview Guide with purpose & connection

4. Results

This section discloses the results of the different analysis's and the answers received from the semi-structured, open-ended interviews conducted.

4.1 Descriptive results

Dependent Variable; as expected, a significant range was found between the lowest and highest rates earned. This aligned with the conjecture that the market varies over the period researched.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Freight Rate USD pr/d	8260	3577	357500	48938.88	48250.414
Valid N (listwise)	8260				

Independent variables; The average monthly rates mirrors some of the same trends found in the daily rates, however the minimum average rate was approximately three times the day rate minimum.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Average Rate monthly	8260	10641	222004	48731.80	33686.249
Valid N (listwise)	8260				

The preliminary research conducted on propulsion systems was to a large degree confirmed in the frequency overview displayed below. Diesel mechanical propulsion systems accounted for 63.8 percent of the samples while hybrid systems made up approximately half of that, with 35 percent. One surprising discovery was made with regards to the diesel electric systems and its spread. Only one vessel could be found to have DE propulsion system within this segment and given size of larger than 15,000 bhp, however the vessel had numerous contract fixtures, and added up to a total of 1.2 percent of the data set.

HB, DE & DM

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	DE	99	1.2	1.2	1.2
	DM	5274	63.8	63.8	65.0
	HB	2887	35.0	35.0	100.0
	Total	8260	100.0	100.0	

The frequency found from the areas of interest were as displayed below. For the areas of operation, the data supported main areas defined for these types of vessels. As seen, the predominant fixtures were in the Northwest Europe area. This may be explained by the high frequency of shorter "spot" contracts, not seen to the same extent in other areas, where longer contracts are more common.

Descriptive Statistics

	N	Sum
NWE	8260	7722
South America, Central America	8260	171
Aus/NZ & SE Asia	8260	203
MED/WA	8260	81
GOM, US, Can	8260	36
Other Areas	8260	45
Valid N (listwise)	8260	

4.2 Results from the One-way ANOVA analysis

Descriptives

Freight Rate USD pr/d

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
DM	5261	50382.97	51253.547	706.626	48997.69	51768.25	3577	357500
DE	99	32017.79	22009.826	2212.071	27628.01	36407.57	8410	127800
Hybrid	2887	46938.00	42888.717	798.215	45372.87	48503.13	5823	324360
Total	8247	48956.54	48284.427	531.691	47914.29	49998.78	3577	357500

The ANOVA descriptive above, show the mean freight rate in USD/d for each propulsion system over the period. The highest average mean, 50.383 was earned by vessels with DM systems, while the HB systems followed with 46.938. At the low end of the scale I found the DE systems with 32.018 in average mean.

Since the sample sizes varied significantly between the groups, along with a violation of the Levene test for homogeneity, the below shown model's significance was less reliable.

ANOVA

Freight Rate USD pr/d

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5.087E+10	2	2.544E+10	10.937	.000
Within Groups	1.917E+13	8244	2325780585		
Total	1.922E+13	8246			

To confirm significance when analysing variations in means between the groups, a Welch test was conducted.

Robust Tests of Equality of Means

Freight Rate USD pr/d

	Statistic[a]	df1	df2	Sig.
Welch	32.593	2	287.050	.000

a. Asymptotically F distributed.

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The significance of the welch test combined with a Games-Howell (equal variance not assumed) Post Hoc Multiple Comparison test, gave the following significant comparisons of average means between groups.

Multiple Comparisons

Dependent Variable: Freight Rate USD pr/d

Games-Howell

(I) Hybrid,DE or DM	(J) Hybrid,DE or DM	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
DM	DE	18365.179*	2322.192	.000	12853.69	23876.67
	Hybrid	3444.968*	1066.052	.004	945.92	5944.02
DE	DM	-18365.179*	2322.192	.000	-23876.67	-12853.69
	Hybrid	-14920.210*	2351.681	.000	-20498.24	-9342.18
Hybrid	DM	-3444.968*	1066.052	.004	-5944.02	-945.92
	DE	14920.210*	2351.681	.000	9342.18	20498.24

*. The mean difference is significant at the 0.05 level.

The AHTS vessels with DM systems were seen to have earned a significant higher average mean rate, compared to both DE and Hybrid systems. For the HB systems, I found the average mean rate to be significantly higher than that of the DE systems. As much as 14.920 separated the latter in HB systems favour.

4.3 Results from multiple regression analysis

Model Summary[c]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.052[a]	.003	.002	48191.701	.003	11.068	2	8257	.000	
2	.710[b]	.504	.504	33982.044	.501	8350.106	1	8256	.000	.910

a. Predictors: (Constant), DM Propulsion (Highest Fuel consumption), DE Propulsion (Medium Consumption)

b. Predictors: (Constant), DM Propulsion (Highest Fuel consumption), DE Propulsion (Medium Consumption), Average Rate monthly

c. Dependent Variable: Freight Rate USD pr/d

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From the multiple regression analysis, the adjusted R squared in model one, indicated that as little as .2 percent of the variance in freight rate could be explained by the propulsion system variables. When adding the average monthly rate variable in model two, the explanation strength of the model increased to 50,4 percent.

