Future Characteristics of Offshore Support Vessels

by

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Abstract

The objective of this thesis is to examine trends in Offshore Support Vessel (OSV) design and determine the future characteristics of OSVs based on industry insight and supply chain models. Specifically, this thesis focuses on Platform Supply Vessels (PSVs) and the advantages of certain design characteristics are analyzed by modeling representative offshore exploration and production scenarios and selecting support vessels to minimize costs while meeting supply requirements.

A review of current industry practices and literature suggests that offshore exploration and production activities will move into deeper water further from shore and as a result supply requirements will increase significantly. A review of the current fleet and orderbook reveal an aging fleet of traditional vessels with little deepwater capabilities and a growing, young fleet of advanced vessels capable of deepwater support. A single-vessel supply chain analysis shows that traditional vessels outperform larger vessels for shallow-water resupply activities, while modern vessels and vessels significantly larger than modern vessels are more cost-effective for deepwater operations. As offshore oilfield supply is more complicated than a single vessel supplying a single platform, we develop a mixed integer linear program model of the fleet selection process and implement it on representative offshore exploration and production scenarios. The model is used to evaluate the cost-effectiveness of representative vessels and the value of flexibility in vessel design for the oilfield operator.

Incorporating industry insight into the results from the supply chain analyses, this study concludes that a) offshore exploration and production will move further offshore into deeper water, b) OSVs will become significantly larger both in response to the increased cargo need as well as to meet upcoming regulations, c) crew transfer will continue to be done primarily by helicopter, d) OSVs will become significantly more fuel efficient, e) high-specification, flexible OSV designs will continue to be built, and f) major oil companies will focus on safety and redundancy in OSV designs.

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Nomenclature

ABS	American Bureau of Shipping
AHT	Anchor Handling Tug
AHTS	Anchor Handling Towing and Supply vessel
BHP	Brake Horsepower
CNG	Compressed Natural Gas
CSV	Crew Supply Vessel
D/E	Diesel Electric propulsion system
DNV	Det Norske Veritas
DP	Dynamic Positioning system
DP II	A DP system that can withstand a single fault of an active component
DP III	A DP system that can withstand a single fault of any component, including a fire in or flooding of any single subdivision or watertight compartment
DWT	Deadweight Tons
ECA	Emission Control Area
FPSO	Floating Production Storage and Offloading ship
FSIV	Fast Support and Intervention Vessel
GRT	Gross Registered Tonnage
IMO	International Maritime Organization
knot	Nautical mile per hour
LBP	Length Between Perpendiculars

LNG	Liquefied Natural Gas
LOA	Length Overall
MARPOL	International Convention for the Prevention of Marine Pollution at Sea
MIP	Mixed Integer linear Program
MPSV	Multi-Purpose Support Vessel
MT	Metric ton, also t or tonne
NLS	Noxious Liquid Substances
nm	Nautical mile
OSV	Offshore Support Vessel
PSV	Platform Supply Vessel
ROV	Remotely Operated underwater Vehicle
SOLAS	International Convention on Safety of Life at Sea

Chapter 1

Introduction

1.1 Offshore oil production

With the rapidly increasing global energy needs experienced over the last century, offshore oil production has become an attractive source of energy. According to the U.S. Energy Information Administration, approximately 59 percent of all energy consumed worldwide is produced from oil and natural gas [1]. Offshore oil and gas production accounts for approximately 25 percent of the domestic oil and gas production [2]. However, the offshore environment differs significantly from land-based oil production scenarios as equipment is either exposed to water or protected from it, installations must be supplied by ship and helicopter, and the marine environment presents significant safety hazards for workers.

1.2 Offshore oilfield supply

Supplying offshore oil production installations is a complex logistics problem that hinges on many factors with significant uncertainties. Since oil production is an expensive process and downtime on an offshore oil production platform has large opportunity costs associated with lost production, it is critical to provide necessary supplies and services without interruption. In the case of equipment failure, repairs must be made quickly, which puts pressure on the delivery of emergency spare parts and possibly maintenance experts. In addition, an offshore oil production platform requires routine deliveries of a number of supplies including chemicals, consumables, and crew. Offshore installations also operate rented equipment, which must be returned quickly in order to avoid unnecessary expensive rental fees.

Offshore activities can be broken down into drilling and production. In general, production is a long-term endeavor with facility lifetimes on the order of 30 years and steady-state demands. Drilling and exploration, on the other hand, involve much more dynamic and uncertain demands as well as a greater variety of marine services and equipment. As a consequence production activities often employ more specialized vessels, whereas drilling activities employ more multi-purpose vessels [3].

1.3 Oilfield logistics market structure

In a typical offshore oil production effort, an oil major contracts with the governing nation to exploit a particular tract of ocean. The oil major then charters drilling units as well as OSVs from companies that specialize in the acquisition and operation of rigs or vessels. In most cases, the oil major pays a daily rate to keep these rigs and vessels on charter, but commits to longer charter periods, on the order of years, at the time of charter, although vessels are also available for short-term charter on the spot market [4]. The oil major is then responsible for scheduling the rigs and vessels, while the charter companies are responsible for maintaining their equipment and purchasing maintenance items, and in the case of drill rigs, consumables such as drill pipe and casing [5]. However, the oil major is responsible for moving supplies to the rigs and as the day rates for drill rigs can vary from $100,000 per day for medium-sized jack-up rig to over $400,000 per day for a larger semi-submersible rig or drill ship [6], it is in the best interest of the oil major to keep drills supplied 100 percent of the time. Because it can take a significant amount of time to hire a vessel on long-term charter, up to several years in some cases where a specialized vessel must be constructed, the oil major must plan for future supply requirements and make sure that it has on charter a fleet capable of meeting any expected demand.

In addition to a charter cost, the oil major usually pays for the fuel burned by support vessels. The oil major must also pay for port taxes and fees when OSVs enter ports to resupply. These taxes are usually levied based on vessel size and amount of cargo carried. Vessel size is often determined by Gross Registered Tonnage (GRT) but sometimes by length overall (LOA). Port tax amounts can vary considerably by port and nation, but can constitute a significant additional cost. An additional factor that affects the oil major's fleet selection decision is national content, which is the requirement by the nation that claims the oil field under exploitation to use domestic vessels whenever available, even if these local vessels are less capable or more expensive than foreign counterparts. Many nations also have cabotage laws that may otherwise impact or restrict the use of foreign OSVs.

1.4 Objective and approach

The purpose of this research is to predict future trends in OSV characteristics. The general approach is two-fold.

First, OSV design is considered on a ship by ship basis, which identifies the trends in existing OSV design characteristics as well as the capabilities of the modern OSV fleet. Part of this analysis includes anecdotal reports from industry, while another portion focuses on collecting vessel design data and identifying design trends by parametric analysis. In addition, OSV capabilities are assessed for single vessel supply scenarios based on measures of merit, such as capacity and cost, and trade-offs in vessel design are considered in terms of individual ship comparisons on these measures of merit.

Second, OSV design is considered in the context of an operational supply fleet servicing an offshore oilfield. In a real supply scenario, there is no single best OSV design because of the varied need for marine services and the trade-offs between flexibility and economy. As such, it is prudent to consider the entire fleet composition for an offshore oilfield supply scenario and draw conclusions regarding the kinds of vessels that minimize total logistic costs for a specific supply scenario and how the demands of the supply scenario affect the characteristics of the vessels selected to be in the fleet. This is accomplished by identifying realistic operational constraints for OSVs servicing oil production units and developing a methodology consisting of heuristic rules and mathematical models of the supply chain. An implementation of the model assesses advantageous OSV fleet compositions from a selection of currently available OSV designs for a specific oil production scenario. Extension to a more general set of oil production scenarios and a larger set of available supply vessel designs, including possible future designs, aims to identify what design characteristics are advantageous for novel oil production scenarios.

1.5 Framework of this report

Following the brief introduction to offshore exploration and production support in this chapter, Chapter 2 focuses on trends in offshore exploration and production, including the move to deeper water, as well as common OSV types and cargoes. Chapter 3 analyzes the state of the modern offshore support vessel fleet and orderbook in terms of vessel ages and trends in vessel capabilities and characteristics over time. In Chapter 4, we examine the suitability of representative supply vessels for particular offshore deliveries based on speeds, capacities, and costs. Chapter 5 lays out a methodology for selecting vessels to support a particular offshore support scenario in order to minimize fuel, charter, and port fee costs subject to meeting the full support requirements of the scenario. Representative vessels and scenarios are tested in the model to gain insight into how vessel attractiveness changes with changes in the supply scenario. Finally, Chapter 6 presents design trends in terms of the feasibility of radical vessel designs as well as overall design trends drawn from both quantitative and qualitative analysis.

Chapter 2

Background

2.1 Offshore oil field trends

The future needs for OSVs stem from future offshore drilling and production activities. According to Atle Gassø of Rolls-Royce, a major OSV designer, the "easy fruit" has already been picked, meaning fields accessible by shallow water drilling have largely been exploited, and most of the new developments are being made in deepwater [7]. The definition of deepwater changes as the capabilities of drill rigs and ships increase, and there is no particular industry consensus: Halliburton defines deepwater as anything greater than 305 meters (1000 feet) [8], while Prosafe Production defines deepwater as 3000 meters (9842 feet) [9]. However, there are several clear deepwater trends. First, technology is developing rapidly, allowing for deeper wells to be drilled every year. In addition, the number of deepwater discoveries in the past decade far outnumber previous deepwater discoveries. Take for example two major deepwater regions: the Gulf of Mexico and off the coast of Brazil as shown in Figure 2-1. Finally, although the recent economic downturn has affected deepwater expenditures, a recent report by energy business analyst company Douglas-Westwood suggests that the "deepwater sector [will] quickly recover and resume its previous growth." Figure 2-2 shows the projected capital expenditures for upcoming deepwater projects broken down by region for the next five years.

The biggest region for current and future deepwater development is off the coast

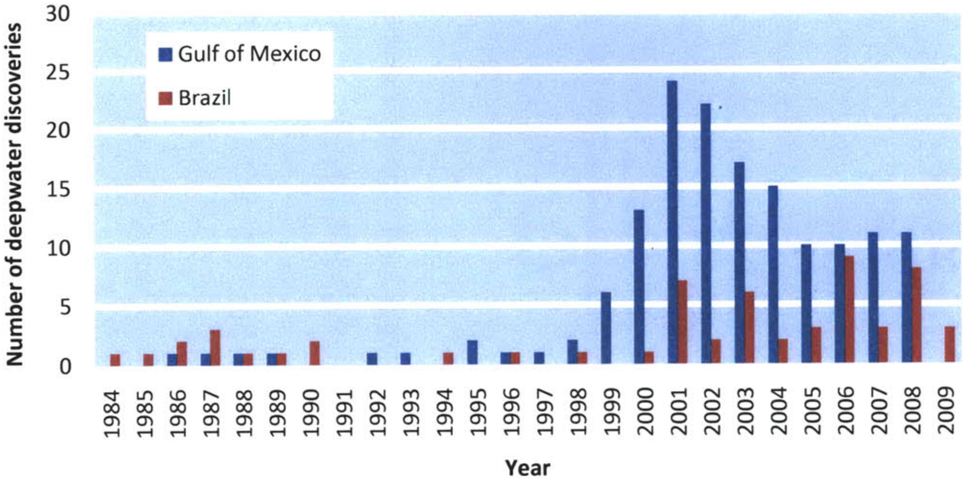


Figure 2-1: Deepwater discoveries by year in the Gulf of Mexico and Brazil [8].

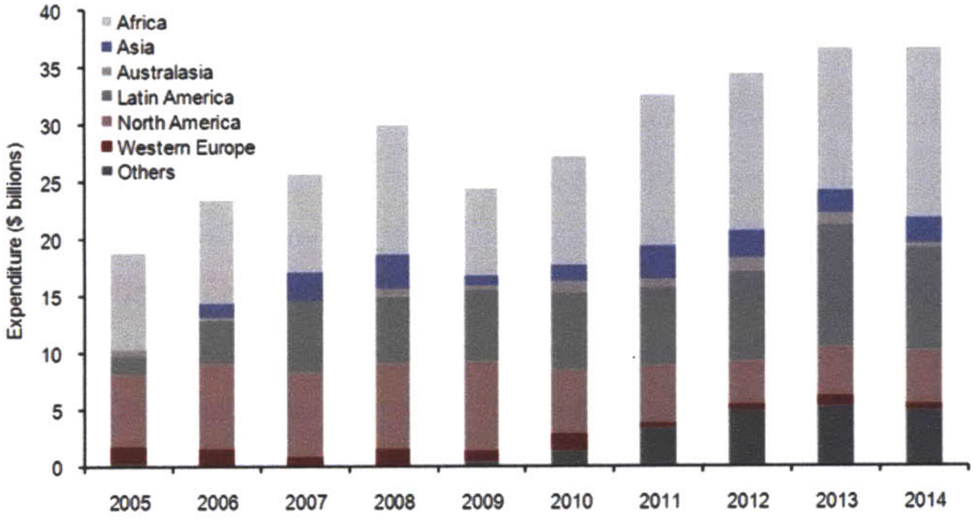


Figure 2-2: Deepwater CAPEX by region [10].

of Africa, with current capital expenditures at roughly $10 billion per year, and future expenditures expected to hit $15 billion per year by 2014. The next major short term area of interest is off the coast of Brazil, in deepwater pre-salt discoveries. The Brazilian national oil company Petrobras plans to spend roughly $90 billion in the next decade on developing deepwater assets, close to half of the total projected operator expenditure of $220 billion over the next decade [11]. Although significant deepwater activity was expected to continue in the Gulf of Mexico, this may be constrained by the repercussions of the recent BP Macondo oil spill as discussed in

Chapter 2.1.1. Finally, although Southeast Asian offshore activity has traditionally been in very shallow water, new deepwater discoveries are being made in Southeast Asia, and in the foreseeable future there will be a rapid increase in deepwater drilling activity in Southeast Asia, everywhere "from the Philippines on down" [12].

In addition to the strong trend toward deepwater exploration and production, there is increased interest in the development of Arctic oil resources. Several factors have made Arctic resource exploration more attractive. In April, Russia and Norway agreed on a long-disputed boundary in the Barents Sea. According to the New York Times, "the agreement could herald oil and natural gas exploration in a huge and potentially lucrative region" [13]. Although both Russia and Norway have existing production projects in other parts of the Barents Sea, geological surveys from the 1980s mark the disputed land as particularly promising. In addition, the long-term thawing of Arctic ice could make new areas of the Arctic available for many activities, including offshore oil exploration and production [14].

2.1.1 Effect of the BP Macondo well blowout

While recent trends look very promising for increased growth in offshore deepwater drilling, they do not account for repercussions following the explosion aboard and sinking of the *Deepwater Horizon* in the Gulf of Mexico and subsequent oil spill. Already, a U.S. moratorium on deepwater drilling has halted all deepwater drilling in the U.S. Gulf of Mexico for over six months, and significantly slowed down shallow water drilling creating a de facto moratorium [15]. The government has restructured its oversight services and created new offshore drilling rules. Although the deepwater moratorium has technically been lifted, the new rules will make it more expensive to drill in U.S. waters in the Gulf of Mexico and increase lead times for permitting. In fact, in the month after the moratorium was lifted, no new drilling permits have been approved [16]. Both expensive drilling permits and longer lead times for permits will dampen growth in deepwater development in the Gulf of Mexico in the short term. In addition, it is likely that repercussions stemming from the spill will not be restricted to merely the U.S. Backlash from the Gulf of Mexico spill prompted Norway to ban new drilling projects in the North Sea in June [17]. However, according to Figure 2-2 the majority of deepwater development expected in the next five to ten years will take place in Africa and Latin America where it is unlikely that repercussions from the Gulf of Mexico spill will be as severe. According to Todd Hornbeck speaking at a Marine Money conference panel discussion, "the world is still drilling...in fact, they may be doubling down" [18]. With regard to the U.S. Gulf of Mexico, according to Paul Bragg, the Chairman and CEO of Vantage Drilling, when there is as much at stake as there is oil in the Macondo basin, government and industry will find a way to make things work [19]. On the other hand, in the Arctic, where the environment is a key issue, and oil spill recovery technology is virtually nonexistent, it is possible that the repercussions from the BP spill will significantly delay further deepwater development.

In summary, the spill will certainly have a short term negative impact on deepwater development, especially in the U.S. waters, but in general, these impacts may be limited to smaller deepwater markets than the large emerging markets of Africa and Latin America. In addition, once new drilling regulations are in place, drilling will likely return to its previous pace in the U.S. Gulf of Mexico.

2.2 The Offshore Support Vessel

2.2.1 Types

Unlike the Model-T, OSVs come in a variety of sizes, shapes, and colors. As many OSV designs are meant for specific roles or purposes, OSVs are generally classified into one of several common groups.

Platform Supply Vessels (PSVs)

The PSV is a broadly defined term to include vessels specifically designed for the purpose of carrying supplies to and from offshore installations. In essence, these are the workhorses of an offshore supply chain. PSVs usually have a large open deck aft on which offshore containers and deck cargo such as casing and drill pipe is transported and internal tanks for fuel, potable water, drilling water, mud, brine, chemicals, and dry bulk. Domestic PSVs range from 55 meters (180 feet) to 79 meters (260 feet) in length and usually stay out for a day or two on "milk runs." However, in deepwater supply operations, the platforms may not have enough storage capacity for drill pipe and casing, so a PSV might stay out for a week at a time continuously supplying a drill rig [20]. A photo of a typical PSV is shown in Figure 2-3, while a typical PSV arrangement drawing is shown in Figure 2-4. Sophisticated PSV designs include integrated tank washing systems and Dynamic Positioning (DP) systems [21].

Figure 2-3: The *Bourbon Hermes*, a 73.20 meter, 3,230 deadweight tonne PSV [22].

Anchor Handling Tug/Anchor Handling Towing Supply Vessels (AHT/AHTSs)

AHTSs are OSVs outfitted with winches and cranes in order to set and lift anchors as well as tow and position movable offshore installations such as semi submersible drill rigs, jack-ups, and barges. In addition, AHTSs have the large deck space and cranes available to deploy a range of equipment required for oilfield exploration [22]. Some AHTSs are equipped to assist in firefighting, rescue operations, and oil spill recovery [21]. While AHTSs have large deck cargo space and tanks for fuel and water, they are not always outfitted with dry bulk, brine, and mud tanks.

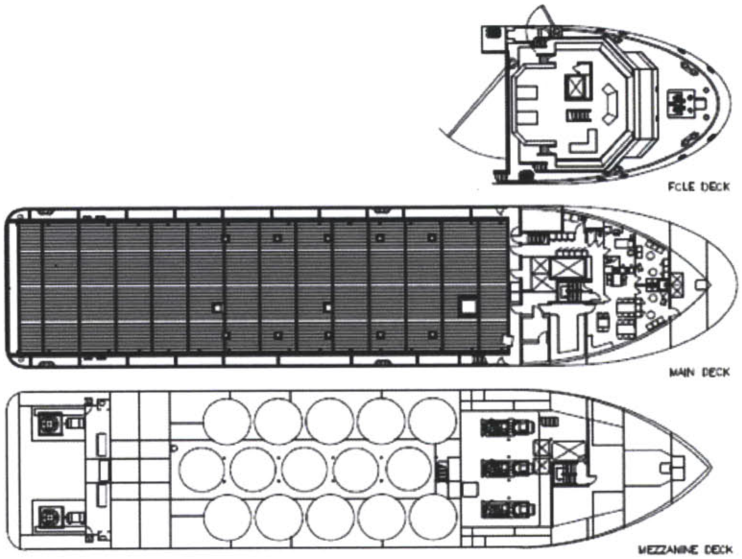


Figure 2-4: Arrangement of the *Bourbon Hermes* [22].

Figure 2-5: The *Far Santana*, a 77 meter, 203 tonne bollard pull AHTS [21].