Looking exclusively at the unstandardized coefficients B in model one, the DE systems indicated to have had a negative rate of 14.879 on average compared to the constant Hybrid, on the dependent variable. The DM systems to the contrary, exhibited an average positive rate of 3.486 compared to the Hybrid, on the dependent variable.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	46896.749	894.897		52.405	.000	45142.525	48650.972		
	DE Propulsion (Medium Consumption)	-14878.961	4925.427	-.034	-3.021	.003	-24534.036	-5223.886	.979	1.022
	DM Propulsion (Highest Fuel consumption)	3486.218	1114.579	.035	3.128	.002	1301.363	5671.073	.979	1.022
2	(Constant)	6185.686	772.455		8.008	.000	4671.480	7699.893		
	DE Propulsion (Medium Consumption)	-16769.985	3473.192	-.038	-4.828	.000	-23578.315	-9961.655	.979	1.022
	DM Propulsion (Highest Fuel consumption)	-11969.326	803.931	-.119	-14.888	.000	-13545.233	-10393.419	.935	1.069
	Average Rate monthly	1.038	.011	.725	91.379	.000	1.016	1.060	.955	1.047

a. Dependent Variable: Freight Rate USD pr/d

After adding the additional independent variable, average rate monthly in model two, the DE systems indicated to have had a negative rate of 16.770 on average compared to the constant Hybrid, on the dependent variable. The DM systems displayed to have had an average negative rate of 11.969 compared to the Hybrid, on the dependent variable.

4.4 Results from area specific multiple regression analysis

In the area specific research, analysing each area independently, the following model summary results were as displayed.

Model Summary[c]

Area	Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
NWE	1	.059[a]	0.004	0.003	49475.035	
	2	.733[b]	0.538	0.538	33693.450	0.777
South & Central America	1	.415[a]	0.172	0.167	12314.175	
	2	.420[b]	0.176	0.167	12316.196	1.537
AUS / NZ Southeast Asia	1	.124[a]	0.015	0.010	13472.087	
	2	.185[b]	0.034	0.025	13375.626	0.985
MED / WA	1	.087[a]	0.008	-0.018	17176.377	
	2	.586[b]	0.343	0.318	14062.081	1.582
GOM / US / CAN	1	.085[a]	0.007	-0.022	48246.305	
	2	.130[b]	0.017	-0.043	48733.105	1.421
Other	1	.462[a]	0.213	0.195	20134.997	
	2	.553[b]	0.306	0.273	19135.759	1.754

c. Dependent Variable: Freight Rate USD pr/d

The NWE area results showed similar regression outcomes as the overall analysis. DM systems were indicated to have had a positive correlation compared to HB systems in model one, with the opposite being true in model two. All results were found to be significant, however the adjusted R squared in model one indicated as little as a .3 % explanatory effect on the DV.

Coefficients[a]

	Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	95.0% Confidence Interval for B Lower Bound	95.0% Confidence Interval for B Upper Bound	Collinearity Statistics Tolerance	Collinearity Statistics VIF
NWE	1	(Constant)	46803.767	926.915		50.494	0.000	44986.762	48620.771		
		DE	-14744.981	5082.963	-0.033	-2.901	0.004	-24708.967	-4780.995	0.979	1.021
		DM	4532.200	1171.237	0.044	3.870	0.000	2236.259	6828.142	0.979	1.021
	2	(Constant)	3610.427	779.424		4.632	0.000	2082.545	5138.308		
		DE	-16043.913	3461.623	-0.036	-4.635	0.000	-22829.633	-9258.193	0.979	1.021
		DM	-12275.535	817.235	-0.120	-15.021	0.000	-13877.537	-10673.534	0.933	1.072
		Avg Rate	1.100	0.012	0.749	94.474	0.000	1.078	1.123	0.952	1.051

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For the South & Central American region, the data showed zero DE systems during the period researched. With regards to the models, both indicated to explain 16.7% of the variance in the DV. Both models resulted in a negative correlation for the DM systems versus the HB, on the DV. It was also detected that the avg. rate variable was found to be insignificant. Indicating a model failure for model two in this area.

Coefficients[a]

	Model		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Collinearity Statistics	
			B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Tolerance	VIF
South Am. Central Am	1	(Constant)	62141.400	3179.506		19.544	0.000	55864.735	68418.065		
		DM	-19712.285	3328.859	-0.415	-5.922	0.000	-26283.787	-13140.782	1.000	1.000
	2	(Constant)	63126.240	3337.578		18.914	0.000	56537.243	69715.237		
		DM	-19174.165	3375.132	-0.403	-5.681	0.000	-25837.300	-12511.030	0.973	1.028
		Avg Rate	-0.034	0.035	-0.069	-0.972	0.333	-0.103	0.035	0.973	1.028

Australia, New Zealand and Southeast Asia displayed similar lack of DE systems during the period. Both models revealed a low 1.0 and 2.5 % adjusted R squared. DM systems were indicated to earn a lower rate compared to HB, however the regression in model one was not found to be significant, under the 95% confidence level set. In the second model the DM systems were indicated to earn a negative rate of 5.763 compared to the constant HB on the DV.

Coefficients[a]

	Model		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Collinearity Statistics	
			B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Tolerance	VIF
Aus/NZ & SE Asia	1	(Constant)	42138.542	2749.978		15.323	0.000	36716.034	47561.049		
		DM	-5173.246	2928.537	-0.124	-1.766	0.079	-10947.842	601.351	1.000	1.000
	2	(Constant)	39589.828	3019.275		13.112	0.000	33636.131	45543.526		
		DM	-5762.926	2922.824	-0.138	-1.972	0.050	-11526.431	0.578	0.990	1.011
		Avg Rate	0.061	0.031	0.138	1.977	0.049	0.000	0.121	0.990	1.011

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For the Mediterranean and West Africa areas, all three systems were found to have operated during the period. Both models indicated DE and DM systems to negatively correlate with HB systems on the DV, but the results were found to be insignificant for both models.

Coefficients[a]

	Model		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Collinearity Statistics	
			B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Tolerance	VIF
MED/WA	1	(Constant)	42243.333	9916.786		4.260	0.000	22500.529	61986.138		
		DE	-14243.333	19833.572	-0.093	-0.718	0.475	-53728.942	25242.276	0.759	1.317
		DM	-6029.931	10108.124	-0.077	-0.597	0.553	-26153.660	14093.799	0.759	1.317
	2	(Constant)	27955.748	8431.990		3.315	0.001	11165.511	44745.986		
		DE	-28192.421	16388.954	-0.184	-1.720	0.089	-60826.998	4442.156	0.745	1.342
		DM	-6979.378	8276.775	-0.089	-0.843	0.402	-23460.543	9501.787	0.759	1.317
		Avg Rate	0.278	0.044	0.586	6.275	0.000	0.190	0.366	0.979	1.022

The regression models covering the Gulf of Mexico, US, and Canadian areas all lacked data on DE systems. The tendency for both models were found to be positively correlating for the DM systems compared to HB on the DV. The results were nonetheless found to be insignificant.

Coefficients[a]

	Model		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Collinearity Statistics	
			B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Tolerance	VIF
GOM US CAN	1	(Constant)	63000.000	24123.152		2.612	0.013	13975.856	112024.144		
		DM	12699.563	25586.467	0.085	0.496	0.623	-39298.394	64697.519	1.000	1.000
	2	(Constant)	59248.681	25241.717		2.347	0.025	7894.021	110603.341		
		DM	10387.480	26161.753	0.069	0.397	0.694	-42839.008	63613.967	0.976	1.025
		Avg Rate	0.095	0.168	0.099	0.569	0.573	-0.246	0.436	0.976	1.025

The analyses covering other areas found the models to explain 19.5 and 27.3 % percent, respectively for model one and two. No DE systems were found have operated in these areas, but the DM systems indicated to have had a negative correlation compared to HB systems, on the DV. All regressions were found to be of significance.

Coefficients[a]

	Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
			B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
Other Areas	1	(Constant)	66892.800	9004.644		7.429	0.000	48733.204	85052.396		
		DM	-32592.425	9550.868	-0.462	-3.413	0.001	-51853.585	-13331.265	1.000	1.000
	2	(Constant)	57689.483	9398.882		6.138	0.000	38721.770	76657.195		
		DM	-33682.750	9088.557	-0.477	-3.706	0.001	-52024.200	-15341.299	0.997	1.003
		Avg Rate monthly	0.258	0.109	0.305	2.368	0.023	0.038	0.477	0.997	1.003

4.5 Results from Interviews

A total of eight respondents participated in answering the open-ended questions from the interview guide. Below are the coded data displayed in table form, with analysis displayed for the respond to each separately asked question, additional data, and main extracted points.