Fast Support and Intervention Vessels (FSIVs) and Crew Supply Vessels (CSVs)

FSIVs are small, fast, and flexible supply ships. They are usually around 40 meters in LOA, and have speeds over 25 knots. FSIVs have a large capacity for passengers, which allow them to act as safety standby vessels and also as crew supply boats. According to Samson Maritime Director Jeremy Williams, speaking of an FSIV class built by Strategic Marine, "These boats have the inbuilt flexibility to allow them to perform a wide range of both inshore and offshore maritime support tasks, including high speed supply runs, crew transfer, safety support and intervention and inshore and offshore survey tasks" [23]. FSIVs are ideal for rapid response search and rescue as well as platform evacuations, but can also be outfitted for oil spill containment and Remotely-Operated Vehicle (ROV) operations [24].

Both FSIVs and CSVs have capacity for deck cargo, and often some limited below-deck tank space. Figure 2-6 presents a photograph of a typical FSIV, and Figure 2-7 presents the corresponding general arrangement drawing. As can be seen from Figure 2-7 , a very large proportion of the main deck arrangement is dedicated to deck cargo compared to the relatively small passenger area forward, which has capacity for 50 passengers [22].

Figure 2-6: The *Bourbon Express*, a 50 passenger, 263 deadweight tonne FSIV [22].

Multi-Purpose/Multi-Role Support Vessel (MPSVs)

MPSVs are a very modern class of vessels designed to provide a variety of subsea support services including ROV support, subsea construction, and postdrilling well services. These vessels are typically very large and much too expensive to employ for simple supply operations. However, the use of MSPVs has enabled significant savings for oilfield exploration by performing some of the postdrilling well support services traditionally performed by drilling rigs, thereby freeing up drilling rigs for drilling [25].

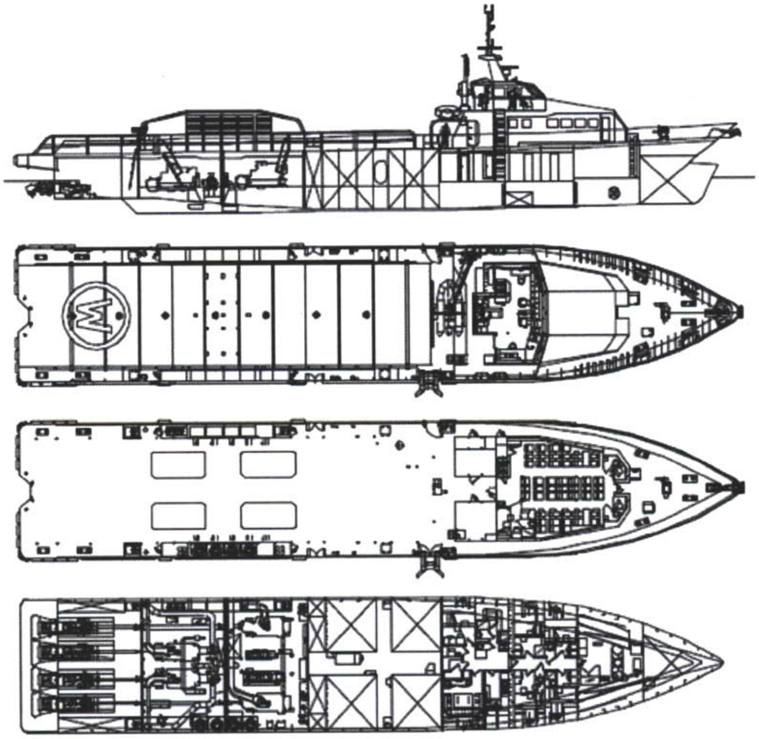


Figure 2-7: *Bourbon Express* general arrangement [22].

Figure 2-8: The *Far Sovereign*, an 85 meter, 3,631 deadweight tonne MPSV [21].

Offshore tugs

Offshore tugs are used to assist in export tanker operations at offshore oil and gas terminals and FPSOs, to assist in rig or barge movements or anchor handling operations, to tow, and to provide safety support for any offshore operation. Offshore tugs typically have no supply capability except for limited crew capacity in rescue situations (see Figure 2-9), and are generally defined by the safety equipment and bollard pull capability. Offshore tugs are often equipped with advanced firefighting systems and oil spill recovery equipment [22].

Figure 2-9: The *Bourbon Rhesos*, a 100 tonne bollard pull offshore tug [22].

Surfer Vessels

Surfer vessels are specifically designed to transport crew quickly. Surfer vessels typically range in passenger capacity from 10 to 100 [22]. Unlike FSIVs and CSVs, surfer vessels do not have a significant cargo capacity. As a consequence, surfer vessels are significantly smaller than FSIVs and CSVs. As an example, Bourbon Offshore's Surfer 326 class is 33.5 meters long, carries 46 passengers, has a cruising speed of 35 knots, and is equipped with firefighting equipment [22]. In general, the larger surfer vessels can perform safety standby operations, while the smaller surfer vessels may lack the required capacity. A photo of a typical surfer vessel is shown in Figure 2-10 and the corresponding general arrangement drawing is shown in Figure 2-11 . The general arrangement drawing showcases the much larger proportion of passenger area compared to deck cargo area in comparison with the FSIV arrangement shown in Figure 2-7.

Figure 2-10: The *Surfer 326 Fi-Fi Combi* [22].

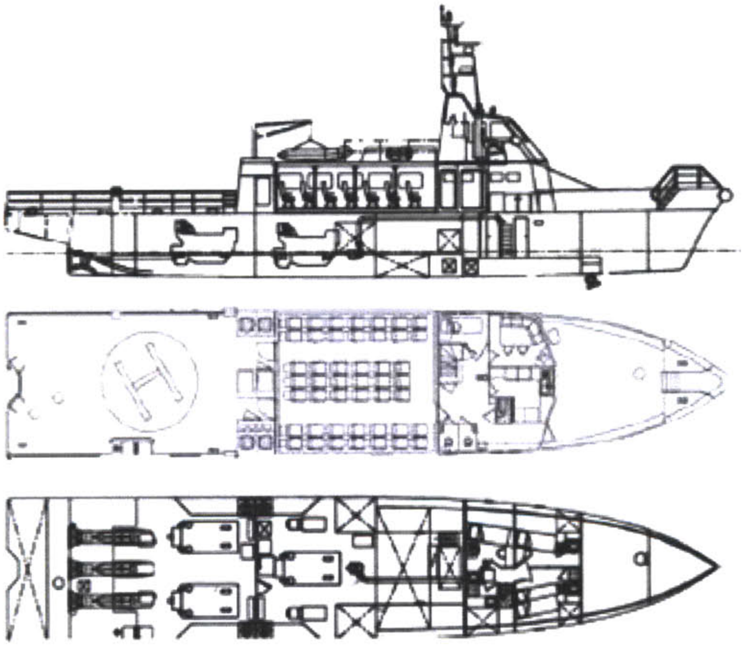


Figure 2-11: *Surfer 326 Fi-Fi Combi* general arrangement [22].

Utility boats

Utility boats are very small, inexpensive boats used to carry small amounts of cargo, but not necessarily specific to the offshore oilfield supply sector. Utility boats can range in size and capability, but can often move a small amount of cargo and possibly several crewmembers.

Specialty vessels

The offshore oil and gas industry employs a number of specialized vessels that perform specific services with respect to well maintenance, exploration, subsea construction, and in colder climates, ice management. These vessels are generally extremely expensive and have very advanced capabilities which may include large compressor capacity, the ability to carry and pump sand and gels into wells, large cranes and hoists for sensor deployment, subsea construction, and ROV operations, cable and pipe laying reels, and moonpools [20]. These vessels rarely transport supplies to and from offshore rigs as a primary mission, and their relatively large expense makes them unattractive as supply vehicles. In fact, these specialized vessels may remain in one location for prolonged periods of time, such as the Schlumberger well-stimulation vessel shown in Figure 2-12, which is pictured performing well-stimulation on a fixed platform in the North Sea [26]. Their main logistic implications involve their impact on drilling and production platform efficiency, which in turn dictates platform supply requirements, as well as their direct consumption of supplies when they are out for days at a time.

Figure 2-12: The *Bigorange XVIII* stimulation vessel alongside a platform [26].

2.2.2 Supply types and transfer methods

Potable water

Potable water is typically carried in below-deck tanks and is required for crew bathing and consumption aboard an installation. Potable water and all subsequent liquid cargoes are typically transferred from the vessel to the installation by hoses, which are connected to transfer manifolds. The pumping power is provided by the vessel, as the cargo must be pumped upward into the installation.

Fuel oil

Fuel oil is used to run generators onboard offshore installations. In most cases, these generators supply electrical power to all of the pumps, equipment, and lighting onboard the installation.

Drilling mud

Drilling mud is a fluid pumped through the inside of the drill pipe that flows out through the drill bit and back to the rig through the riser, thereby cooling the bit and removing cuttings. The mud is chemically engineered to prevent well collapse and blowouts and its required composition changes as the well is drilled and different kinds of substrate are encountered [20]. Mud composition is a very precise science and drillers are very particular about the source of their mud [27].

Brine

Brine is extremely concentrated saltwater, which is used to create salt solutions to pump into wells whenever the substrate is salt. Since salt dissolves easily in normal drilling fluid, the brine is pumped through the well and as salt comes out of solution on the well walls, it strengthens the well walls to prevent collapse [20].

Dry bulk

Dry bulk refers to solid cargoes carried in special tanks such as cement, barite, a heavy clay that makes drilling mud dense, and bentonite, a light clay that keeps chemicals in solution [20].

Deck cargo

Deck cargo includes tools and equipment required for drilling such as drill pipe, casing, risers, bits, collars, and blow-out preventers. In addition, offshore containers, half-heights, and skips are often shipped as deck cargo and may contain stores and provisions, equipment, or even liquid cargo in some cases [5]. Deck cargo is typically lifted from the OSV to the platform by a platform-mounted crane [3].

Crew

Offshore installations can require between 6 and 150 crew members at a time, depending largely on the activity of the installation. Production platforms require much less crew than an active drilling unit. Crews are usually transferred to offshore units by helicopter, but occasionally from a ship to the platform in crew baskets that are hoisted by a platform-based crane. As can be seen in Figure 2-13, this is not always the most elegant, quick, or safe method, which has prompted the development of novel approaches to crew transfer, such as the Frog 9 high capacity transfer capsule developed by Reflex Marine and Seacor for the *Seacor Cheetah*, a radically-designed, high-capacity CSV.

Dynamic positioning

DP refers to an automatic onboard system that links navigation controls and sensors with propulsion in order to keep a vessel on station despite wind and wave action. This allows for more steady cargo transfer as well as increased safety. Class notations exist for dynamic positioning systems and mainly recognize the level of redundancy in a DP system. In a DP I system, a loss of position may occur due to any single-

Figure 2-13: left: a crew basket hoisted from a platform [28], right: a typical crew basket [29]

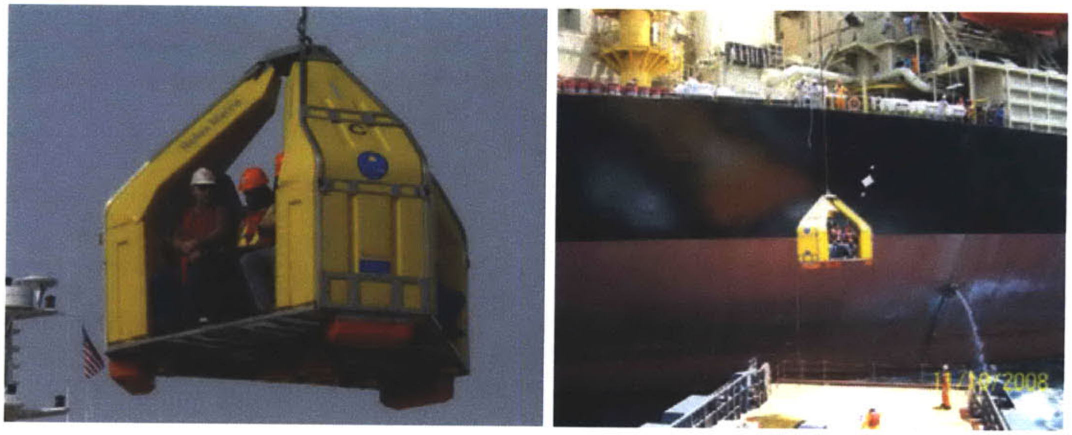


Figure 2-14: *Seacor Cheetah's* Frog 9 high capacity crew transfer system [30].

point failure. In a DP II system, loss of position does not occur due to a single-point failure of any active component, such as thrusters, engines, or generators. In a DP III system, the vessel will hold position even with the loss of an entire watertight compartment or fireproof subdivision [31].

Recent advances in DP technology have included increased precision and the ability to incorporate relative references that allow the system to compensate for floating rig movement while keeping a vessel on station next to rigs. Most modern OSVs are built with DP technology installed as it relieves operator stress from having to manually keep a vessel on station, and helps avoid costly collisions [20].

Chapter 3

The state of the modern offshore support vessel fleet and orderbook

3.1 Overview

In 2005, Ahmad Sarthy and J. L. Ham of the American Bureau of Shipping (ABS) published a review of the offshore support vessel (OSV) fleet named *Modern Offshore Support Vessels: Class and Statutory Perspectives* at the International Conference on Techonology & Operation of Offshore Support Vessels [32]. The analysis performed in that review boiled down to a prediction of increased demand for OSV newbuildings based on an ageing fleet, the inability of the existing fleet to meet the demand for sophisticated vessels required in deepwater operations, and the expected growth of offshore oilfield development based on high oil prices. The purpose of this section is to update the analysis performed by Sarthy and Ham in 2005 with the current fleet status and orderbook in order to identify trends in OSV design and be able to distinguish between vessel designs that represent modern OSVs as compared to traditional OSVs.

3.2 Fleet review and analysis

For the purpose of this analysis, offshore support vessels are grouped into one of four categories: (1) anchor handlers, (2) platform supply vessels, (3) crewboats, and (4) multi-purpose construction vessels. The anchor handler category includes AHT and AHTS-type vessels. The platform supply vessel category includes only PSVs. PSVs are often referred to as *supply boats* and are designed with a forward deckhouse and large open aft cargo deck. The crewboat category includes CSVs and FSIVs. Crewboats are often referred to as *hotshot* vessels and typically have a limited amount of deck space for cargo as well as limited tankage for fuel and water. The multi-purpose construction vessels category is broadly defined to include support vessels with some construction capability including installation, maintenance, or repair. Specialized vessels in niche markets such as cable-laying, pipe-laying, dive-support, geophysical research, well-stimulation, well-intervention, and accommodation vessels are beyond the scope of this analysis.

All information used to generate the plots and figures in this analysis was taken from the IHS Fairplay database as of July 2010, Clarkson's reports, and individual vessel specification sheets. Vessel specification sheets were taken from owner and operator websites and are not cited individually.

3.2.1 Fleet age structure

The average age of the fleet is slightly under 18 years, which is roughly five years younger than the average age of the fleet in 2005. However, a closer look at the age structure of the fleet reveals additional complexity (see Figure 3-1). First, roughly half of the entire fleet measured in terms of gross tonnage is under five years old, whereas in terms of numbers of vessels, half of the fleet is under 18 years old. This highlights the recent trend to build larger vessels. In addition, Figure 3-1 shows the existence of two separate fleets: one old and one new. While the old fleet constitutes a large number of vessels, it does not constitute a large proportion of the tonnage. These vessels were not designed for current deepwater needs, which facilitated the ramp up in vessel construction over the last five years, as predicted by Sarthy and Ham in 2005. Hence, the modern fleet is composed mainly of vessels under five years old.

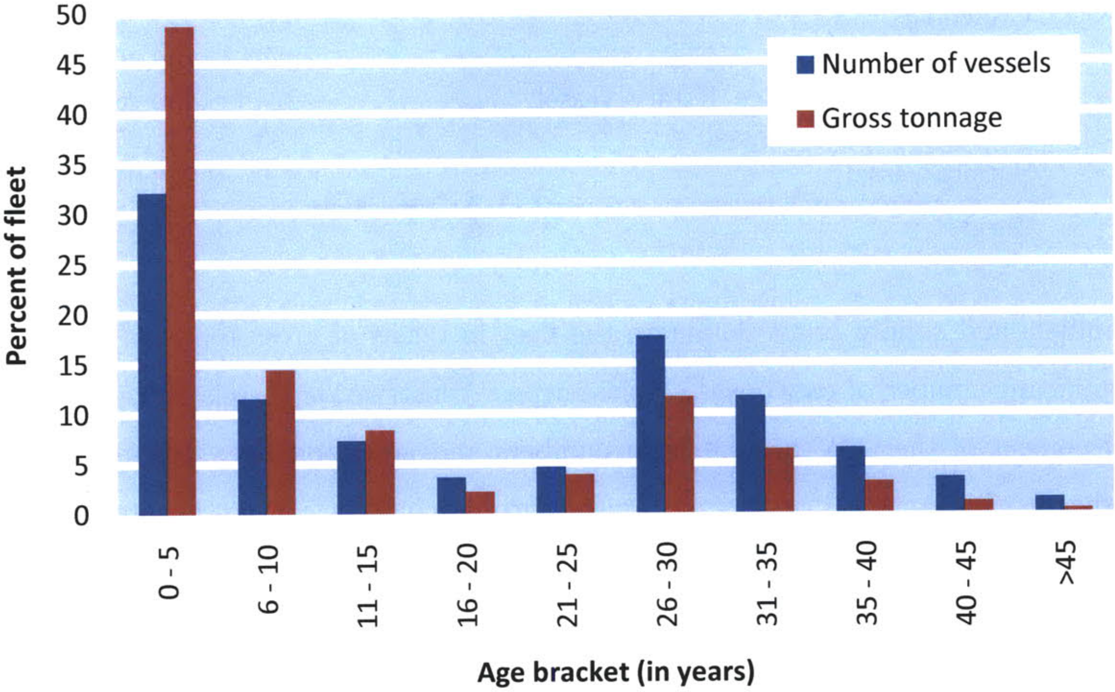


Figure 3-1: OSV fleet age structure.

3.2.2 Existing fleet size and composition

Although it is difficult to count every ship in service, the existing OSV fleet, assumed to include anchor handlers, supply vessels, crewboats, and multi-purpose construction vessels, stands at just over 5,600 vessels and 6.7 million gross tons (see Table 3.1).

Since 2005, only about 150 vessels have officially left service, although Tidewater, the world's single largest operator of OSVs, fields a large fleet of vessels in layup, currently estimated to include at least 42 anchor handlers and 21 supply vessels (for more information see Table 3.3). Over the same time period, roughly 1,800 new vessels have been constructed, representing a 40 percent increase in fleet size in the past five years.

The existing OSV fleet composition as of July 2010 is shown in Figure 3-2. Anchor

Table 3.1: Fleet size by vessel type.

Vessel Type	Number of Vessels	GRT
Anchor Handling Tug	180	75,380
Anchor Handling Tug Supply	2,228	3,462,558
Crewboat	921	224,262
Maintenance/Utility Vessel	235	106,803
Offshore Maintenance/Utility Vessel	224	400,287
Offshore Support Vessel	33	231,755
Supply Vessel	1,829	2,226,070
Total	5,650	6,727,115

handlers and supply boats dominate the fleet in terms of gross tonnage, despite a significant number of crewboats. Multi-purpose construction vessels make up about 10 percent of the OSV fleet in both numbers and gross tonnage. Figure 3-2 also indicates that anchor handlers and multi-purpose construction vessels are typically larger than supply vessels.