1.In your opinion, what are the main elements driving forth less fuel consuming vessels?		
Essence from the answers obtained	Additional data	Main extractions
There seems to be consensus among the respondents, that the main driver for less fuel consuming vessels have been the cost aspect, including abilities to lower operational costs by reducing fuel. In addition, two other points were raised; The market downturn and cost focus seen across the up-stream logistics. Environmental issues hereunder emission, stricter legislation, and public opinions. Viewed to be of a secondary nature.	Technological evolution for more efficient consumption believed to have gained momentum Optimization of equipment and crew awareness of importance Change in party covering fuel costs predicted to possibly affect FOC focus Attractiveness for buyers	• Cost • Environment • Market

2. Do you think that the AHTS segment has seen focus on fuel consumption in the past?		
Essence from the answers obtained	Additional data	Main extractions
There was perceived to be an orientation towards a higher focus on FOC during recent years. However, the majority view capabilities and configurations for executing the required scope of work, as the primary focus for charters hiring the vessels. Total cost was described as more valued and fixated on. Higher rates could easier be defended when fuel and total cost were lower. Consumption efficiency seemed to have gained more traction after latest downturn in the market.	Proven technological consumption -reducing innovations implemented in similar segments, have not yet been implemented in AHTS vessels. Higher fuel prices mentioned to have had an impact, strengthening the focus.	• Last decade + / - experienced a higher focus on consumption • Capabilities such as BP and Bhp more significant

3. To what extent do you think the rate obtained by a AHTS is dependent on its fuel consumption?		
Essence from the answers obtained	Additional data	Main extractions
Conflicting responses were detected for this question. Vessel owners operating in the NWE area, predominantly expressed little faith in rates being dependent on consumption. However, voices were heard supporting consumption superior vessels, all other specifications aligned. Interview objects from the oil companies expressed a larger weighting for consumption profiles influencing rates GOM area explained to notice growing focus on consumption in the tendering process for vessels.	Perceived to vary dependent on the market and buyer/seller power. Length of contracts deemed to affect to what extent the FOC is weighted. Stronger positive correlation for fuel-efficient vessels on long term contracts. Less important in a spot market with uniform vessels. Track-record of vessel and crew competence valued.	• Less overall, supply and demand main driver • Significant driver in the tendering process of late. • Difference in views between buyer/seller

4. Has there been any change in the correlation between fuel consumption and rates earned by AHTS in the past three decades?		
Essence from the answers obtained	Additional data	Main extractions
There was detected variance in what degree participants viewed the change in correlation between consumption and rates. Mainly responds favoured a stronger positive correlation, for the last decade. Less fuel-efficient vessels were seen to have lowered their rates to equal that of the total cost for IOCs, competing with more technologically advanced vessels with DE/HB configurations contrasting DM-AHTSs. Rates again argued to predominantly depend on balance between supply and demand and to a lesser extent the fuel consumption. However, "one might be able to get slightly better paid/ be a preferred candidate for the IOCs if a more fuel-efficient performance can be proven, all other capabilities uniform", stated two of the owners. Little impacted in the GOM area until recent. Some higher fuel consuming vessels have seen rates lowered by Pemex. In very rare instances a low fuel consuming vessel has created a bonus to shipowners.	Oil companies started to implement fuel penalty clauses in contracts. This has been a relatively new thing. The PSV market differs from the AHTS market, where we have seen a transfer from conventional fuel driven vessels leaning more towards battery/LNG vessels (mainly in the North Sea). This has been achieved by upgrading existing PSV tonnage.	• Stronger positive correlation between less FOC vessels and rates, during last decade • Seller/buyer's power and supply/demand thought to be of far greater significance • Total cost for IOCs getting more attention

<table>
<tr><td colspan="3">5. In your opinion, how has the cyclic market for AHTS influenced the fuel consumption correlation to rates earned</td></tr>
<tr><th>Essence from the answers obtained</th><th>Additional data</th><th>Main extractions</th></tr>
<tr><td>Lack of assurance in the answers were detected. Some responders had no opinion on the subject.

Owners convinced that prior markets fluctuations had seen little influenced on the FOC and rate correlation. Balance between seller and buyer, and the supply/demand environment believed to have weighed heavier.

IOCs and brokers were less opposed, and expressed belief in the fuel-efficient vessels being more prone to win contracts and earn higher rates in a buyer's markets</td><td>.</td><td>• Split views among seller and buyer
• Seller argue little influence
• Buyer claims a stronger effect in competitive markets</td></tr>
</table>

<table>
<tr><td colspan="3">6. Do you believe that fuel consumption will have a significant influence on AHTS rates going forward?</td></tr>
<tr><th>Essence from the answers obtained</th><th>Additional data</th><th>Main extractions</th></tr>
<tr><td>Similar spread detected as in the answers for question 5. However, respondents expressed more confident from both stands.

Owners for the most part believed future rates would have little dependence on the FOC profile

IOCs, brokers and builders on the other hand, uttered faith in the fuel-efficient vessels being more prone to win contracts and earn higher rates going forward</td><td>Existing fleet viewed as having similar engine set-up in NWE, by owners

Type of AHTS required for the operations, capacities, and specification to show stronger effect on rates.

The industry downturn believed to have compelled vessel owners to scrap AHTS vessels due to their design inherent lack of efficiency.</td><td>• Sellers not convinced FOC will move rates
• Buyer side more positive to FOC affecting rates in the future</td></tr>
</table>

7. *Would you say that your answers reflect the global AHTS industry? If no, what geographical variations do you see with regards to the connection between consumptions and rates?*		
Essence from the answers obtained	Additional data	Main extractions
Participants were understood to be quite consistent in their view, that the consumption focus and correlating exposure onto rate levels were present in all geographical areas. The NWE area was particularly believed to enjoy a higher focus of late. Brazil was highlighted by several objects, as an area with stricter consumption attention form charterers. Including FOC in the tendering process and contract. GOM area believed to catch up to other areas in terms of FOC focus	Many IOCs operate worldwide and are perceived to maintain a uniform FOC policy, regardless of area of operation. Fuel consumption penalty clauses in contracts so to penalize owners not delivering according to contractual agreements regarding FOC, more and more common in Brazil.	• Answers mainly reflecting worldwide operations • Brazil a stricter area with regards to FOC • GOM staring to catch up

8. *Apart from what we have discussed so far, is there anything relevant to the topic you would like to add?*		
Essence from the answers obtained	Additional data	Main extractions
Little additional thoughts and insights were shared by participants at this concluding question. One of the interviewees shared some supplementary data and notions.	Advocated for technologically advanced vessels able to perform rig moves quicker The day rate of rigs far outweighs vessels. Consumption efficient vessels believed to be favoured by charters Owners ability to show savings believed to be of importance.	

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5. Discussion

For the discussion section the goal was to collaborate the findings from both the QUAN and QANT methods. Elaborate on similarities and conflicting findings, while critically evaluating each of the research questions and the results' relevance.

5.1 Variations in rate levels for AHTS vessels

From an early stage of the thesis process it was evident that scarce literature and research could be found on the subject; consumption and rates in the AHTS segment. This both encouraged me to focus on the area, but simultaneously made the task more challenging. An overall limitation became the lack of literature and research to support and compare my methods and results. As such, the quantitative methods were particularly prone to limitations.

From the one-way ANOVA, results indicated a variance between the different propulsion systems available for the large AHTS vessels. On average the DM systems were found to earn a higher rate compared to the two systems, argued to have a better FOC profile by Myklebust & Aadnanes, (2011). This was contrary to my initial hypothesis stated in 2.9.1.

The analysis although significant, had some limitations with respect to the outcome. Looking specifically at the DE vessel from the research, the vessel fitted in to the category prescribed, however it's lower bhp and bollard pull capacity, diverged compared to many of the DM and HB vessels. Dahle & Kvalsvik, (2016) findings on the specifics influencing rates for AHTS vessels supported a positive correlation between the two capacities and rate levels, making this research less reliable as not all other vessel variables were constant.

The second-hand data set used in the research, along with my interpretation and investigation in to the vessels specification sheets should be addressed. For the second-hand data I was prone to trust the given information, it would however be naïve to think that errors could not occur in such a vast data set. Rate levels and consumption profile are sensitive data for buyer and seller, possibly resulting in inaccurate and approximate information.

The participants from the QUAL interviews did support a noticeable difference in consumption profiles of the vessels in question. Although they predominantly credited abilities to conduct the scope of work in a safe and efficient manner, as prime correlating factors with rate levels. This notion corresponded with the test for variance in means between systems, as the DM and HB systems enjoyed a more similar rate on average and encompasses more uniform spec characters.

5.2 Correlations between consumption and rate levels for AHTS

From the overall regression results I detected a low indication of .2 percent of the rate levels to be explained by the different propulsion systems and consumption profile. The low explanatory effect of consumption on rate levels could be seen in parallel with the insignificant findings using various consumption variables by Dahle & Kvalsvik, (2016). It may also reveal the difficulty in proving such correlation with the propulsion systems as variables, or simply make claim for a diminutive correlation.

The first model in the analysis including that of a sellers' market, detected a negative correlation between both HB and DE systems, while the DM systems indicated a positive correlation with rate levels. This supported a confirmation of the hypothesis 2.9.2.1. The findings should be viewed in parallel with owners participating in the interviews, and their claim for little overall correlation between consumption and rates for AHTS vessels.

The introduction of the moderator variable, avg. monthly rate in model two, sought to research a market climate more in favour of buyers'. Post adding this variable the explanatory effect of the model rose to an indicated 50,4 percent. The results revealed a change in the correlation, showing the HB systems to have a positive correlation with rate levels. The result partially confirmed my hypothesis in 2.9.2.2 regarding the HB system, while the premise for a similar correlation with DE systems were rejected.