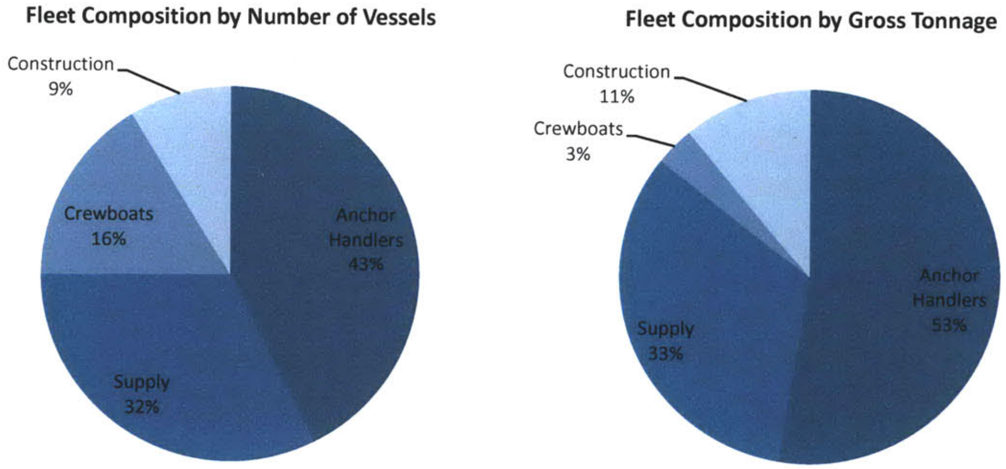


Figure 3-2: OSV fleet composition.

3.2.3 Orderbook size and composition

While contract details for ships on order are often not public, information drawn from Clarkson's, the IHS Fairplay database, and the Offshore Support Journal indicate an orderbook that stands at just under 800 vessels and 2.0 million gross tons. According to Sarthy and Ham, in 2005 when the OSV market was expected to boom, the orderbook stood at just over 200 vessels including 76 anchor handlers [32]. Unfortunately, it is difficult to reconcile these figures as it is difficult to tell exactly which ship types were counted and not counted. In any event, these figures represent a two to four-fold increase in orderbook size over the past five years, leaving one to wonder whether continued rapid growth of the OSV fleet is sustainable. Table 3.2 shows the current orderbook by vessel type.

Table 3.2: Orderbook size by vessel type.

Vessel Type	Number of Vessels	GRT
Anchor Handling/Tug	35	31,509
Anchor Handling/Tug/Supply	396	954,522
Crewboat	59	18,880
Maintenance/Utility Vessel	41	28,984
Offshore Maintenance/Utility Vessel	29	217,253
Offshore Support Vessel	15	89,738
Supply Vessel	224	617,097
Grand Total	799	1,957,983

The OSV orderbook composition as of July 2010 is shown in Figure 3-3. Compared to the current fleet composition, in which crewboats make up 16 percent of the total number, in the orderbook, crewboats only make up 7 percent. In addition, while anchor handlers make up 43 percent of the current fleet, they make up 54 percent of the orderbook. Construction vessels represent 9 percent of the current fleet but 11 percent of the orderbook, while supply vessels make up 32 percent of the current fleet and only 28 percent of the orderbook.

The drive towards building multi-purpose construction vessels is in part due to the increased need for subsea installation and maintenance activities that accompany exploration and production activities in deeper water. Compared with 2005, when supply vessels made up half of the orderbook and anchor handlers merely a third, the current orderbook represents a shift from supply vessel construction to anchor handler construction. As over 92% of the current anchor handler fleet is composed of AHTS vessels with supply capabilities, this shift from pure supply vessels to AHTS suggests that owners and operators believe the initial investment in the more capital-intensive AHTS vessels is worth the additional charter rates they can get from marketing the anchor handling capabilities. It also implies that anchor handling demand has increased faster than supply demand in the past five years. Both implications are consistent with deeper water exploration and production, which require more sophisticated mooring systems and additional non-supply support activities.

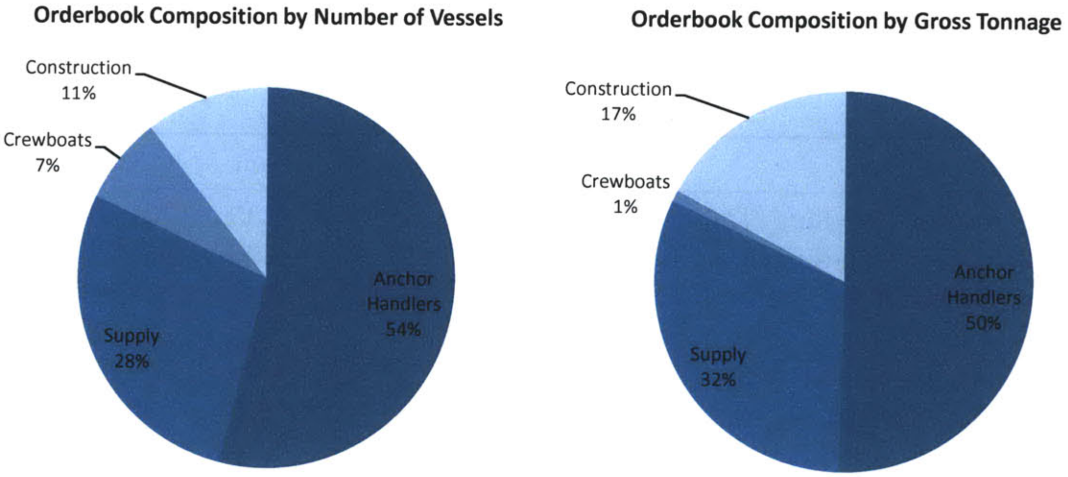


Figure 3-3: OSV orderbook composition.

3.2.4 Owners and operators

As the anchor handling and supply vessel fleets make up over 74 percent of existing OSV fleet in terms of number of boats and over 85 percent of the existing OSV tonnage, we focus on operators with significant anchor handling or supply vessel fleets.

Table 3.3 shows the largest owners and operators of anchor handling vessels. Together, they operate over 26 percent of anchor handlers worldwide and over 33 percent of anchor handling tonnage. Notably, Bourbon Offshore, Swire Pacific, Maersk Offshore, and China Oilfield Services have increased their anchor handling fleet size since 2005. Aside from Tidewater, few operators have anchor handling vessels in layup. Many of the vessels in layup are literally sitting in the mud and will probably never see service again.

Table 3.3: World dominant anchor handler operators.

Operator	Boats	Tonnage	Avg. age	>20 yrs	% >20 yrs	Deepwater	On order	Laid up
Tidewater	194	259,223	18.9	122	63%	20	4	42
Bourbon Offshore	61	125,087	4.5	3	5%	13	31	0
Swire Pacific	60	95,013	11.4	13	22%	21	13	0
Maersk	58	243,516	12.2	14	24%	36	2	0
China Oilfield Serv	51	69,195	22.2	33	65%	2	2	0
Maridive	31	30,664	18.0	18	58%	0	3	0
Zamil Offshore	31	44,825	6.5	2	6%	10	2	0
Edison Chouest	28	79,609	8.3	3	11%	11	2	0
Emas Offshore	27	53,739	3.8	0	0%	12	4	0
Farstad	25	85,990	10.8	4	16%	16	0	0
Whitesea	25	24,548	26.2	20	80%	0	0	0
Alam Maritim	23	30,940	3.8	0	0%	1	1	0
Seacor	19	34,553	11.6	4	21%	12	1	1
Seabulk	11	17,316	14.5	4	36%	3	0	0

Table 3.4 shows the largest owners and operators of supply vessels. Together, they operate over 28 percent of supply vessels worldwide and over 36 percent of the total supply vessel tonnage. On average, both the major anchor handler and supply vessel operators own larger vessels than the rest of the fleet. While major players from 2005 such as Edison Chouest Offshore and Bourbon Offshore have increased their supply fleet, smaller players such as Abdon Callais, Hornbeck Offshore, and Gulf Offshore have also made significant supply vessel acquisitions.

Table 3.4: World dominant supply vessel operators.

Operator	Boats	Tonnage	Avg. age	>20 yrs	% >20 yrs	On order	Laid up
Tidewater	110	154,055	19.1	55	50%	20	21
Edison Chouest	60	129,484	11.2	0	0%	0	1
Bourbon Offshore	57	120,217	5.9	4	7%	11	0
Abdon Callais	46	28,534	5.3	0	0%	3	0
Hornbeck	46	80,788	8.1	0	0%	1	3
Gulf Offshore	36	81,706	8.4	3	8%	5	0
Seacor	26	24,003	10.3	5	19%	0	0
Trico	25	33,320	22.2	17	68%	6	0
Gulfmark	23	36,615	5.7	1	4%	0	0
China Oilfield Services	22	43,811	6.2	3	14%	0	0
Esnaad	20	16,781	22.1	15	75%	0	0
China Marine Bunker	20	8,849	35.3	20	100%	0	0
DOF	17	54,968	7.4	0	0%	4	0
Hercules	16	3,830	28.1	14	88%	0	0

3.2.5 The AHT and AHTS subsector

The current anchor handling fleet comprises roughly 2,400 vessels with about 430 new vessels being built or on order. This corresponds to about 43 percent of the current

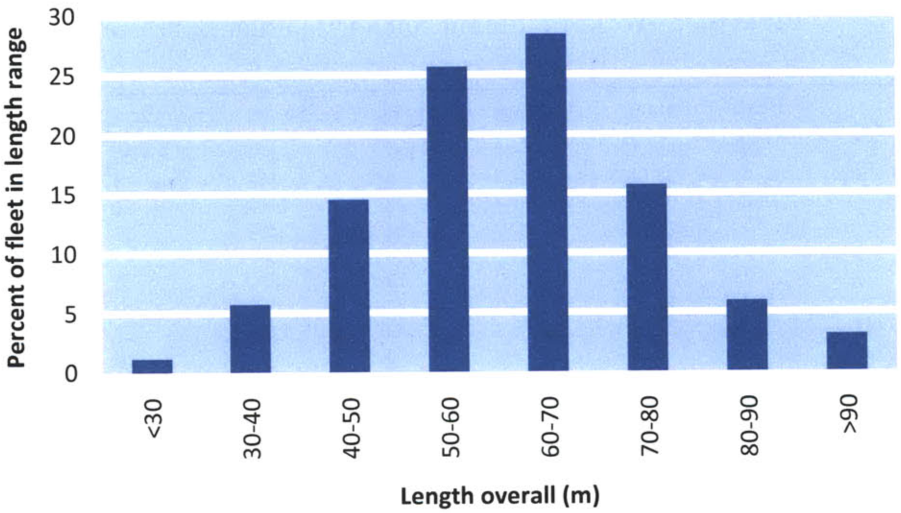


Figure 3-4: Overall length distribution of anchor handlers built between 2005 and 2010.

fleet and 54 percent of the orderbook. While larger anchor handlers are required for deeper water activities, Figure 3-4 shows that the overall lengths of the anchor handlers built in the past five years follow a distribution similar to a Gaussian with the majority of anchor handlers between 50 and 70 meters, and under four percent of new anchor handler vessels being over 90 meters.

Yet, Figure 3-5 clearly shows that the overall length distribution of the orderbook is shifted to the right of the length distribution of the current fleet, implying that new vessels are being built larger on average than current vessels. Despite this phenomenon, it is still clear that the majority of vessels on order are in the 50 to 80 meter length range, while roughly 6 percent of newbuilds are pushing the 90 meter envelope.

In contrast to the Gaussian distribution of overall length in both the existing fleet and the orderbook, brake horsepower follows a weighted distribution with a long tail as shown in Figure 3-6. While the shift is less clear than for length, newbuilds are being constructed with slightly more installed power than their predecessors. As service speed among anchor handling vessels is relatively constant, the additional brake horsepower installed at the higher end represent additional capability such as stronger winches, better bollard pull, and better dynamic positioning performance.

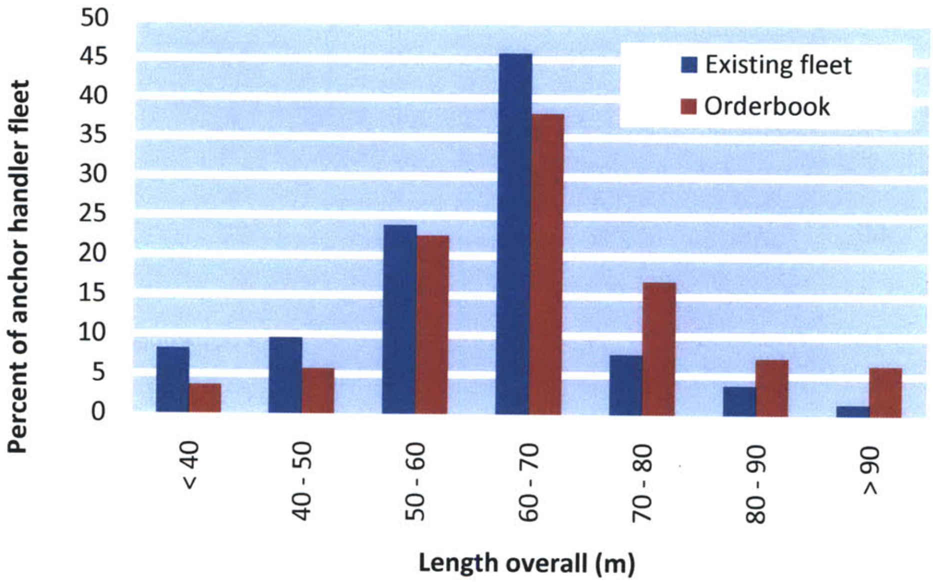


Figure 3-5: Overall length distribution of the current anchor handler fleet and orderbook.

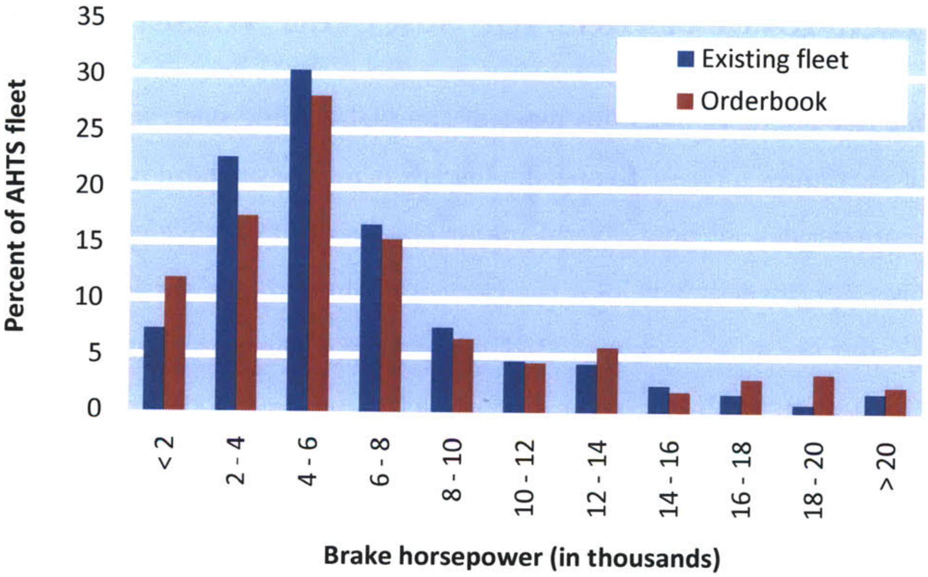


Figure 3-6: Brake horsepower distribution of current anchor handler fleet and orderbook.

This phenomenon is further illustrated in Figure 3-7, which shows asymptotic behavior of the fleet as length overall approaches 90 meters. Only 70 vessels exceed 90 meters in overall length.

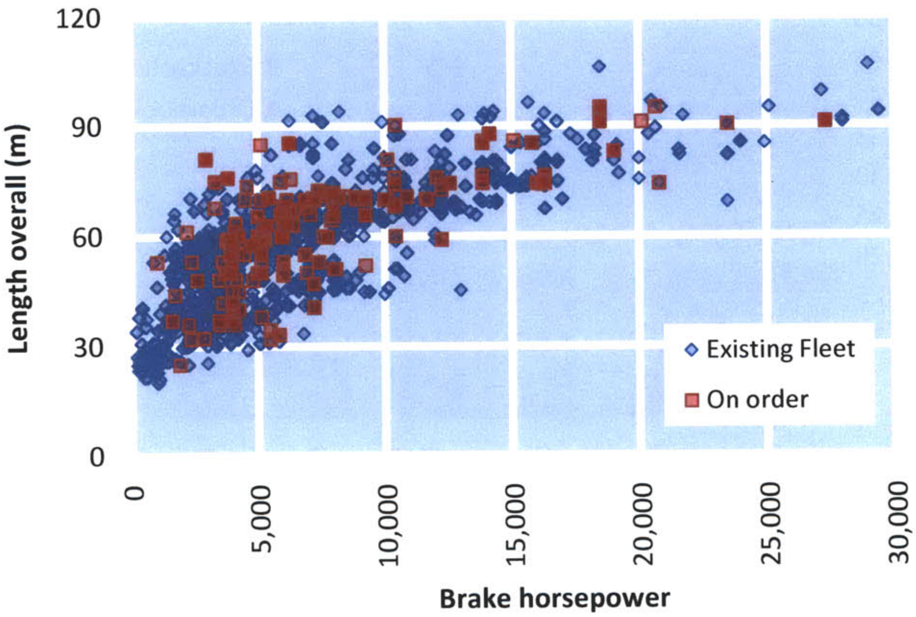


Figure 3-7: Comparison of lengths and brakehorsepower for the current anchor handler fleet and orderbook.

3.3 High-level trends for selected vessel types

Although anchor handlers make up most of the global OSV fleet, many other vessel types are of particular interest to specific fields within the offshore industry. In order to provide an overview of how several major classes of OSV have changed in recent years, Figures 3-8 through 3-11 plot the change in three major vessel characteristics: LOA, GRT, and brake horsepower (BHP) over time. The three time periods correspond to the fleet in 2005, the vessels constructed between 2005 and 2010, and the orderbook in 2010. Table 3.5 shows the sample sizes for each vessel class and time period corresponding to the trends shown in Figures 3-8 through 3-11.

As can be seen from Figure 3-8, accommodation vessels have tended to be built shorter, but with more capacity, although the ones on order are being built longer and with more capacity. As accommodation vessels are not always self-powered, it may not be significant that the average installed power is smaller in the orderbook than for recently-built vessels. While the orderbook calls for slightly smaller AHT/salvage vessels with significantly lower installed power, both AHT and AHTS vessels are being ordered longer, with more tonnage, but without increases in installed power.