The participating IOCs confidence in efficient FOC being of importance and correlating with rates, supports this result. Although model two to some degree implicated a more buyer oriented market, the method and variable choice had its limitations.

Foremost the Durbin-Watson test indicated a positive autocorrelation between the IV avg. rate and the DV. The variable avg. rate was arguably removing the peaks in the rates earned, however this could be viewed as inadequate to explain the entire representation of the market climate. Additional variables and models would conceivably have given a more precise picture of the period researched, determining buyer or seller power. Total utilization of the vessels, oil prices and investment levels in the E&P business were in retrospect viewed to possibly have added more certainty and segregation between the two distinct powers'.

Responses from the interviews suggested that a difference in correlation between FOC and rates would depend on length of charter, long-term or spot. Dividing on charter type was supported by Tvedte & Sterud, (2016) research, and could have assisted in giving this thesis more precise results. The lack of spot fixtures in other areas outside the NWE region, along with access to more exact figures from long term contracts, was given weight when choosing to research the two charter types combined.

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5.3 Main geographical areas of operations and their variance

For the area specific research, results were exposed to the similar mentioned model limitations, discussed in the previous section. Some perceived variance between areas were however detected, supporting my hypothesis in 2.9.3.

5.3.1 Northwest Europe

The NWE area results indicated a support for DM systems having a positive correlation compared to HB systems in the model favouring seller, with the opposite being true in model two, supporting buyer. All results were found to be significant, however the explanatory effect was close to zero, supporting a low or insignificant FOC correlation with rates. This was also addressed to be the case by the owners operating in the region, from the interviews. It’s worth noticing that conflicting feedback from the interviews were detected, as participants also uttered belief in a stronger FOC focus and correlation to rates in more recent years for this region.

5.3.2 South & Central American

For the South & Central American region, only DM and HB systems were found to have operated. Both models indicated to explain some 16.7% of the variance found in the rates and both showed a negative correlation for the DM versus the HB systems. Although the avg. rate variable was found to be insignificant in model two, the trend and support for more FOC focus and rate relevance in this area gained specific support from the interviewees, with one owner stating “*Brazil differs slightly from the other regions in terms of actually having to include vessels fuel consumption figures as part of the contract. In Brazil, when the IOCs are evaluating offers, the fuel consumption will play a significant part in their evaluation. If a vessel consumes more than what is included in the contract, the Owners will need to compensate the Charterer for such excess fuel consumed*»

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5.3.3 Australia, New Zealand and Southeast Asia

AUS, NZ and SE. Asia also showed lack of pure DE systems during the period. 1.0 and 2.5% adjusted R squared for the regressions, indicated a week explanatory effect. For model one it indicated little correlation between propulsion system and rates and for the second model it indicated that the avg. rate monthly was poorly reflecting the market for this region. DM systems were indicated to earn a lower rate compared to HB's in a sellers' market, however this regression was not found to be significant. In the model reflecting stronger buyer power, the DM systems were indicated to earn lower rates compared to the HB systems. While this model can be rightfully critiqued, the tendency noticed aligns with respondents from this area, with one local IOC representative stating; *"Vessel operators have...adjusted vessels with a heavy fuel burn to become more competitive when tendering…instead of being muscled out by larger or more technologically advanced vessels that have a lower burnt rate, ie a diesel electric AHTS as opposed to a direct shaft driven AHTS."*

5.3.4 Mediterranean and West Africa

For the MED and WA areas, all three systems were found to have operated during the period. Both models indicated DE and DM systems to negatively correlate with HB systems, but results were found to be insignificant for both models. Lack of substantial QUAN data samples along with no specific mentioning from respondents regarding this area, made a conclusion difficult to draw.

5.3.5 Gulf of Mexico, US and Canadian

The regression models covering the GOM, US and CAN areas all lacked data on DE systems and overall these areas were found to have the lowest number of samples, with only 36. The low sample size and non-significant models, rejected any considerable weighing from the QUAN methods, pointing to a positive correlation for the DM systems compared to HB with rates.

The QUAL interviews gave an area specific insight from one owner stating; *"Lower fuel consumption has not impacted the profits of Mexican shipowners, however, with higher fuel consuming vessels, rates have been lowered by Pemex and decreasing profits for owners. In very rare instances in the past, a low fuel consuming vessel has created a bonus to shipowners." … I do think that lower fuel consumption can justify higher rates to owners. This we see already in the recent contracts we have obtained with Pemex", s*upporting a momentum for less FOC correlating positively with rates, in recent years. It should be noted that the answer outlined came from an owner with primarily other vessel types within the offshore segment.

5.3.6 Other Areas

The analyses covering other areas found the models to explain 21.3 and 30.6 percent, respectively for model one and two. All regressions were found to be of significance, less no DE systems were found to have operated in these areas. The DM systems indicated to have had a negative correlation compared to HB systems, indicating a preference and positive correlation between the latter and rates. The result could to a degree be explained by the trend seen in recent years, with high-end HB vessels being chartered out from the North Sea market to work in Russian waters, an area which fell under "other".

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Participants from the QUAL methods were thought to represent a broad spectre of the AHTS business cycle. It should however be emphasised that it would have been more ideal to have additional respondents. Specifically, IOCs and owners from all geographical areas and their shared experience, could have elevated the thesis and strengthen the results. A total coverage was not accomplished due to the absents of responds from certain targeted candidates and the limited time and resources of the student during the research period.

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6. Conclusion

This research has sought to explain the relationship between fuel oil consumption and rates earned, for the large AHTS vessels. It has made attempts to explain how this segment differs from other shipping and offshore markets, with arguments for the insufficient and unsuitable adoption of said segments consumption variables, when researching the AHTS vessels.

The thesis introduced a method for studying consumption correlations with rates, based on utilizing the vessels different propulsion systems as variables. Additionally, it used interviews with key individuals to strengthen the quantitative results. The study found overall indications for variations in rates earned pendent consumption profile. It also found that different power distributions between buyer and seller, conceivably impacted the correlation. Lastly the research detected inclinations for variations between different areas of operations, with regards to consumption and rate correlation.

The overall research indicated different propulsion systems on average earned significantly different rates, answering my initial research question from 2.9.1. Diesel mechanical systems proved superior to that of the hybrid systems, with pure diesel electric earning the lowest of the three. To what extent other variables affected this result was challenging to read from the One-way ANOVA. However, it did stimulate a precedence to further research the possible correlation between consumption and rates.

In answering research questions, 2.9.2.1 and 2.9.2.2, the regression models combined with the respondent's views, indicated that consumption have played a diminutive part in determining rate levels for these vessels. On average, superior propulsion systems were found to have earned less than that of the traditional diesel mechanical systems in periods sought reflecting a strong seller power climate, including peak rates over the period.

The reversed state, researching a market with strong buyer power, resulted in a differing outcome. Under this scenario the model indicated a positive correlation between the consumption-superior hybrid systems and the rates earned. Both models were viewed to have shortcomings and the explanatory effect found, was small. The interviews did however support the indications found in both models, giving the results more leverage for a claim regarding consumption influencing rates, in a buyers' market.

For the area specific research this thesis could show variations between areas and consumption-rate correlations. For the NWE region, the results aligned with that of the overall regression. In South & Central Am. the tendencies were found to support HB systems positive correlation with rates, with AUS, NZ & SE. Asia seeing similar inclinations.

MED/WA and US/CAN/GOM gave insignificant results from the models. The latter got support from a local shipowner, stating a rise in correlation; consumption-rates, while the MED/WA regions could not be determined either way due to diminutive data reliability.

Further research is recommended to strengthen and explain the correlating trends indicated in this study. The deviating views on consumption importance between owners and IOCs, could be an interesting angel to trail. The approaching IMO requirement for mandatory consumption registration will perceivably generate more accurate consumption data for the AHTS, and assist in building more precise models for the future. The area specific research could possibly benefit from case studies for each segregated area, determining more clearly a possible variance and FOC-Rate correlation.

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Appendices

Appendix 1: Interview Guide

- Please state your job title.

- In your opinion, what are the main elements driving forth less fuel consuming vessels?

- Do you think that the AHTS segment has seen focus on fuel consumption in the past?

- To what extent do you think the rate obtained by a AHTS is dependent on its fuel consumption?

- Has there been any change in the correlation between fuel consumption and rates earned by AHTS in the past three decades?

- In your opinion, how has the cyclic market for AHTS influenced the fuel consumption correlation to rates earned?
- Do you believe that fuel consumption will have a significant influence on AHTS rates going forward?

- Would you say that your answers reflect the global AHTS industry? If no, what geographical variations do you see with regards to the connection between consumptions and rates?

- Apart from what we have discussed so far, is there anything relevant to the topic you would like to add?

- Could I contact you by e-mail or telephone if further questions or clarifications are needed?

Appendix 2: Project Approval, NSD

NSD

Marius Imset

3603 KONGSBERG

Vår dato: 16.01.2018	Vår ref: 58154 / 3 / STM	Deres dato:	Deres ref:

Simplified assessment from the NSD Data Protection Official for Research

In reference to the notification form received 07.01.2018 for the project:

58154	*The AHTS, Is there a correlation between fuel consumption and charter rates?*
Behandlingsansvarlig	*Høgskolen i Sørøst-Norge, ved institusjonens øverste leder*
Daglig ansvarlig	*Marius Imset*
Student	*Thomas Nordvik Strande*

Assessment

After reviewing the information in your notification form, including attachments, the Data Protection Official for Research has concluded that the project comes under the Norwegian Personal Data Act § 31. The personal data that is collected will not be sensitive, the project is consent based, and has low impact on personal privacy. The project has therefore been given a simplified assessment. You can now start your data collection. You have an independent responsibility to follow the conditions below and to read carefully the guidance given in this letter.