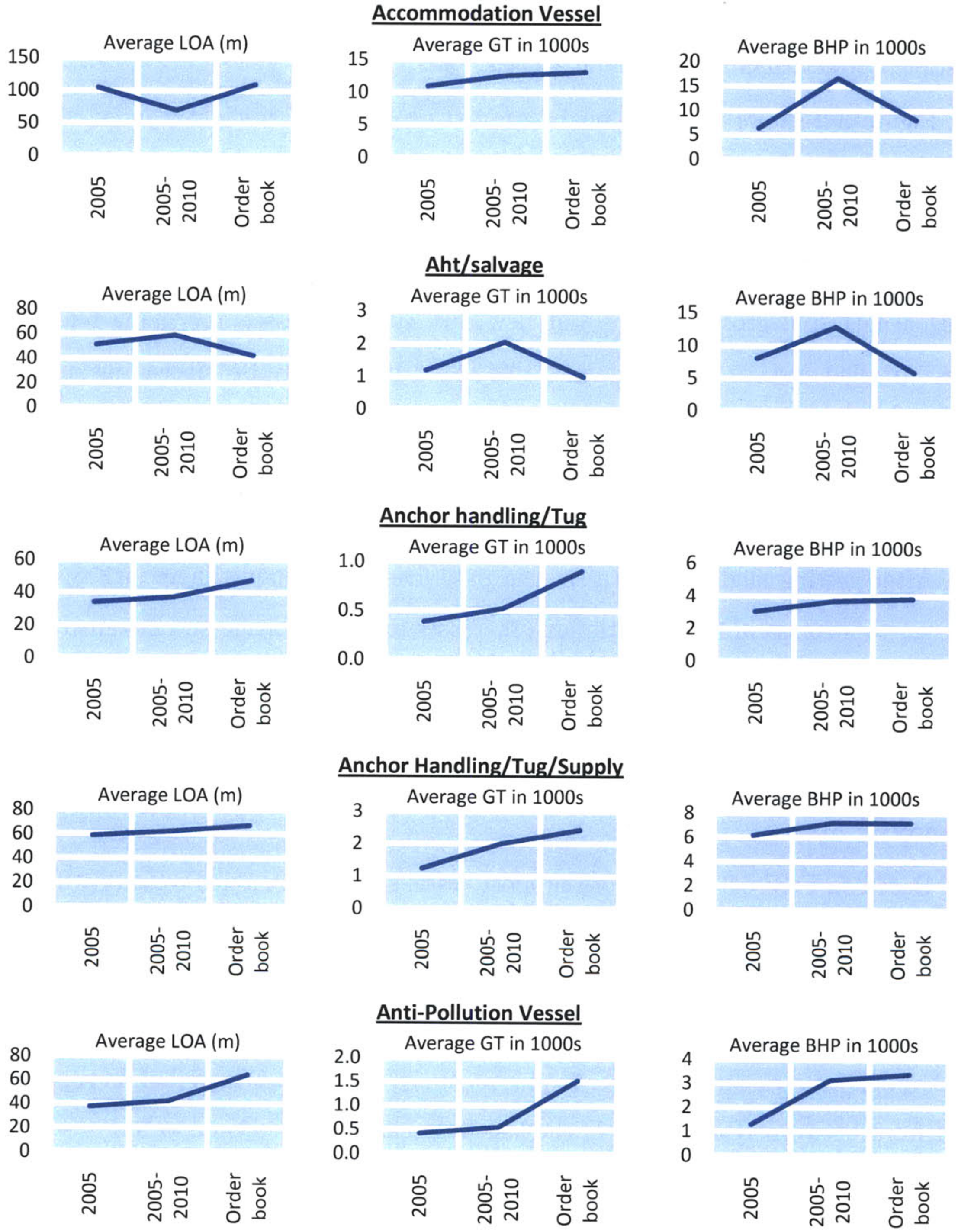


Figure 3-8: Trends in LOA, GRT, and BHP from 2005 to today's orderbook for accommodation, AHT/salvage, AHT, AHTS, and anti-pollution vessels.

Anti-pollution vessels show a similar trend, as the boats on order are longer, with on average three times the gross tonnage compared to the 2005 and recently-built fleet. However, new anti-pollution vessels are not being built with significantly more installed power than recently-built vessels.

Figure 3-9 shows that crewboats are getting longer with slightly more capacity, but that boats on order have less installed power than recently-built vessels. This probably speaks to the current lack of a defined value proposition for high speed crew or supply delivery by sea. Dive support vessels have also seen an increase in both length and gross tonnage, but new dive support vessels are being built with less installed power. Unfortunately, this trend may partly be misleading due to a small sample size, but on the other hand, dive support vessels operate mainly in one location and the growing efficiency of new DP systems and Diesel-Electric (D/E) propulsion systems alleviates power needs.

After getting slightly shorter in the past five years, maintenance/utility vessels are set to increase in length with large increases in both tonnage and installed power. Both offshore construction vessels and offshore maintenance/utility vessels are set to increase in size phenomenally by every measure. This is probably a result of the increasing load requirements that come hand in hand with deepwater construction projects.

Based on Figure 3-10, offshore support vessel size has remained relatively flat over the past five years and the orderbook does not show significant changes. However, the installed horsepower has increased dramatically, probably as a result of some offshore support vessel designs being fitted with DP systems for the first time. However, the orderbook reflects current power requirements as the average installed horsepower is flat from between vessels built in the last five years and vessels on order.

Oil well production test vessels got shorter and decreased in capacity in the last five years. New oil well production test vessels on order are somewhat larger and longer than recently-built vessels, but will also have less installed power. This lack of interest in installed power speaks to the vessel's primary mission as well testing as opposed to ferrying supplies. While oil well stimulation vessels share the future decrease in

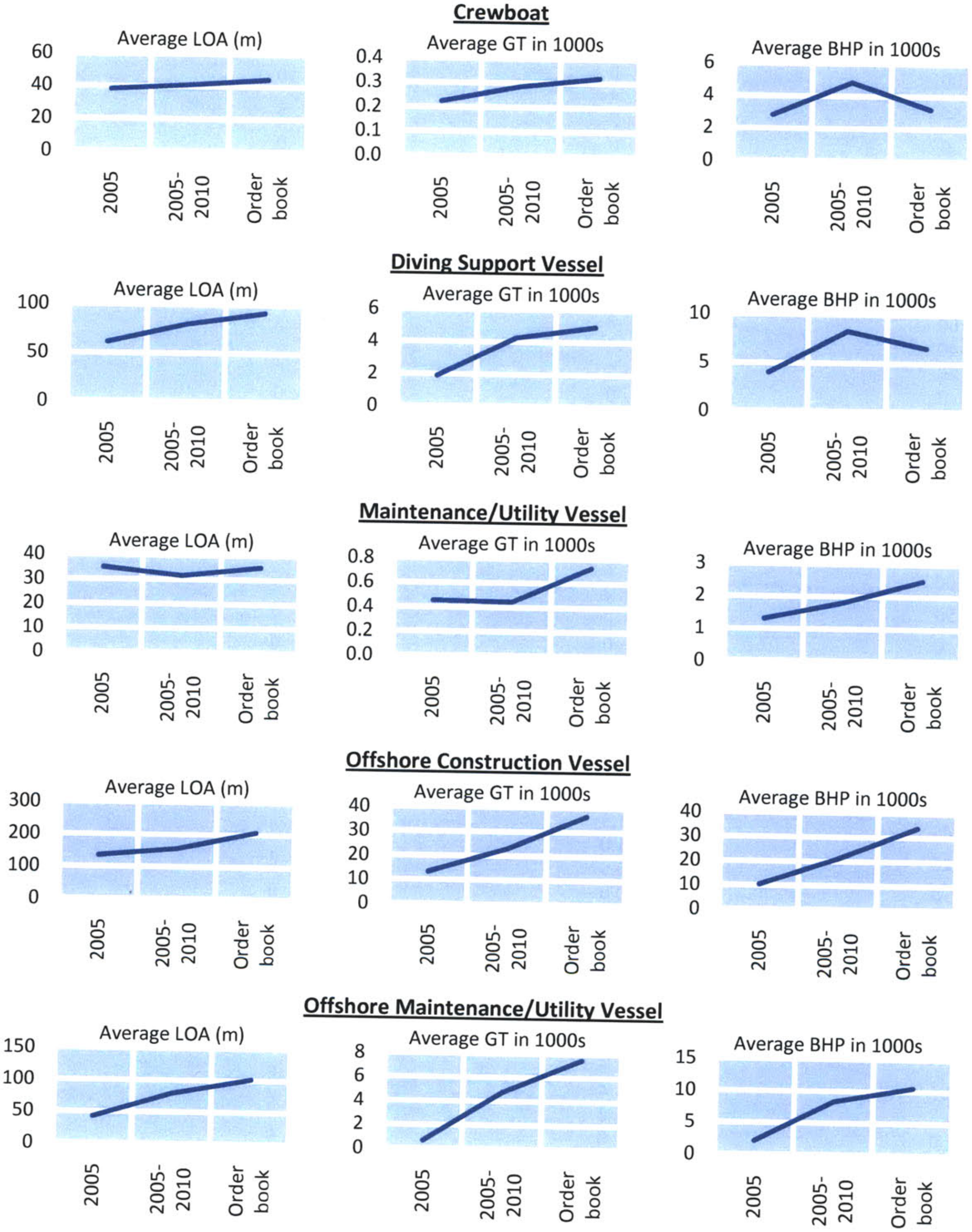
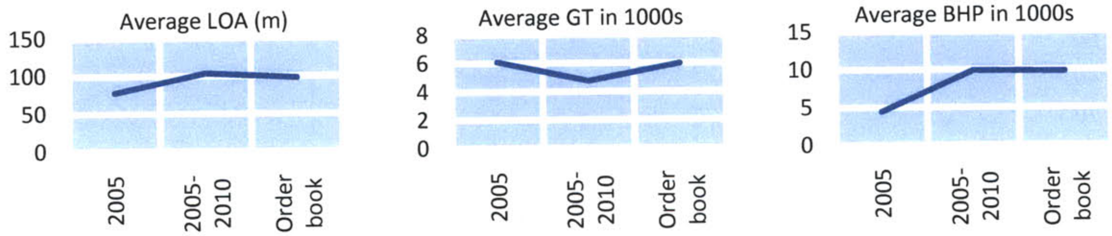
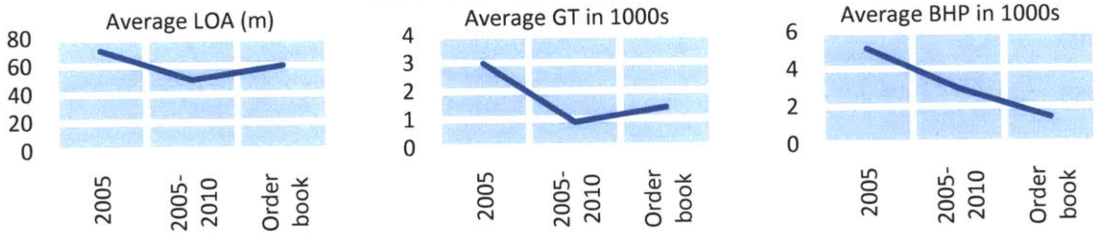


Figure 3-9: Trends in LOA, GRT, and BHP from 2005 to today's orderbook for crewboat, diving support, maintenance/utility, offshore construction, and offshore maintenance/utility vessels.

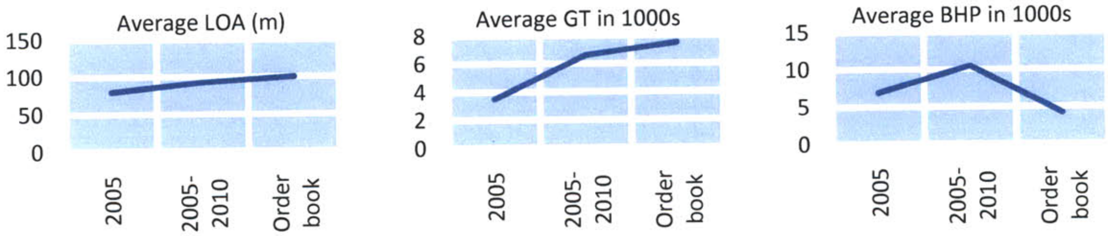
Offshore Support Vessel



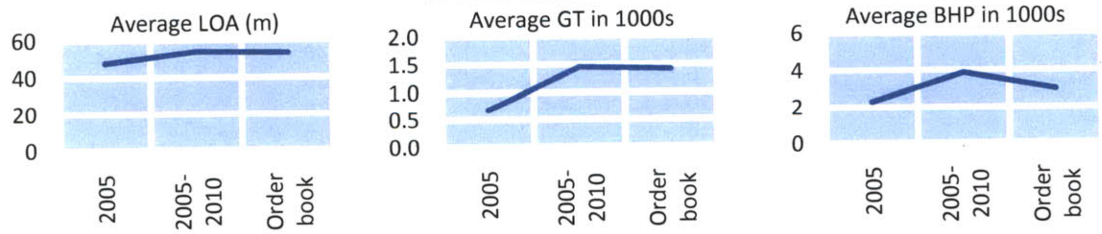
Oil Well Production Test Vessel



Oil Well Stimulation Vessel



Safety Standby Vessel



Seismic Survey Vessel

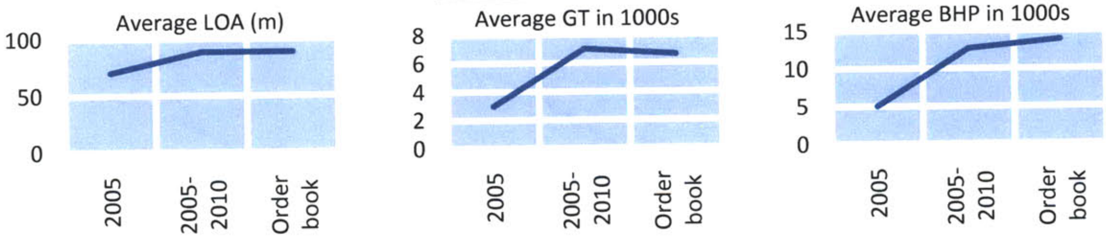


Figure 3-10: Trends in LOA, GRT, and BHP from 2005 to today's orderbook for offshore support, oil well production test, oil well stimulation, safety standby, and seismic survey vessels.

installed power of oil well production test vessels, they are set to get slightly longer and higher capacity. Again, these vessels are meant to stay on location and do not need power for speed. Both safety standby and seismic survey vessels grew in length, gross tonnage, and installed power over the last five years, but this growth has been halted in every category except seismic survey installed power, which will continue to increase slightly.

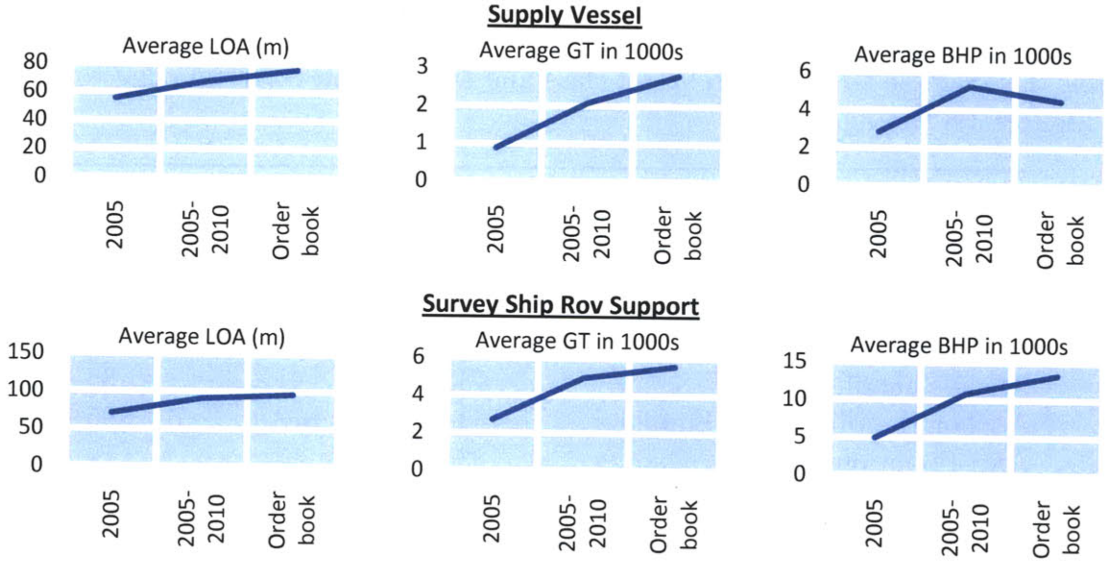


Figure 3-11: Trends in LOA, GRT, and BHP from 2005 to today's orderbook for supply and survey ship ROV support vessels.

Figure 3-11 shows a pronounced increase in supply vessel length and gross tonnage that will continue with the current orderbook, but a recent increase in installed power that will be somewhat reversed by the vessels on order. This speaks to the focus of platform and vessel operators on vessel capacity rather than speed, and perhaps in some degree to the increased propulsive efficiencies of modern PSV designs. On the other hand, survey ships providing ROV support have been getting larger in every category and should continue to get larger in the next five years. This is a rapidly developing class of vessels that are expected to stay on station in increasingly harsh conditions.

In general, vessels in most categories are growing, except seismic survey vessels, oil well production test vessels, and AHT/Salvage vessels. However, while most vessels are getting both longer and larger, not nearly as many vessels have upward trends in

Table 3.5: Sample size for each vessel class and time period corresponding to trends in Figures 3-8 through 3-11.

	Fleet Size		
Vessel Type	2005	2005-2010	Order book
Accommodation Vessel	27	4	5
Aht/Salvage	10	15	6
Anchor handling/Tug	143	41	35
Anchor Handling/Tug/Supply	1446	872	396
Anti-Pollution Vessel	336	17	11
Crewboat	648	287	59
Diving Support Vessel	189	38	27
Maintenance/Utility Vessel	179	61	41
Offshore Construction Vessel	28	7	10
Offshore Maintenance/Utility Vessel	169	62	29
Offshore Support Vessel	20	14	15
Oil Well Production Test Vessel	14	1	1
Oil Well Stimulation Vessel	22	7	8
Safety Standby Vessel	320	101	35
Seismic Survey Vessel	179	27	19
Supply Vessel	1448	480	224
Survey Ship ROV Support	28	9	6

installed power. Vessels with declining trends in installed power include accommodation vessels, AHT/Salvage vessels, crewboats, dive support vessels, oil well production test vessels, oil well stimulation vessels, and supply vessels. In some cases this decrease in installed power can be attributed to increased propulsive efficiencies due to more care in designing hull forms and D/E propulsion for DP systems, but in general, this decrease in installed power is a result of functional requirements. For vessels that are mainly stationary, increased speed does not help the primary mission, and for vessels that ferry supplies, it is cheaper to increase ton-miles/day by investing in capacity rather than speed.

3.4 Dependence on the price of oil

The high degree of uncertainty in the price of oil as we see it today has a retarding impact on the development of new deepwater drilling activity as it hinders the long-term planning required especially for deepwater fields that can be very expensive to exploit. Nevertheless, the number of undeveloped deepwater discoveries is high, suggesting that despite uncertainty regarding the price of oil, deepwater development growth will happen.

While it is difficult to forecast the price of oil, Figure 3-12 presents a strong correlation between the price of oil and OSV newbuilding. At this point in time, the OSV fleet and orderbook appear to be lagging behind the recent drop in oil prices. This gap will eventually be rectified by an increase in the price of oil, a decrease in OSV construction, or growing deepwater development without an accompanying increase in the price of oil.

3.5 Summary

The size of the offshore support vessel fleet has grown by 40% to roughly 5,600 vessels in the past five years. The move to deeper water exploration, drilling, and production activities has facilitated demands for larger, more powerful vessels. Despite significant

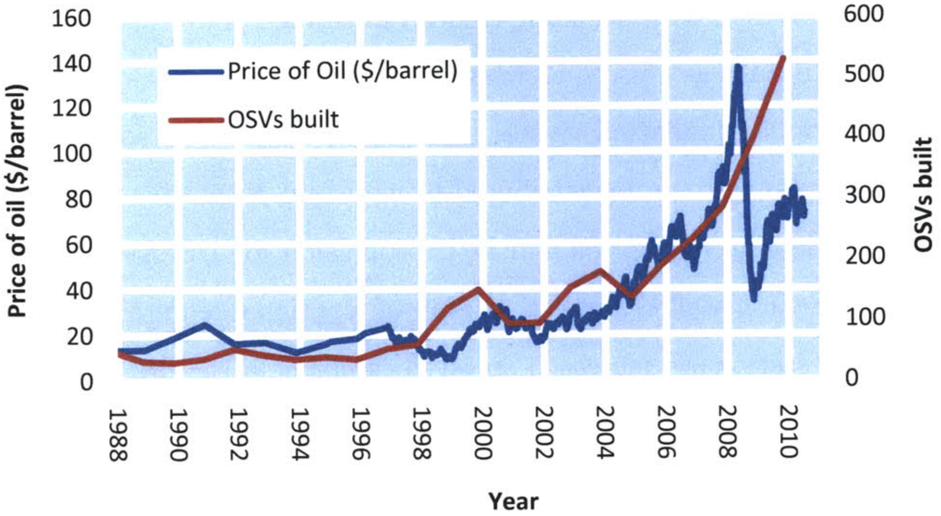


Figure 3-12: Correlation between the price of oil and OSV construction.

uncertainty in the current global economy and possible repercussions stemming from the BP Macondo spill in the Gulf of Mexico, the offshore support vessel orderbook stands at around 800 vessels and 2.0 million gross tons, representing 14% of the current fleet by number and almost 30% of the current fleet by gross tonnage. It also represents a two to four-fold increase in orderbook size from 2005. While this unexpected resilience in vessel demand may underscore the need for more capable and advanced vessels for deepwater work, it may be offset by the current historic mismatch between the price of oil and the offshore support vessel orderbook.

Chapter 4

Single vessel supply analysis

4.1 Hypothesis

As offshore exploration, drilling, and production activities move further offshore, the dominant changes to supply requirements are the need for larger quantities of materials and increasing distances from shore. It is expected that as the magnitude of supplies and distance from shore increases, larger vessels become more economical. In order to illustrate the effect of both the step change in material requirements from shallow water activities to deepwater activities and the increasing distance from shore, we analyze the cost per delivery for representative supply vessels from 2000, 2010, and a possible future design for representative supply scenarios covering startup and resupply activities for shallow water, midwater, and deepwater drill rigs.

4.2 Representative supply scenarios

In order to test the effect of supply vessel characteristics on delivery costs, we choose a set of supply scenarios that represent certain offshore supply needs. As drilling platforms tend to require significantly larger quantities of materials than production platforms, and as requirements vary greatly depending on the type of rig, we focus on drilling rig supply requirements and differentiate between shallow water jack-up rigs, midwater floaters, and deepwater floaters, as classified by Transocean, a major

(a) *Trident VI*, a shallow water jack up.

(b) *Paul B. Lloyd Jr.*, a midwater floater.

(c) *GSF Development Driller II*, a deepwater floater.

Figure 4-1: Representative offshore drilling rigs.

offshore drill rig operator. Each scenario corresponds to the requirements for a rig representing each category as taken from Transocean's fleet list on their website. Figure 4-1 shows the three representative rigs.

For each representative rig, both a startup delivery and routine supply delivery is considered as shown in Table 4.1. Drilling rigs are often unloaded before being towed to a new drilling location and require a sizable startup delivery before drilling can commence. This startup delivery includes full tanks of consumables such as mud, fuel, water, and stores, as well as the drilling equipment needed to begin drilling. By contrast, frequent resupply deliveries are much smaller and only replace spent consumables and swap out drilling equipment according to the progress of the well. Table 4.2 defines the cargo requirements for each supply scenario, and Table 4.3 defines the loading, unloading, and docking times. The supply requirements in Table 4.2 are based on a one-time delivery. For example, the startup delivery requirement of 400 cubic meters of mud for the shallow water drilling case implies that the rig cannot begin drilling until 400 cubic meters of mud have arrived, regardless of how many vessels it took to deliver the required quantity. The cargo delivery requirements listed in Table 4.2 are based on the rig cargo capacities as taken from their official specification sheets in conjunction with assumptions made based on typical drilling operations. Loading times are estimated based on cargo delivery requirements and cargo flow restrictions depending on the type of rig.

It is expected that as offshore oil exploration and production moves into deeper

Table 4.1: Supply scenario matrix.

Scenario	Representative Rig	Max depth	
Shallow water startup	*Trident VI* Jack-up	67 m	(220 ft)
Shallow water resupply	*Trident VI* Jack-up	67 m	(220 ft)
Midwater startup	*Paul B. Lloyd Jr.*	610 m	(2,000 ft)
Midwater resupply	*Paul B. Lloyd Jr.*	610 m	(2,000 ft)
Deepwater startup	*GSF Development Driller II*	2,286 m	(7,500 ft)
Deepwater resupply	*GSF Development Driller II*	2,286 m	(7,500 ft)

water and further offshore, deliveries corresponding to the representative deepwater startup and resupply scenarios will become more common.

Table 4.2: Supply scenario delivery requirements.

Scenario	Potable water (m^3)	Fuel (m^3)	Deck cargo (m^2)	Mud (m^3)	Dry bulk (m^3)
Shallow water startup	350	300	600	400	250
Shallow water resupply	300	300	300	0	0
Midwater startup	670	1,500	950	500	550
Midwater resupply	575	1,500	475	0	0
Deepwater startup	750	2,000	1,330	1,500	800
Deepwater resupply	675	2,000	665	0	0

Table 4.3: Supply scenario timing.

Scenario	Unloading time (hrs)	Loading time (hrs)	Docking time (hrs)
Shallow water startup	15	9	2
Shallow water resupply	5	3	2
Midwater startup	15	9	2
Midwater resupply	5	3	2
Deepwater startup	25	15	2
Deepwater resupply	5	3	2

4.3 Representative supply vessels

In order to compare the evolution of supply vessels over the past decade and determine the economic potential in future large designs, we choose as representative supply vessels a traditionally designed supply vessel from the late 1990s, the Trico *Elm River*, and a large modern PSV, the Maersk *Vega*. In addition, we extrapolate the Maersk *Vega* characteristics to create a fictional future supply vessel. This extrapolation is performed by scaling the ship length by 120 percent, the ship cargo volume by 120 percent cubed, and the ship deck area by 120 percent squared. The extra cargo volume obtained is split according to the needs in the deepwater scenarios, so mud and drybulk capacity are increased dramatically, fuel capacity is slightly increased, and no water capacity is added. The charter rate is expected to scale mainly with deadweight, which we assume to scale with volume, or 120 percent cubed, but as this is a very difficult number to determine, we perform a sensitivity analysis on the charter rate in Section 4.5.2. While these vessels certainly do not represent all supply vessel designs in service, they can be used as a basis for comparing the performance of older, smaller vessels against newer, larger vessels and potentially much larger designs. Table 4.4 shows the relevant supply vessel characteristics as adapted from operator specification sheets.

Table 4.4: Selected characteristics of representative supply vessels.

Name	Potable water capacity (m^3)	Fuel capacity (m^3)	Deck area (m^2)	Mud capacity (m^3)	Dry bulk capacity (m^3)	Fuel consump. at 10 kts (MT/day)	Charter rate ($/day)
Trico *Elm River*	568	600	330	272	125	7.5	9,000
Maersk *Vega*	1,000	1,500	940	619	400	13.0	15,000
Future vessel	1,000	2,300	1,354	1,500	800	18.7	26,000

Henceforth, the *Elm River* is identified as the 2000 PSV, the *Vega* is identified as the 2010 PSV, and the future design is identified as the Future PSV.

4.4 Methodology

Each scenario is evaluated for a range of possible distances from shore, from ten nautical miles up to 500 nautical miles. For each scenario range combination, the delivery cost is calculated by summing the vessel charter and the fuel consumption costs. First, the number of ships needed to meet the supply scenario requirements is found by dividing each supply requirement by the corresponding ship capacity and rounding up. The cargo requirement for which this ratio is largest determines the number of vessels required. The total trip time is calculated by adding the times required for loading, sailing, docking, and unloading. Total trip charter costs are equal to the number of vessels times the charter costs for those vessels times the total trip time.

To find the fuel costs, the voyage is broken down into the same four categories, loading, sailing, docking, and unloading. Each category has a corresponding fuel consumption rate based on the vessel's fuel consumption at design speed. Near the design point, fuel consumption is scaled as a cubic, and vessel speed is chosen to minimize the total cost with a lower bound of ten knots. An example of such an optimization is shown in Figure 4-2 where the fuel costs and charter costs are calculated per deadweight ton-nautical mile for the 2010 PSV assuming that the vessel is continuously sailing. In this case, the optimum speed is around 7.2 knots. However, in real supply situations significant amounts of time are spent not sailing, and emphasis is placed on predictability and reliability. Therefore, in practice, vessels rarely sail at speeds below ten knots. With current relationships between fuel costs and charter prices, the most economical speed is below ten knots in all the cases analyzed; that is, similar graphs as that shown in Figure 4-2 show that every vessel is best operated below 10 knots for optimal \$/DWT-nm efficiency. As such, we use our lower bound of ten knots as the trip speed for all vessels in all scenarios. For each category, loading, sailing, docking, and unloading, we find the fuel consumed by multiplying the time it takes to perform the activity by the fuel consumption rate for that activity. The fuel consumption total is then multiplied by the cost of fuel, which we estimate to be

1500 $/MT and takes into account the transportation costs of getting the fuel to the shore base.

We recognize that the PSVs in our model can sail faster than 10 knots. Most have maximum speeds between 12 and 14 knots. Although we use 10 knots, it is possible that vessels might sail faster if it allows for the reduction of a vessel from the fleet, or in the case of an emergency. Therefore, using 10 knots as vessel speed assumes that the oilfield operator wishes to operate vessels at their most efficient speed, but will not run vessels slower than 10 knots because it would interfere with voyage planning and reliability.

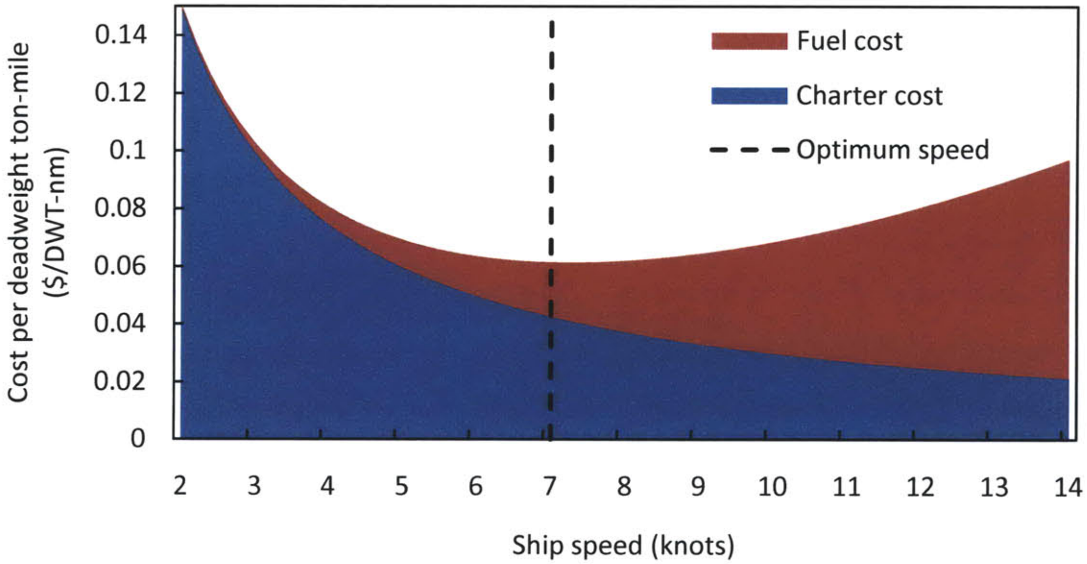


Figure 4-2: Cruising speed optimization for the 2010 PSV according to optimal $/DWT-nm.

We assume that the values for fuel cost and charter rates are correlated, regionally-dependent and relatively uncertain going forward. While this may diminish the absolute accuracy of our results as time goes on, the relative comparison between vessels should remain valid. As the price of oil increases, both the demand for PSVs and PSV charter rates increase. Additionally, the price of fuel increases. As long as these increases are relatively similar, our relative comparisons among vessel types hold.

4.5 Results

For a given set of supply requirements, the distance from shore has an absolute impact on cost, but little impact on the relative attractiveness of one vessel design versus another vessel design. For most scenarios fuel costs increase from roughly 30 percent of total costs at ten nautical miles from shore to roughly 50 percent of total costs at 500 nautical miles from shore. In order to compare the most relevant results, we only show results for the shallow water case 50 nautical miles offshore, the midwater case 100 nautical miles offshore and the deepwater case 200 nautical miles offshore. These offshore distances represent distances from port and not necessarily the shortest straight-line distance from the platform to land.

The single most important factor in the delivery cost is the number of vessels or trips required to make the delivery. As this is based on the cargo where the ratio between the rig need and vessel capability is greatest, matching a vessel's cargo capacity configuration to the service in which it is employed is extremely important in order to keep down fuel and charter costs. Table 4.5 shows how many of each type of vessel are required for the representative supply scenarios.

Table 4.5: Number of vessels required for each supply scenario.

	2000 PSV	2010 PSV	Future PSV
Shallow water startup	2	1	1
Shallow water resupply	1	1	1
Midwater startup	5	2	1
Midwater resupply	3	1	1
Deepwater startup	7	3	1
Deepwater resupply	4	2	1

As can be seen from Table 4.5, the standard 2000 PSV is designed for shallow water resupply runs, for which only one vessel is required. In practice, drilling rigs often have two dedicated support vessels, which are both used at startup to ferry out large quantities of mud and supplies [33]. However, as requirements increase for midwater and deepwater activities, the traditional 2000 PSV no longer has enough capacity to keep up and at the extreme of a deepwater startup, seven vessels are required.

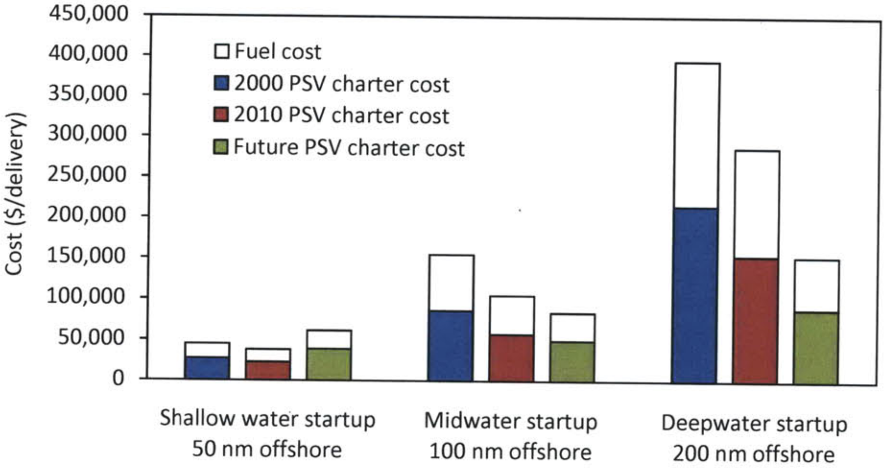
The modern 2010 PSV offers the advantage of being able to handle anything up to a midwater resupply run with only one vessel. However, midwater startup deliveries can require more than one modern 2010 PSV. With the extremely large deepwater startup delivery requirements, up to three 2010 PSVs may be needed. Finally, the Future PSV has been scaled up in such a way that it can handle all of the representative scenarios with a single vessel. As such, the Future PSV provides a basis for the magnitude of cost savings that may be achieved by using larger vessels matched exactly to delivery requirements.

Figures 4-3a and 4-3b show the fuel, charter, and total costs for all three representative vessels in every startup and resupply scenario considered.

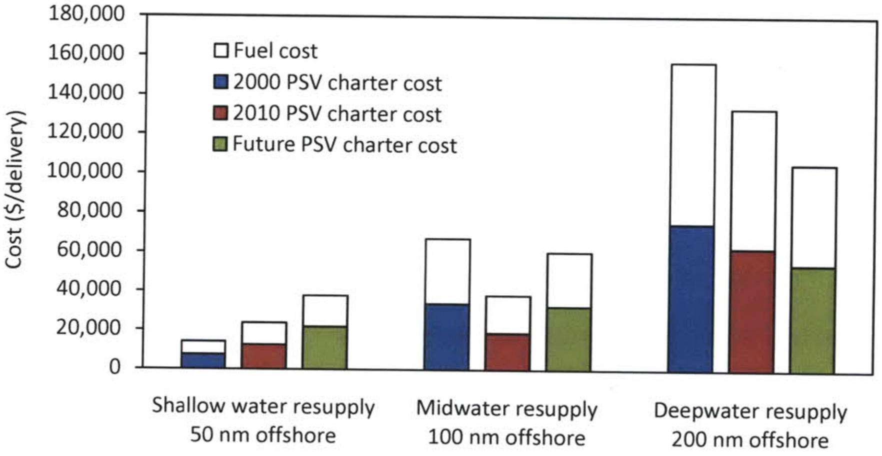
In Figure 4-3, the shaded portions of the cost bars represent the charter costs, colored according to vessel type. The fuel cost for each vessel is shaded in white and stacked on top of the vessel's charter cost bar. The cost bars are grouped by supply scenario.

As can be seen from Figure 4-3a, for the larger startup deliveries, the 2010 PSV is the most cost-effective vessel in shallow water and the Future PSV is the most cost-effective vessel in midwater and deepwater. Here larger vessels perform better in the shallow water cases because we assume that the industry-standard two vessel startup supply tactic is being replaced by a single vessel delivering all the cargo required to startup a drilling rig. However, while this may save costs for the startup delivery, the resupply delivery costs can suffer. For example, in Figure 4-3b, the 2000 PSV outperforms the 2010 PSV for shallow water resupply. Similarly, the 2010 PSV outperforms the Future PSV for midwater resupply. However, the total costs are also significantly lower for the resupply deliveries than the startup deliveries. Yet, as resupply deliveries are required more frequently than rig startups and rig moves, one might select a vessel optimized for resupply despite slightly less economical startup delivery costs. In order to fully appreciate these trade-offs one must evaluate the attractiveness of each vessel in the context of a fleet servicing multiple platforms for extended periods of time as described in Section 5.

In addition, Figure 4-3 shows that the relative advantage of a particular vessel



(a) Comparison of fuel and charter costs for startup deliveries.



(b) Comparison of fuel and charter costs for resupply deliveries.

Figure 4-3: Comparisons of startup and resupply delivery costs for representative vessels.

for a particular supply scenario is much more extreme for startup deliveries than for resupply deliveries in deepwater. Again, this difference becomes extremely relevant when considering the best set of vessels for a particular offshore oilfield as opposed to for a single platform.

4.5.1 Conclusions

The cost comparisons show that in general smaller vessels are advantageous for shallow water operations but are surpassed in cost-effectiveness by larger vessels for midwater and especially deepwater installations. In addition, the cost-effectiveness of a particular vessel in a particular service is heavily influenced by the ratio of the supply requirements to the capacity of the vessel and thereby the number of vessels required for a task. In fact, the number of vessels required for a task in combination with the vessel charter rate is the most important cost driver. As such, matching a specific vessel to a specific supply scenario can be a very important component of reducing offshore supply costs. Finally, as the difference between startup costs and resupply costs for different vessels becomes larger in deeper water, it is critical to consider the impact on overall fleet cost over time when choosing vessels that may have advantageous characteristics for one particular kind of supply activity.

4.5.2 Sensitivity

As estimating charter costs for existing vessels classes is difficult and estimating charter costs for as yet undeveloped vessels is not very reliable, a basic feasibility check is required on the charter rate of the Future PSV. In particular, we focus on the deepwater startup scenario, as this presents the largest advantage for the Future PSV when compared to the modern 2010 PSV. The Future PSV would have to charge \$62,000/day rather than the estimated \$26,000/day, when supplying a field 200 nautical miles from shore in order to have the same total cost as three 2010 PSVs chartered at \$15,000/day. Even when we almost triple the expected charter cost, the Future PSV still performs as well as the 2010 PSV. Furthermore, at a day rate of \$45,000/day, which corresponds to the total charter cost for the three 2010 PSVs, using one Future PSV still yields significant fuel savings that make the Future PSV much more attractive than using three 2010 PSVs. In conclusion, even if the day rate for the Future PSV will be significantly higher than we estimate, the Future PSV will still be the most attractive option for deepwater supply based mainly on its cargo-carrying capabilities.