Conditions for our assessment

Our recommendation presupposes that you will carry out your project in line with:

- the information given in your notification form and attachments
- the requirement of gaining informed consent
- confirmation that you will not collect sensitive personal data
- the guidance in this letter
- Høgskolen i Sørøst-Norge guidelines for data security

Guidance

The requirement of informed consent

The sample should receive written and/or oral information about the project, and should consent to participate. This information must at the very least include:

- that Høgskolen i Sørøst-Norge is the data controller
- contact information for the project leader (or student and supervisor)
- the project's main objective and what the data will be used for

Dokumentet er elektronisk produsert og godkjent ved NSDs rutiner for elektronisk godkjenning.

NSD – Norsk senter for forskningsdata AS Harald Hårfagres gate 29 Tel: +47-55 58 21 17 nsd@nsd.no Org.nr. 985 321 884
NSD – Norwegian Centre for Research Data NO-5007 Bergen, NORWAY Faks: +47-55 58 96 50 www.nsd.no

- what data will be collected and what this involves for study participants
- when the project will be completed and when personal data will be anonymised/deleted

On our website you can find more information and an template of an information letter.

Guidelines for research ethics
Read carefully these guidelines for research ethics.

Notify us if you make any significant changes to your project
If your project changes, it may be necessary to send in a Change Request form. On our website you will find information as to which changes you must notify us about, and you can download the Change Request form.

Information about your project will be posted on our website and in the Notification archive
We have posted information about your project on our website. All of our institutions have access to their own projects in the Notification archive.

We will contact you about the status of processing personal data at project completion
At project completion 15.06.2018 we will contact you in order to confirm the status of processing personal data in your data set.

Does this apply to your project?

If you are going to use an external data processor
If you are going to use an external data processor (external transcribing assistant/online survey provider) you must enter into an agreement with those concerned. For advice on what a data processor agreement should contain see The Norwegian Data Protection Authority's website.

If the sample has a duty of confidentiality
We draw your attention to the fact that certain groups (ex. teaching and health personnel/ government employees) have a duty of confidentiality. They can therefore not divulge information that identifies individuals, unless the individuals concerned have given their consent prior to the interview.

Research at your own workplace
When carrying out research at your own workplace you must be aware of your double role as both researcher and employee. When recruiting informants it is especially important that the invitation to take part is communicated in such a way that participation is voluntary.

Take a look at our website or contact us if you have any questions. We wish you good luck with your project!

Yours sincerely,

Marianne Høgetveit Myhren

Appendix 3: Project Participation Form

Request for participation in research project

"The AHTS, is there a correlation between fuel consumption and rate- level"

Background and Purpose

The AHTS vessels have a larger fuel requirement when conduction certain operations in comparison to the PSV vessels (in which we have seen higher focus on fuel consumption in recent years). Since its common for the charterer to pay for fuel for both these vessel types, I want to research if there is any correlation between the vessels fuel consumption and the vessels rate levels.

My master thesis at the University College of Southeast Norway, will through empirical research try to obtain evidence and answer the following questions:

- Are the vessels with the best fuel consumption profile the only ones being hired in today's tough market? Are they getting a better rate (premium)?
- Is there historical evidence of variations in rates of these vessels compared to less fuel-efficient ones?

You have been selected to participate in this project based on your key industry position and your respectable knowledge of the offshore business.

What does participation in the project imply?

If participating in the project, I will do a personal interview with you, either face-to-face, by telephone, or email. The questions will be on the topics of AHTS vessels fuel consumption and possible correlations with rate levels and aspects that are likely to shed light on this. My goal is to get your reflections on the subject. The interview could be audio recorded. If it is, the recordings will be deleted at the end of the project.

What will happen to the information about you?

All personal information will be treated confidentially. Only student and supervisor will have access to personal data, and these will be encrypted. Participants in the project will not be recognized in the publication.

The project is scheduled to end on the 15th. of May 2018. All information will then be anonymized.

Voluntary participation

It is voluntary to participate in the project, and you can at any time choose to withdraw your consent without stating any reason. If you decide to withdraw, all your personal data will be made anonymous.

If you would like to participate or have any questions regarding the study, please contact Student Thomas Strande by telephone; (*removed in appendix),* or email: (*removed in appendix*) or Supervisor Marius Imset by telephone; (*removed in appendix*), or email: (*removed in appendix*)

The study has been notified to the Data Protection Official for Research, NSD - Norwegian Centre for Research Data.