However, in this single vessel analysis methodology, it is difficult to evaluate the true effects of economies of scale and redundancies and contingency planning over a longer time frame. Therefore, we perform a fleet portfolio model as discussed in

Chapter 5

Fleet portfolio modeling

An offshore oilfield operator's long-term fleet planning analysis strives to identify the optimal mix of vessels that minimize costs subject to constraints on support requirements and supply reliability. As most OSV owners prefer to find long-term vessel contracts and support vessels are often built when long-term contracts are available, we focus on offshore oilfield planning in the context of deciding which vessels to hire on long-term charter contracts. We gain insights into advantageous vessel designs for representative offshore support scenarios by choosing vessels from the perspective of the oilfield operator with the expectation that vessel construction will quickly mirror the needs and desires of oilfield operators.

5.1 Hypothesis

As an oilfield operator, fleet planning choices are often made between individual vessel flexibility and specialization, fleet reliability, and fleet cost. We hypothesize that as offshore drilling and production activities move further from shore, the most desirable vessels to perform support functions will be larger and more flexible. As distances and support requirements increase and vessels must spend proportionally larger amounts of their time sailing to and from the field as compared with shallow water, near-shore activities, fuel costs become a larger component of operating costs. Recall that in Chapter 4 fuel costs typically become up to 50 percent of total operating costs when far from shore. As fuel costs rise, it becomes more attractive to invest in vessel capabilities that save fuel, but more importantly save costs per DWT-nm. Since more of the time is spent sailing, cost per DWT-nm becomes more important. In order to reduce cost per DWT-nm, one can increase vessel size or vessel fuel efficiency. In the case of PSVs, we believe that while vessel efficiency will continue to increase with technology, the only real solution to this shift in supply requirements is a move toward larger vessels.

While this hypothesis could be tested for any number of support vessel activities, we focus on supply vessels as supply activities are straight-forward and involve relatively few assumptions. The context of fleet planning is necessary as vessels are rarely fully-utilized for supplying a particular facility, but are often occasionally shared among several platforms in an oilfield.

5.2 Representative supply scenarios

For the sake of simplicity, we consider a shallow water and a deepwater scenario, each with two drilling and three production platforms. Although this assumption limits the relevance of our specific results in terms of the vessels chosen, the same methodology can be applied to any given offshore oilfield support scenario. In addition, the vessel value comparisons we make should hold even for different combinations of drilling and production platforms. The key is to choose enough platforms of both types to be able to evaluate the ability of vessels to perform secondary roles while not engaged in their primary activity.

The shallow water supply scenario is composed of two drilling rigs based on the *Trident VI* jack-up rig as described in Section 4.2 and three production platforms. These requirements are summarized in Table 5.1.

The deepwater supply scenario is composed of two drilling rigs based on the *GSF Development Driller II* as described in Section 4.2 and three production platforms. These requirements are summarized in Table 5.2.

Table 5.1: Daily cargo demands for a representative shallow water drilling and production scenario.

	Fuel (m^3/day)	Mud (m^3/day)	Water (m^3/day)	Deck (m^2/day)	Bulk (m^3/day)
Drill rig 1	95	33	96	128	17
Drill rig 2	95	33	96	128	17
Production platform 1	1	0	2	17	0
Production platform 2	1	0	3	20	0
Production platform 3	1	0	3	20	0
Total	193	67	200	313	33

Table 5.2: Daily cargo demands for a representative deepwater drilling and production scenario.

	Fuel (m^3/day)	Mud (m^3/day)	Water (m^3/day)	Deck (m^2/day)	Bulk (m^3/day)
Drill rig 1	633	125	195	284	53
Drill rig 2	633	125	195	284	53
Production platform 1	7	0	4	37	0
Production platform 2	7	0	6	44	0
Production platform 3	7	0	6	44	0
Total	1287	250	406	693	107

5.3 Representative vessels

In order to simplify the analysis, the available pool of vessels was chosen to mirror the kinds of choices among vessel types and sizes that oilfield operators have available today without comparing every vessel design available on the market. In addition, these models require the fleet to be able to handle the worst-case scenario. For example, it is possible that both drilling rigs require a startup delivery simultaneously with one planned production platform delivery. Assuming this is the worst possible case, and that no single vessel can simultaneously supply more than one of these demands, the fleet must have at least three vessels: two vessels capable of performing a drill rig startup delivery and one vessel capable of performing a single production platform supply run. In practice, one would like to hire the smallest possible vessel (i.e. the least expensive vessel) to keep around in the event of worst-case contingency circumstances. As such, these roles are often filled by CSVs and FSIVs. In order to capture the role of CSVs and FSIVs in fleet portfolio decisions, we add a representative CSV from 2000 based on the Trico *French Broad River* and a representative FSIV from 2010 based on the Bourbon *Deneb* to the vessel list. In addition, we also created a possible future FSIV design by scaling up the representative 2010 FSIV in the same manner as the 2010 PSV was scaled up to create the Future PSV in Section 4.3. Selected particulars for the representative vessels considered in the fleet selection are shown in Table 5.3.

Table 5.3: Selected characteristics of fleet portfolio model representative vessels.

Name	Potable water capacity (m^3)	Fuel capacity (m^3)	Deck area (m^2)	Mud capacity (m^3)	Dry bulk capacity (m^3)	Fuel consump. at 10 kts (MT/day)	Charter rate ($/day)
2000 PSV	568	600	330	272	125	7.5	9,000
2010 PSV	1,000	1,500	940	619	400	13.0	15,000
Future PSV	1,000	2,300	1,354	1,500	800	18.7	26,000
2000 CSV	8	46	181	0	0	1.7	2,500
2010 FSIV	12	136	248	119	0	1.9	5,000
Future FSIV	13	235	357	206	0	2.7	9,000

5.4 Methodology

In practice offshore support vessels often spend a considerable amount of time performing tasks they were not specifically designed for but can still accomplish. In addition, many vessels are designed to be multi-purpose, such as crew boats with large open decks for carrying deck cargo. As each vessel has a unique set of capabilities and associated costs and many of the tasks can be performed by different vessels, choosing a fleet of vessels to provide a required level of service to the field while minimizing vessel charter costs, fuel costs, and port fees can be a difficult problem to solve by hand, but is easily modeled as a Mixed Integer linear Program (MIP) and solved by a generic MIP solver.

The modeling approach employed here can be likened to the alchemist's mixing problem, who has a limited number of resources available at certain costs which he can mix in different proportions to create several different metals, say bronze, silver, and gold. Assuming he has been contracted to create a certain amount of each metal, he would like to choose the amount of each resource that he buys in order to minimize costs but still fulfill the contract. Here, we seek to choose the vessels in a way to minimize the total cost while still fulfilling the field requirements for each supply and marine requirement.

The flow chart in Figure 5-1 describes the input and output to the model as well as the general process.

5.4.1 Model assumptions

1. Each vessel leaves from port, steams directly to the center of the supply field, unloads all cargoes in sequence at quantities corresponding to the supply policy, steams directly to port, and is reloaded with cargo for an assumed port turnaround time before heading back out, repeating its cycle. An additional component of cycle time is added for platform dockings and undockings and intra-field transit if the vessel typically serves more than one platform on a given supply run.

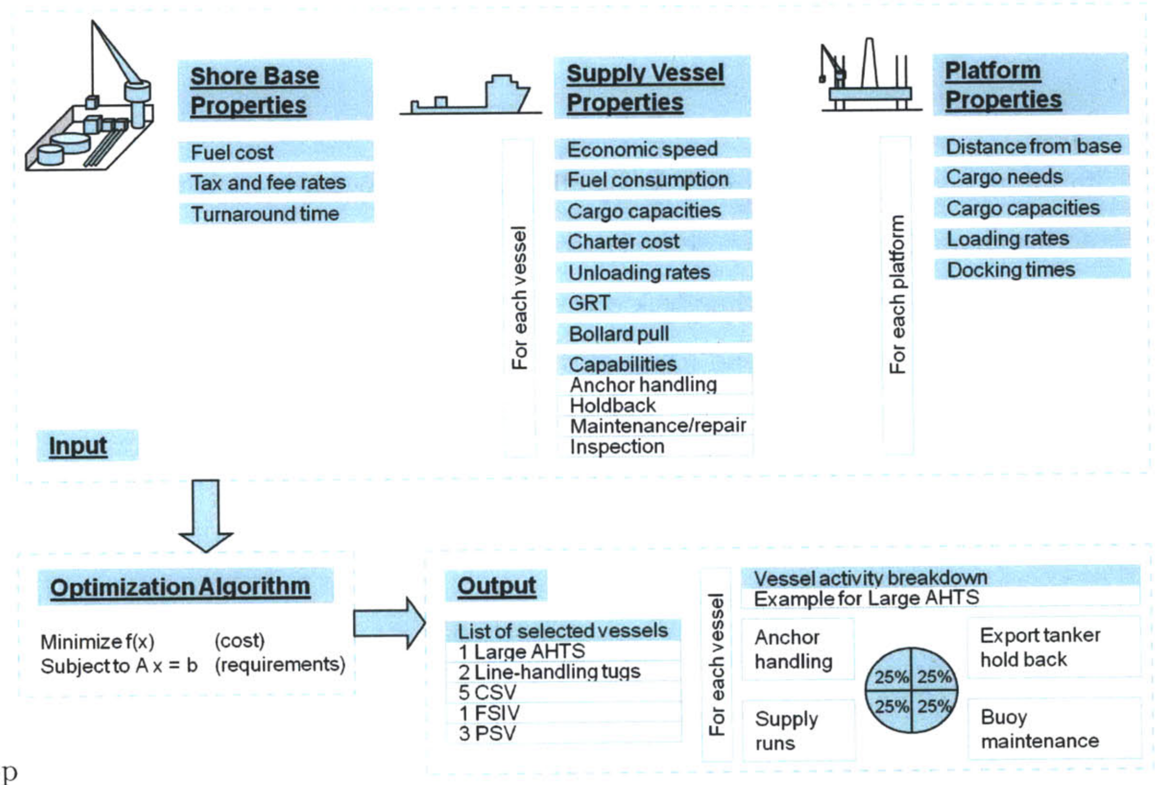


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Figure 5-1: Model flowchart.

2. Platform demands are aggregated into a demand rate for each cargo.

3. Vessels only steam at cruise speed (10 knots).

4. Vessels in the fleet cost a daily charter fee in addition to the fuel required to steam to the field and back.

These assumptions are depicted graphically in Figure 5-2.

5.4.2 Sets

M Marine service vessel activities, indexed by i.

N Supply activities, indexed by i.

K Available vessels, indexed by k.

S Required cargoes, indexed by s.

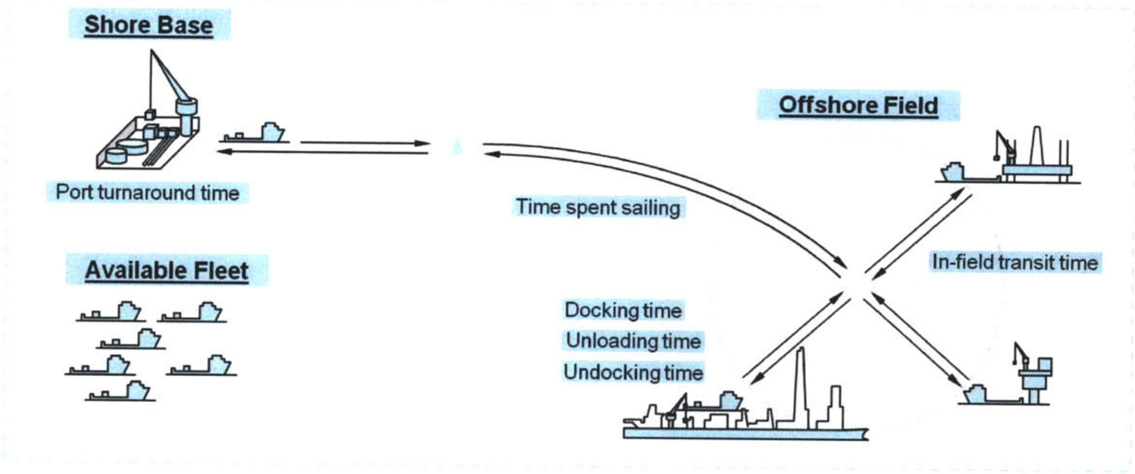

Figure 5-2: Model diagram.

H	Supply field requirements, including cargoes and marine service activities ($H = M \cup S$), indexed by h.

As it is possible that the optimal fleet will not have 100 percent utilization, one of the marine service vessel activities is considered to be idling. At idle a vessel burns a small amount of fuel but incurs no additional variable costs.

5.4.3 Decision Variables

Decisions are made for each vessel determining if it is selected to be in the fleet and if so, what fraction of its time it spends on each activity.

δ^k	Binary variable that is equal to 1 if ship k is in the optimal fleet and 0 otherwise.
x_i^k	Continuous variable between 0 and 1 that represents the fraction of time ship k spends performing activity i.

For example, if $x_2^4 = 0.5$, and $i = 2$ represents anchor handling, and $k = 4$ represents the AHTS *Dino Chouest*, then the *Dino Chouest* is in the fleet and spends half of its workday anchor handling. In order to ensure that ships can only perform work if they are in the fleet, we employ the forcing function in Equation 5.1.

$$\sum_{i \in N \cup M} x_i^k = \delta^k, \quad \forall k \tag{5.1}$$

5.4.4 Data

C^k	Charter cost of ship k in dollars per day.
$R_{i,h}^k$	Completion rate of requirement h while ship k is performing activity i. For supply activities, the completion rate is a rate (such as m^3/day), but for service activities it is measured in hours/day. Some activities such as a supply run where 50% tank capacity fuel and 100% tank capacity water is delivered may have positive completion rates for more than one requirement. Multiple calculations are required to generate the R matrix, but all of this calculation can be done a priori.
D_h	Demand for requirement h in the appropriate unit of weight or volume per day for supplies and hours/day for marine requirements.
F_i^k	Fuel cost for ship k performing activity i in dollars per day.
G_i^k	Port fees and taxes including port entry tax, cargo tax, and pilotage fees for ship k performing activity i in dollars per day.
U^k	Maximum utilization of a particular ship expressed as a fraction out of one.
P^k	Vessel type, such as PSV, AHTS, CSV, and FSIV.
$W(P)$	Number of vessels of type P that need to included in the fleet. For example, if the fleet requires two PSVs, this number might be two.

5.4.5 MIP Formulation

minimize over δ, x,

$$\sum_{k \in K} C^k \delta^k + \sum_{k \in K} \sum_{i \in N \cup M} \left(F_i^k + G_i^k\right) x_i^k \tag{5.2}$$

subject to

$$\sum_{k \in K} \sum_{i \in N \cup M} R_{i,h}^k x_i^k \geq D_h, \quad \forall h \tag{5.3}$$

$$\sum_{i \in N \cup M} x_i^k = \delta^k, \quad \forall k \tag{5.4}$$

$$\sum_{i \text{ not idling}} x_i^k \leq U^k, \quad \forall k \tag{5.5}$$

$$\sum_{k: P^k = p} \delta^k \geq W(p), \quad \forall p \tag{5.6}$$

$$x_i^k \in [0,1], \quad \delta^k \in \{0,1\}, \quad \forall i, k. \tag{5.7}$$

The first term in the objective function in Equation 5.2 represents the total charter costs of all the vessels selected to be in the fleet while the second term represents the sum of the fuel and port fees associated with each vessel activity combination for the amount of time that each vessel performs each activity. The constraint in Equation 5.3 ensures that the total oilfield demand for each cargo and marine service activity is met by vessel activities. The next constraint in Equation 5.4 ensures that a vessel can only perform activities if it is selected to be in the fleet. Equation 5.5 constrains the total fraction of a vessel's time that is spent on productive activities to be below that vessel's input maximum utilization level. For example, if the operator believes that maintenance will cause downtime of 10 percent, only 90 percent of the vessel's time can be utilized doing activities that are not idling. The constraint in Equation 5.6 ensures that at least a certain number of vessels of a particular type are represented in the fleet. In the implementation this constraint can be made very flexible to effectively require a certain number of vessels from any particular set of vessels. In the following representative cases, this constraint is used to require a minimum number of vessels capable of performing rig startup deliveries that could occur simultaneously. Finally, the constraint in Equation 5.7 defines the decision variable representing vessel activity as continuous between zero and one and the decision variable representing whether a vessel is in the fleet as binary. In cases where sister ships are part of the potential fleet, it is easy to modify this methodology to change the δ^k variable to be integer instead of binary.

5.4.6 Implementation

Microsoft Excel is employed to input and store the data. We developed code in Microsoft Excel Visual Basic for Applications (VBA) to manipulate the data to form the appropriate structures, such as C, F, G, R, and D, to convert the formulation into standard form by using a mapping function for the two different decision variable types, and to hook into an external solver to find the optimal values for the decision variables. The external solver we used was the open source program lp_solve. We linked to lp_solve using its VBA Application Program Interface (API). Data output is restructured in VBA and sent to a Microsoft Excel sheet as well as a text document for user verification. The lp_solve solution was validated against the well-known optimization solver CPLEX, which yielded identical results with similar running times. System setup and solution take less than one minute.

5.4.7 Validation

The methodology was validated on a real offshore production support scenario with data provided by a major oil company. When contingency constraints were applied, the model results closely matched the fleet in operation, while highlighting some opportunities for slight improvements.

5.5 Shallow water scenario

5.5.1 Constraints and assumptions

Constraints and assumptions play a critical role in the output fleet. As such, it is important to understand exactly what additional assumptions and constraints are input into the fleet portfolio model. Initially we generate the required level of contingency planning based on a hypothetical worst-case scenario. When we discuss contingency planning we mean the ability of the fleet as a whole to handle unexpected needs. Clearly, the actual worst-case can always be worse than our hypothetical worst-case and could include catastrophic damage and possible subsequent pollution. We assume that in cases of catastrophic damage, such as a blowout and fire like aboard the *Deepwater Horizon*, having another PSV on charter will not contribute significantly to the emergency response. Likewise, in extreme cases, the oilfield operator will have to make instantaneous decisions that will likely cost more than most spot hire rates. Instead we plan for a worst-case scenario in which the supply requirements line up in the way that requires the most vessels. We use this approach because the cost of failure for idling a drill rig or production platform exceeds \$100,000/day for jackups, and \$400,000/day for a large drillship [6]. This method translates into the following assumptions and constraints for the shallow water mixed production and drilling fleet:

1. no nighttime operations, a 12-hour working day
2. the fleet must consist of a minimum of three vessels to fulfill the worst-case scenario of two drill rig startup deliveries coinciding with one production delivery
3. the fleet must consist of a minimum of two vessels able to deliver quantities corresponding to a drill rig startup delivery.

5.5.2 Results

Table 5.4 shows the selected vessels, vessel utilization, and vessel costs. These costs are also displayed graphically in Figure 5-3.

Table 5.4: Fleet composition, utilization, and costs for the optimal fleet supporting a representative shallow water drilling and production scenario.

Vessel	Number	Utilization	Charter cost ($/day)	Fuel cost ($/day)	Port fees ($/day)	Total cost ($/day)
2000 PSV	2	56%	9,000	3,397	1,227	27,247
2000 CSV	1	100%	2,500	3,613	1,605	77,18
Total	3	71%	20,500	10,407	4,058	34,965

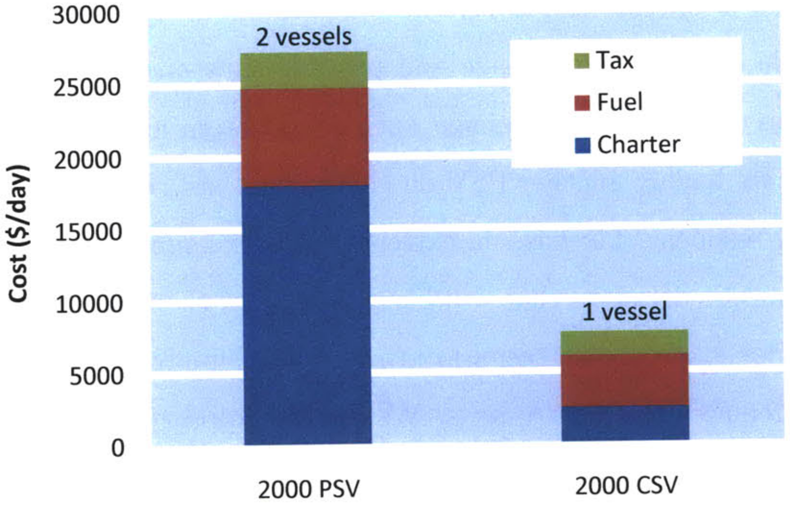

Figure 5-3: Daily costs for vessels in the optimal fleet supporting a representative shallow water drilling and production scenario.

As can be seen from Table 5.4 and Figure 5-3, the optimal fleet under the supply requirements, constraints and assumptions is composed of two 2000 PSVs and one 2000 CSV. In general, the two PSVs provide the capability to handle two rig startups simultaneously, while the CSV provides the ability to handle contingencies in the event that both PSVs are deployed. However, the utilization levels indicate that the CSV is 100% utilized. Careful inspection of the decision variables reveals that the CSV is constantly employed on deliveries during which it only carries deck cargo. The CSV is the most cost efficient vessels for fulfilling the deck cargo requirements in the field and is therefore employed for this task. This causes the PSVs to have low utilization numbers, associated with their higher relative port fees and fuel burn to deliver a square meter of deck cargo as compared to the CSV.

In addition, the low utilization rate of the PSVs indicates that there may be room for a reduction in total costs by improving scheduling and contingency planning. However, in practice, keeping utilization rates high while maintaining a fleet capable of responding to contingencies is very difficult.

5.6 Deepwater scenario

5.6.1 Constraints and assumptions

The assumptions and constraints for the deepwater mixed production and drilling fleet are:

1. no nighttime operations, a 12-hour working day
2. the fleet must consist of a minimum of five vessels to fulfill the worst-case scenario of two vessels being at sea when two drill rig startup deliveries coincide with one production delivery
3. the fleet must consist of a minimum of two vessels able to deliver quantities corresponding to a drill rig startup delivery.

5.6.2 Results

Table 5.5 shows the selected vessels, vessel utilization, and vessel costs. These costs are also displayed graphically in Figure 5-4.

As can be seen from Table 5.5 and Figure 5-4, the optimal fleet under the supply requirements, constraints, and assumptions is composed of two 2010 PSVs, two Future PSVs, and one 2010 FSIV. All of the PSVs are operating at maximum utilization, while the FSIV provides a reserve capacity. While the supply vessels are clearly more cost efficient for getting the cargo to the field, the incremental cost of adding another PSV to the fleet is significantly greater than adding the 2010 FSIV, which has very low charter costs. Although the utilization appears to be very high with very little

Table 5.5: Fleet composition, utilization, and costs for the optimal fleet supporting a representative deepwater drilling and production scenario.

Vessel	Number	Utilization	Charter cost ($/day)	Fuel cost ($/day)	Port fees ($/day)	Total cost ($/day)
2010 PSV	2	100%	15,000	9,045	8,172	64,435
Future PSV	2	100%	21,600	12,836	13,510	95,892
2010 FSIV	1	51%	5,000	3,159	943	9,102
Total	5	90%	78,200	46,922	44,308	169,429

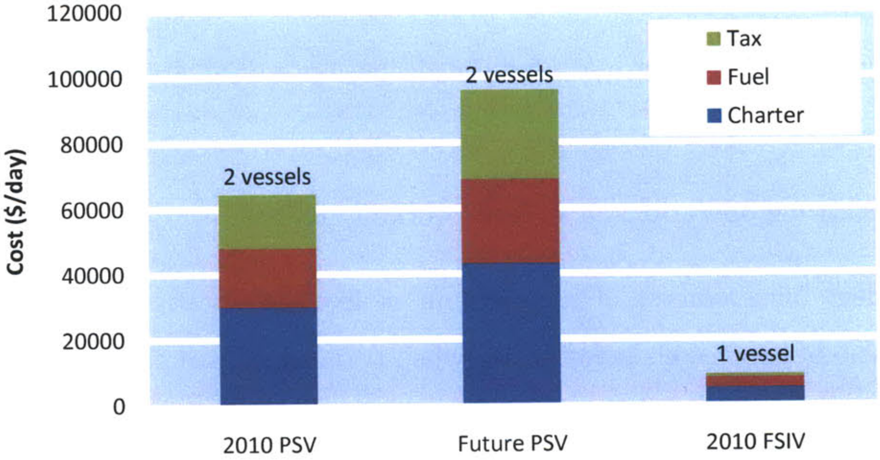

Figure 5-4: Daily costs for vessels in the optimal fleet supporting a representative deepwater drilling and production scenario.

reserve capacity, the restriction on nighttime operations eases up considerably with further distances from shore because more of the vessels time is spent sailing, which can be done at night, as opposed to maneuvering, docking, loading, and unloading.

5.7 Sensitivy to water depth

Although it is impossible to predict exactly how the supply requirements change as exploration and production move further offshore, it is possible to get an idea by examining the trends from the three representative scenarios considered. Figure 5-5 shows how each demand changes with distance from shore and water depth for the representative mixed drilling and production scenarios. The shallow water, midwater, and deepwater scenarios are plotted as points and curves are fit to them. While the trends in Figure 5-5 are based on few data points and may not be accurate in magnitude, publicly available floating drill rig specifications support the relative relations.

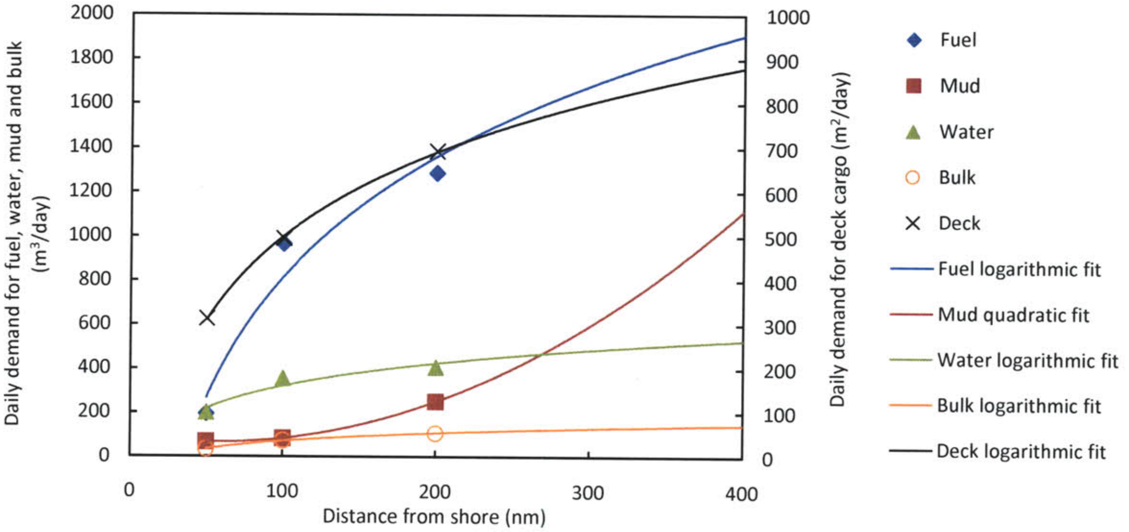

Figure 5-5: Extrapolation of cargo demand from representative supply scenarios with two drilling rigs and three production platforms to similar scenarios at increasing distances from shore and corresponding implicit water depths.

With the information in Figure 5-5, it is possible to select fleets for any water depths using our methodology. Again, the results are only as good as the inputs, but the methodology is flexible to accommodate any specific offshore drilling scenario and potential vessel pool. Keep in mind that in this case the input scenarios include two drilling rigs and three production platforms at varying water depths and distances from shore. Of particular interest when considering the sensitivity of the fleet to the distance from shore is which vessels enter and leave the optimal fleet as the distance from shore increases as shown in Figure 5-6.

When performing this analysis, any distance from shore past 400 nautical miles with the associated increasing requirements for cargo yielded fleets in excess of ten Future PSVs. While this is possible, it is assumed that prior to using ten Future PSVs, a larger vessel will be designed and used to replace several smaller ships. This

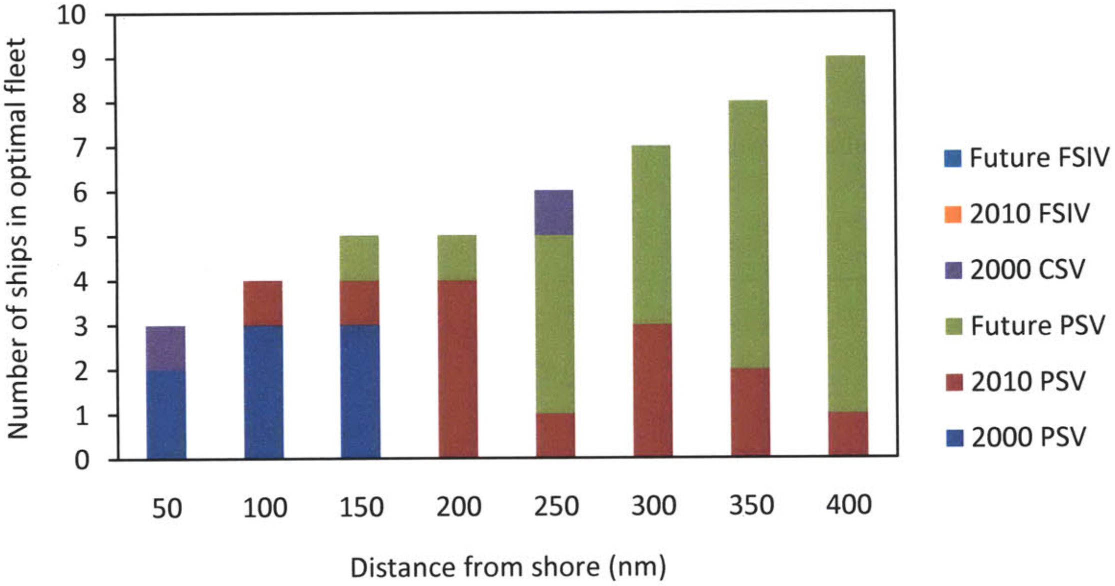

Figure 5-6: Fleet composition for varying distances from shore and corresponding cargo demands.

replacement phenomenon is easy to see in Figure 5-6. Between 150 nautical miles and 200 nautical miles from shore, the cargo requirements increased, yet the total number of vessels remained the same because three 2000 PSVs were replaced by three 2010 PSVs. The red bars representing the 2010 PSV show how it becomes more attractive for increasing distances and then falls off until only one 2010 PSV remains in the fleet at 400 nautical miles from shore. It is important to note that the transition is not smooth. This is a result of using integer decision variables for number of vessels in the fleet. Sometimes a combination of ships might be less cost effective per ton of cargo, but still get the job done and be more cost effective as a total fleet.

In addition, notice the relatively limited role of CSVs and FSIVs in the optimal fleets. At 50 nautical miles from shore, the 2000 CSV provides the contingency requirement as there are only two PSVs which take care of the drilling platforms in the worst-case, but no other PSVs to take of the production platforms. Here, the CSV is capable of making a production delivery run and takes that spot. At 250 nautical miles, the CSV is in the fleet for a different reason. Here, the total number of vessels required for the worst-case is met without the CSV, however, the CSV fills the gap on cargo requirements. The larger PSVs can move almost all of the cargo, but there is a tiny bit left over. While the CSV is the most inefficient vessel to move this cargo, it is cheaper to charter one small PSV in conjunction with the CSV to fill the gap than it would be to switch one 2010 PSV to a Future PSV. Also, as the cargo requirements become greater, the cargo deliverability of crewboats is vastly diminished in comparison to the large PSVs. Delving into the details on these results reveals that when CSVs do enter the fleet, they mainly fulfill a gap need for deck cargo. In comparison to PSVs, CSVs have a much larger ratio of their deadweight dedicated to deck cargo. Consider that a typical CSV or FSIV can have a third as much deck space as a PSV, but orders of magnitude less hull volume. This is mainly due to the fact that deck area scales with the square of length, whereas internal volume scales with the cube of length. Hence, as distances from shore increase, maintaining crewboats in the fleet will require explicit needs for contingency vessels carrying deck cargo. Indeed, it makes intuitive sense that light, fast vessels might carry out high value deck cargo, while larger, slower vessels transport fuel, mud, water, dry bulk, and lower value and heavier deck cargo to deepwater fields.

Finally, note that the 2010 FSIV did not enter the fleet at 200 nautical miles from shore, which should mirror the representative deepwater scenario, where a 2010 FSIV is present. The reason the selected fleets differ is because the 200 nautical mile case in this analysis is actually not the deepwater scenario, but a fit to the cargo requirements trend, and therefore different enough to have a different optimal fleet.

5.8 Extra vessel contingency

The vessel contingency plans in the above scenario consist of planning for the expected worst-case and then requiring enough vessels to be in the fleet to handle that case. Another way to consider contingency is to require a fleet composition such that one vessel is always available to handle an unexpected need. We implement this type of contingency plan by replacing constraints in Equation 5.6 that refer to the worst-case scenario with the constraint in Equation 5.8 below.

$$\sum_{k \in K} x_{i\ \text{idling}}^{k} \geq 1 \tag{5.8}$$

This constraint ensures that on average, one vessel is not performing any particular duty and would be ready to respond to a possible contingency. Figure 5-7 shows the minimum-cost fleets for the varying scenarios under this contingency plan. As expected, the most inexpensive vessel, the 2000 CSV appears in the minimum-cost fleet for every scenario. Unfortunately, it is possible that a 2000 CSV in reserve might not be able to handle all contingencies. For example, if a quick load of mud is required, the 2000 CSV with no mud capacity will be of no use. However, the insight gained from this exercise can be extended to any particular contingency plan of this sort. For example, if the oilfield operator wishes to have an extra vessel in reserve to cover a particular contingency, the vessel with the lowest charter rate but enough capability to handle that contingency will be chosen.

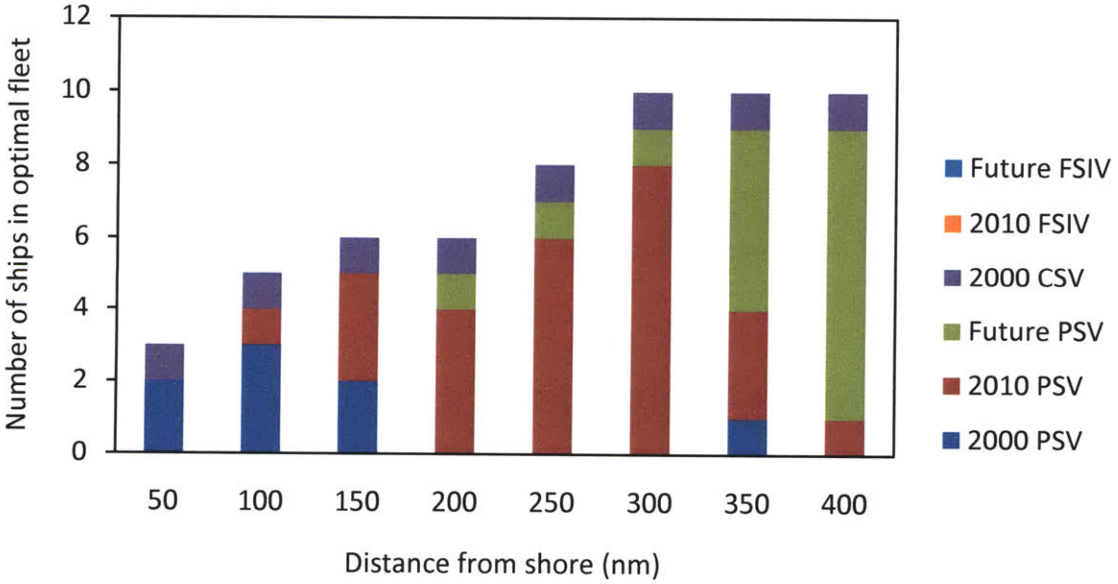

Figure 5-7: Fleet composition for varying distances from shore and corresponding cargo demands under a contingency plan that requires one vessel to be available at all times.

5.9 Fleet flexibility

Vessel flexibility is often considered from the OSV owner's perspective. OSV owners would like a vessel to be flexible so that it can perform in many roles, which increases charter opportunities and thereby keeps the vessel on contract a large percentage of the time. The owner must factor in the supply and demand of the different activities he wishes the OSV to perform. However, another way to consider vessel flexibility is in the context of an oilfield operator choosing a fleet to service the field. In this case, vessel flexibility is important because it allows a vessel to perform other activities when it would otherwise have nothing to do. Take for example an anchor handler. Most of the time, an anchor handler is performing activities that only an anchor handler can perform such as setting anchors and performing rig moves. However, it is unlikely that the field requires exactly 100% of the anchor handler's time. Most anchor handlers also incorporate supply capabilities and are used as supply vessels to make rig startup deliveries. If the spot hire rate is significantly higher than the time charter rate, an oilfield operator may choose to commit to a longer contract in order to secure the low rate and use the AHTS to perform supply runs when its anchor handling capabilities are not required. Since spot hire rates vary wildly and are not a consistent multiple of long-term charter rates, we take an example scenario and test the effect on cost of varying ratios of spot hire rates to long-term time charter rates.

Our base scenario is the deepwater supply scenario from Table 5.2. We introduce a requirement for 45 days of anchor handler service per month. This corresponds to 36 hours of anchor handler service per day. In order to fill the anchor handler service requirements, we introduce a common deepwater AHTS design, the UT 722 LX, to the fleet (see Table 5.6). Clearly, the fleet will require at least one AHTS full time, accounting for 24 of 36 hours of anchor handling per day. However, the remaining 12 hours of anchor handling per day could be performed by an additional AHTS on charter that also performs other duties while it is not anchor handling, or by an AHTS that is chartered in for half of the month.

First, we run the fleet optimization considering only AHTS vessels on time charter.

Table 5.6: Selected characteristics of the UT 722 LX, a representative deepwater AHTS design.

Name	Potable water capacity (m^3)	Fuel capacity (m^3)	Deck area (m^2)	Mud capacity (m^3)	Dry bulk capacity (m^3)	Fuel consump. at 10 kts (MT/day)	Charter rate ($/day)	Bollard Pull (MT)
UT 722 LX	1,220	561	500	500	283	13.0	50,000	237

The resulting fleet has five 2010 PSVs and two UT 722 LX AHTS vessels and a total cost of $274,635/day. Next, we run the fleet optimization with only 24 hours of anchor handling required. The resulting fleet has one 2000 PSV, five 2010 PSVs, and one UT 722 LX AHTS. In effect, the supply activities that the second AHTS did in its spare time has been replaced by hiring a 2000 PSV. In order to fill the remaining 12 hours per day of anchor handling required, an AHTS must be spot hired. Figure 5-8 shows the total fleet cost at varying ratios of spot hire rate to time charter rate for the AHTS. It is possible for the spot hire rate to be either higher than or lower than the time charter rate, depending on whether the market is expected to go up or go down. However, we consider the case in which the market is going down to be trivial for the oilfield operator, who would prefer to spot charter in for short-term needs if spot charters are cheaper than time charters.

Judging by the results from Figure 5-8, in this case the oilfield operator would rather hire the AHTS on long term charter so long as the spot hire rate was more than 1.75 times the time charter rate. This particular threshold will vary from case to case, especially depending on how often the spot hire is required. However, this method of analysis can be used to find the value an oilfield operator places on flexibility in its chartered vessels. Since the spot hire rate is often above 1.75 times the charter rate, vessel flexibility is often valued by the oilfield operator as well as the OSV owner.

We recognize that spot hire availability may be extremely limited in some geographic regions and under certain market conditions. For example, contracting vessels can be very cumbersome and difficult depending on the host government. Additionally, when the market goes up, more oilfield operators are seeking time charters, which

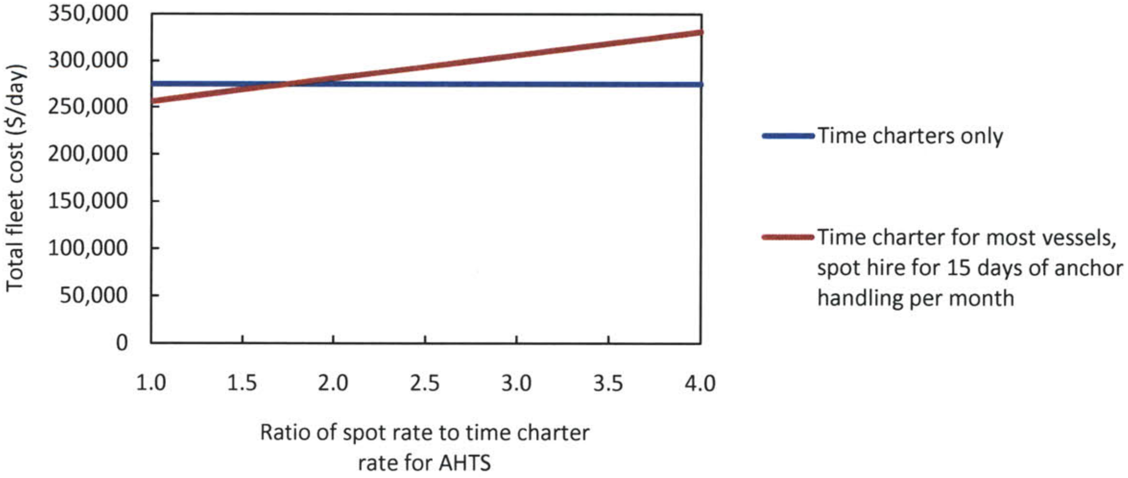

Figure 5-8: Total fleet cost for varying ratios of spot hire rate to time charter rate considering one case in which all vessels are on long term charter and another where part of the anchor handling work is spot hired.

causes oilfield operators to hoard vessels and makes spot hires expensive and difficult to find. As such, it is impossible to generate a generic threshold that applies to any situation. However, the relative difficulty to spot hire vessels pushes the threshold for taking on a time charter to the left, thus increasing the value of flexibility to oilfield operator.

Chapter 6

Conclusions

This chapter is intended to use the insights gained the previous chapters to discuss and test OSV design trends. First, we discuss two innovative vessel design concepts and test the advantages of these vessels in our model. Next, we discuss insights into specific vessel design trends based on extensive industry interviews and publications. Finally, we distill all of the information contained in this report into a short list of OSV design trends in Section 6.10: Concluding comments.

6.1 Innovative vessel concepts

Over the past several years, innovative vessel concepts have been built by major operators. We discuss the merits of these designs and under what conditions they provide advantages over existing vessels.

6.1.1 Large deadweight PSVs

In many deepwater scenarios, mud supply is currently a bottleneck. This is only expected to get worse with water depth, as shown in Figure 5-5. A mud change occurs at the request of the drillers when they need a change in mud composition or density. An industry rule of thumb for a typical deepwater mud change volume is around 6,000 barrels (950 m^3) [34]. As such vessels have been designed and built around this

Figure 6-1: The *HOS Centerline* MPSV [35].

standard. PSVs in the current fleet built before 2005 have an average deadweight of 1,000 tons, while PSVs built between 2005 and 2010 have an average deadweight of 2,500 tons. Pushing the boundary of this trend toward increasing deadweights have been vessels explicitly designed to service more than one drilling platform. These vessels incorporate mud capacities that are multiples of the standard 6,000 barrel mud change volume. For example, Chouest has built a class of 280 foot (85.3 m) PSVs that feature 15,644 barrels of liquid mud capacity, and Hornbeck Offshore Services has converted a set of sulphur carriers to MPSVs, the *HOS Centerline* and *HOS Strongline*, with mud capacities of just under 31,000 barrels and over 8,000 DWT (see Figure 6-1). These vessels with their extremely large mud capacities may become attractive for either supply scenarios that include multiple deepwater drilling rigs or rigs in extremely deepwater where the mud requirements to fill the riser are very high.

In order to evaluate the effectiveness of these high deadweight PSV designs, we introduce the *HOS Centerline* into our model with the same representative supply scenarios used in Chapter 5. While the *HOS Centerline* would typically be employed at very high dayrates for specialized offshore services that require large amounts of liquid storage and pumping [27], we use $50,000/day, which we consider to be the lowest possible charter rate we can imagine her doing supply work for. The results

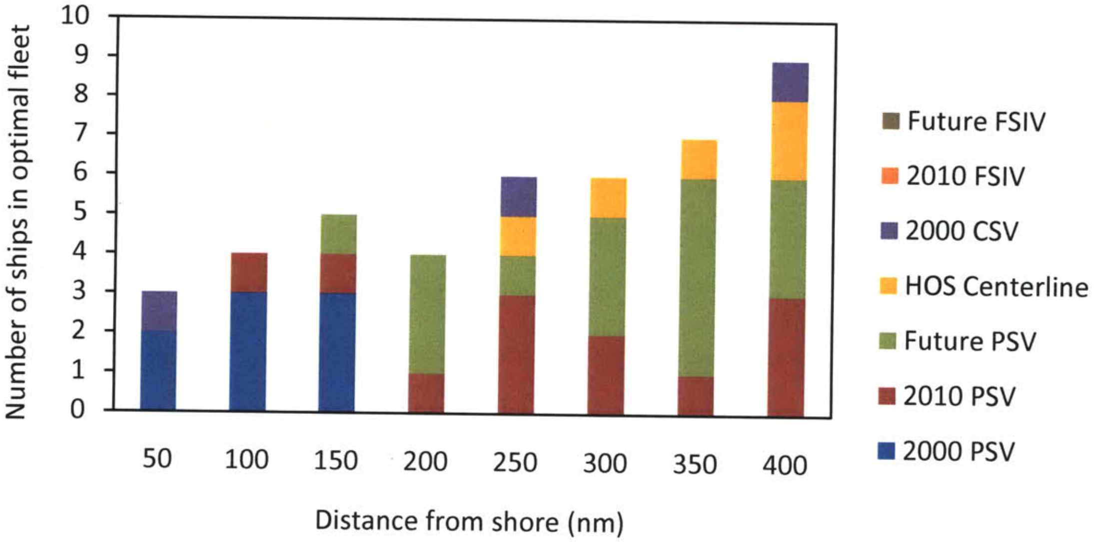

Figure 6-2: Selected fleets for a representative oilfield supply scenario including the *HOS Centerline* at a charter rate of $50,000/day.

are shown in Figure 6-2 and show that at a charter rate of $50,000/day the *HOS Centerline* is attractive in offshore support scenarios at least 250 nautical miles from shore, which correspond to daily mud delivery volumes of greater than 400 m^3 (2,500 barrels) according to Figure 5-5.

While the representative supply scenario explicitly correlates water depth with distance from shore, which is an oversimplification, the results indicate that depending on the charter rate, large deadweight PSVs such as the *HOS Centerline*, among others, are attractive designs for drilling scenarios requiring large quantities of mud. Indeed, according to Rene Leonard of Bollinger, Vice President of Engineering at Bollinger Shipyards, new vessels are on the drawing board for significantly increased mud capacity vessels [34]. These vessels are intended to serve up to three offshore drilling platforms in one run, and their capacities may exceed 18,000 barrels of liquid mud.

6.1.2 Faster and larger FSIVs

Launched in 2008, the *Seacor Cheetah* is a twin-hulled catamaran FSIV capable of speeds up to 40 knots [36]. At such speeds, the intent of the vessel is to compete with helicopters for crew transfer. Despite being significantly faster than any other OSVs, the *Seacor Cheetah* and her sister ship have not succeeded in displacing helicopter crew transport. According to industry interviews, most platform operators prefer to send crew out to platforms on helicopters, and will likely not change their mind in the near future. The main advantage of an extremely fast crew boat is reduced crew transport cost when compared to a helicopter, while the disadvantages include paying crew for an extended crewboat ride and long crewboat ride recovery periods for platform personnel. In addition, highly-trained technical crew are often required on short notice.

Even as a contingency vessel, a faster FSIV does not offer significant advantages over a traditional PSV, let alone a standard CSV. For example, when comparing a 12.5 knot PSV with a 25 knot CSV on a delivery to a platform 100 nautical miles from the shorebase, the CSV does the trip in four hours, while the PSV takes eight. Considering the time it takes to load, dock, undock, and unload, this is not a significant advantage. Even if an FSIV can do 40 knots like the *Seacor Cheetah*, the sailing time is reduced to 2.5 hours, a 5.5 hour improvement over the typical PSV. There are probably few situations in which a 5.5 hour improvement in delivery time can justify the extreme fuel costs associated with a 40 knot supply run as well as keeping an expensive crewboat on charter. If the vessel is not held on charter, the time associated with finding an FSIV would eliminate the advantage of the time saved by vessel speed. Even on the most expensive semi-submersible rigs, whose average dayrate is around 400,000 $/day, a 5.5 hour advantage on a show-stopping delivery is worth about $90,000 [6]. However, an FSIV cannot bring significant quantities of any cargo but deck equipment, and as such, it is unlikely that extremely fast FSIVs will be a significant part of the contingency planning of deepwater rigs. Consider also that a 40 knot FSIV has only a 1.5 hour advantage over a standard 25 knot CSV at 100 nautical miles from shore. This 1.5 hour advantage translates into a $25,000 advantage for a drilling rig with a dayrate of $400,000. As the contingencies a crewboat can handle probably do not occur more than once every couple weeks, it is unlikely that faster FSIVs will provide any significant advantage over traditional CSVs.

The only possible niche for fast crewboats is in the delivery of extremely low-cost personnel to highly-manned and tightly-clustered production and drilling platforms very far from shore [37][38]. These conditions presently only exist in very few deepwater fields, mainly off the coast of Brazil. Even these CSV opportunities are extremely limited by vessel motions, which are severe at high speeds and can be very uncomfortable for crew. As such, we expect only innovative hull shapes, such as Small Waterplane Area Twin Hull craft (SWATHs), that significantly reduce ship motions to offer feasible crew transport solutions.

6.2 Redundancy

In the recent past, major oil companies have focused increasingly on reliability and incident avoidance. In the wake of the BP Macondo spill, accident avoidance will be intensified. Even before the Macondo spill, most newbuild OSVs were expected to be DP II for almost all service types. In the future, almost all OSVs will be expected to not only be built, but also operated, according to DP II standards, and some oil companies are already requesting DP III vessels [38] or DP II vessels that are easily upgradeable to DP III [39]. The demand for redundancy is so great that even crewboats are being outfitted with DP II systems [40].

6.3 Automation

Aside from specialized large vessels, OSVs are typically built to minimum manning standards by staying below 6,000 GRT. As even standard PSVs are getting significantly more complex, outfitted with DP systems, advanced liquid cargo handling systems, and often Diesel Electric (DE) propulsion, while the number of crewmembers stays constant, automation is playing an increasingly important role in vessel design. In fact, a large portion of the price increase for a standard PSV from $3 - 4 million in the 1970s to $30 - 40 million today can be attributed to the increase in vessel automation [38]. Modern vessels often have integrated fuel-tracking, onboard maintenance-tracking systems, and DP systems.

6.4 Diesel electric propulsion

Diesel electric propulsion allows higher propulsive efficiencies during DP operations where varying amounts of power may be required due to changing wind and wave strength. In addition, D/E systems allow for significantly more design creativity with respect to tank placement and arrangements. This frees up hull space for cargo while placing crewmembers further from noisy components such as thrusters [31]. In particular, the GPA 654 PSV has taken advantage of a D/E system by increasing cargo capacity below deck by 30 percent and moving accommodations up by one deck [31].

6.5 Safety

All major operators are committed to safety as a priority company mission. OSV designs are adapting to reflect that commitment. The recent Rolls-Royce design in their UT-700 AHTS class exemplifies safety-minded design. The vessel features small cargo deck cranes that move on rails mounted on the port and starboard gunwales. These cranes eliminate a large portion of manual handling on deck of ropes, wires, chains, shackles, and deck cargo and are part of a larger system designed to minimize the amount of manual work on deck. The vessel also features a 360 degree bridge view, made possible by a wet exhaust system that eliminates the need for a smokestack [7]. As vessel safety and an alert crew go hand in hand, a number of improvements in crew comfort directly support the demands of oil companies in the area of safety.

6.6 Crew comfort

A side effect of increasing OSV complexity is the difficulty in hiring and training crew. Modern OSV operators must be significantly more specialized and technical than their counterparts 30 years ago, and the need for additional training is expected to continue to increase with advances in automation. In addition, the increasing demands on crew require levels of performance that are difficult to achieve in the relatively uncomfortable environment of the traditional OSV. In order to attract good crew and keep their level of performance and safety high, OSV operators are expecting vessel designs that are more comfortable and appealing to mariners. Newbuilds are increasingly conforming to class society comfort notations, and designers have made a number of conscious design decisions to increase habitability. Such improvements include increased engine room insulation, more spacious cabins, and moving accommodations higher to avoid bow thruster noise and vibrations. Comfort improvements not only attract quality crew, but also reduce crew exhaustion and thereby increase vessel safety.

6.7 Harsh environments

In general, deepwater operations require the ability to operate in harsher weather conditions than are usually present in shallow water. Extreme ship motions interfere heavily with cargo transfer from the OSV to the drilling platform [4], and make crew uncomfortable. Modern OSV designs such as the Rolls-Royce UT755 LN and the Guido Perla & Associates GPA 640 PSV [41] have roll-stabilizing features such as anti-roll tanks. Harsher weather conditions in deepwater also add a qualitative reason why OSVs will get bigger rather than faster to meet growing deepwater demands. Bigger vessels are more stable in rough seas, and moving fast through rough seas is uncomfortable, inefficient, and can be unsafe.

6.8 Environmental performance

Increased environmental performance on vessels has two main components: reducing emissions from fuel consumption, and reducing the probability of pollution by oil or chemical spill. In general, reducing emissions helps operating costs when it means reduced fuel consumption, but hurts operating costs when it means burning more expensive fuels. Operators and oil majors are already pushing for increased efficiency of both propulsion systems and hull forms, which will both aid environmental performance. Design choices enhancing fuel efficiency and environmental performance will be made inasmuch as they pay for themselves with reduced operating expenses or are required by regulations. Emission Control Areas (ECAs) are being set up in a number of areas that OSVs operate in. These will precipitate the burning of more expensive fuels, and thereby provide even greater incentives for increasing efficiency. As stringent emissions regulations are being put into place rapidly, we expect significant moves toward more efficient hullforms, more efficient propulsion systems, and changes in fuels. It is even possible that we will see a move toward LNG-fuelled ships, such as the Eidesvik VS 489 PSVs running on dual-fuel Wärtsilä engines and set to deliver first quarter 2011 [42].

On the pollution outflow front, a number of recent regulations have changed the design requirements for OSVs carrying certain amounts of fuel or Noxious Liquid Substances (NLS). For example, MARPOL regulations will force "protectively located fuel tanks for all ships with an aggregate oil fuel capacity of 600 m^3 and above" for ships delivered after August 2010 [31]. In addition, MARPOL regulations cover vessels carrying more than 800 cubic meters of NLS. Complying with these regulations effectively forces PSVs to become double-hull vessels, which significantly reduces their fuel, mud, and bulk capacities. According to industry interviews, this has the effect of up-sizing all boats by about 20 feet in length or 50 percent in deadweight. According to Guido Perla & Associates, a previously 3,000 DWT PSV must now be 4,500 DWT to carry the same amount of fuel and liquid mud [31]. Complying with these regulations will be essential in order to operate in the U.S. and the North Sea, and as such Clean Class notations will be an integral part of future OSV designs.

6.9 Flexibility

While Section 4 clearly shows the advantages of vessels specialized for a particular task, the uncertainties inherent in the offshore industry often make it difficult for OSV operators to purchase specialized vessels without long-term commitments from oil companies. Edison Chouest Offshore appears to follow this business model and is able to obtain long-term charters prior to building vessels, but most OSV operators do not have this luxury. As such, vessel designs will probably become even more flexible and multi-purpose. Particularly as vessels work further offshore in deeper waters, the cost of adding capabilities to a vessel decreases in comparison to the cost of getting a vessel out to the work site in terms of both time and fuel. We expect to see some creative designs that allow easy vessel reconfiguration for a particular contract that may require a shift in cargo capacity or additional installed gear. For example, a vessel might remove winches and anchor handling gear in order to free up deadweight for mud volume [38]. Already, vessels are using multi-purpose cargo tanks that have the ability to change cargo types. Perhaps in the future we will see vessels that have tank modules and can quickly adjust their cargo capacity breakdown between bulk and liquid cargo.

As exemplified for anchor handlers in Chapter 5.9, both OSV owners and oilfield operators can benefit from vessel flexibility. A similar conclusion is drawn by Geoff Dean of Offshore Ship Designers in his study *Optimizing Operations & Towing Capabilities of AHTS Vessels in Lieu of Changing Demand.* Dean found that although a dedicated, specialized, ocean-going tug would strongly outperform the AHTS vessels currently performing long-distance ocean towage of drill rigs, production platforms, and barges, AHTS vessels will continue to be used for this task. Even though the AHTS vessels have extraneous tanks for offshore supplies, large open decks, and sub-optimal propulsion systems for ocean-towing, they are much more likely to find work when there is no ocean-towing business available [43]. Most OSV owners agree that vessel flexibility, and the corresponding ability to obtain charter contracts during slow times, albeit at lower rates, is worth the added expense in the long term.

6.10 Concluding comments

In the OSV industry, the end users are the major oil companies and independent drilling companies. As such, they control the eventual path of OSV design. Since oil companies are primarily interested in cost, reliability, and safety, we can expect to see a number of performance improvements in these areas. On the cost side, it is likely that larger vessels will offer lower cost solutions for upcoming deepwater challenges. These vessels will be more technically advanced to handle deepwater challenges and safer and more comfortable to attract the best possible crew and keep that crew alert.

Summarizing the insights gained from the single vessel supply analysis, fleet selection model, and industry feedback, we make the following conclusions regarding the OSV industry and design trends.

1. Offshore exploration and production activity will continue to move into deeper water further offshore with expenditures of between \$25 and \$35 billion per year worldwide for the next five years.

2. OSVs will become significantly larger as a result of both increased cargo demand for deepwater operations and MARPOL regulations effectively requiring double-hulled OSVs.

3. Helicopters will continue to be relied upon for most crew transfer worldwide, with the possible exception of some Brazilian fields.

4. OSVs will need to become significantly more fuel efficient as a result of increased regulatory pressure on emissions and increased time spent sailing in order to reach deepwater fields.

5. While the supply of traditional OSVs may surpass demand, high-specification OSVs with advanced deepwater capabilities will continue to be in demand, commanding high dayrates. As such, increased design flexibility among deepwater OSVs will be advantageous to both oilfield operators and OSV owners.

6. Major oil companies will focus on safety and redundancy, especially in the wake of the BP Macondo spill, and OSV designs will mirror this focus with increased use of DP III systems and equipment that keeps crewmembers off the working deck.

In conclusion, we can expect to see traditional OSVs to begin to finally leave the fleet after 30 - 45 years of service, and smaller numbers of more advanced vessels taking their place as offshore drilling and production shifts to increasingly deeper water. While a portion of the OSV fleet is oversupplied, demand will continue to exist for deepwater-capable vessels, whose designs have been pioneered over the past decade to include significant automation, flexibility, and redundant dynamic positioning systems.

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