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INTRODUCTION TO NORWEGIAN OFFSHORE AND MARINE OPERATIONS

Bachelor's Thesis 2013

ABSTRACT

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Despite the fact that offshore business does not confine to maritime industry, it is a significant sector of the world merchant shipping. It entails the use of specialized vessels in various operations. In Finland, the offshore business has remained insignificant due to lack of natural oil and gas resources. The situation is altogether different in neighbouring Norway. Its maritime and offshore businesses are very important industries to the society and major employers.

Offshore operations often restrict regular merchant shipping near the operating area, and one objective of this thesis was to justify these constrictions and clarify the methods used in the operations. The material for the thesis was compiled from various literary sources, statistics, interviews, lecture notes and other available material. The thesis discusses the different aspects related to the subject while maintaining a seafarer's perspective on the issue.

The combination of harsh environmental conditions, high regard to safety and Nordic welfare status have contributed to the development of one of the most advanced sectors of the global merchant shipping. The international nature of maritime business enables professionals to work outside their immediate surroundings. The introduction of the nature of offshore business and related special operations are aimed to help seafarers to understand this complex concept and perceive future developments.

SUMMARY IN FINNISH

KYMENLAAKSON AMMATTIKORKEAKOULU
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Vaikkei pelkkään merenkulkuun rajoitukaan, on offshore toimialana merkittävä maailman kauppamerenkulun osa-alue. Siihen liittyy vahvasti erityyppisten erikoisalusten käyttö ja erilaiset aluksilta tehtävät operaatiot. Suomessa offshoreala on toistaiseksi jäänyt merenpohjan öljy- ja kaasuvarojen puuttuessa varsin vähäiseksi. Tilanne on toinen naapurimaassa Norjassa. Sen merenkulku- ja offshorealat ovat yhteiskunnallisesti erittäin merkittäviä teollisuudenaloja ja suuria työllistäjiä.

Offshore-operaatiot usein rajoittavat tavanomaista kauppamerenkulkua operointialueella ja eräs opinnäytteen tarkoituksista on perustella näiden rajoitusten tarve sekä selventää toimintatapoja. Opinnäytetyön materiaali on kerätty erilaisista kirjallisista lähteistä, tilastoista, haastatteluista sekä luentomateriaalista. Aihetta tarkastellaan eri suunnilta, kuitenkin merenkulkijan näkökulma säilyttäen.

Yhdistelmä vaikeita luonnonoloja, turvallisuuden arvostamista korkealle sekä pohjoismainen hyvinvointiyhteiskunta ovat edesauttaneet yhden globaalin kauppamerenkulun sektorin kehittymisessä. Merenkulun kansainvälinen luonne mahdollistaa ammattilaisten työskentelyn oman välittömän ympäristönsä ulkopuolella. Johdatuksella offshoreen sekä siihen liittyviin erikoisoperaatioihin on tarkoitus helpottaa merenkulkijoita monimutkaisen kokonaisuuden ymmärtämisessä sekä auttaa hahmottamaan kehitystä tulevaisuudessa.

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1 PURPOSE AND OBJECTIVE

All seafarers most likely have some understanding of what the word offshore refers to. However, the understanding may be rather constricted and vague. The purpose of this thesis is to help seafarers – those still studying and those already working – to understand the basic principles of the offshore sector and the different operations it involves. Although offshore business is global and exists in all sea areas of the world, the focus of how it works and how operations are carried out is limited here to the so-called Norwegian sector of the North Sea and rest of the Norwegian Continental Shelf (NCS). This is due to the geographical closeness to Finland, the vast spread of sector reaching the arctic waters, difficult environmental conditions and rapid development – especially in technology and safety culture – within that area. References to other geographical locations exist when necessary to elucidate further. Different restrictions imposed to regular merchant shipping by offshore operations are generally known, but justification may remain unknown for many seafarers. The urge to give reason for these constraints is evident.

The objective of this thesis is to identify different important parts of the offshore business to give a comprehensive view by examining it from different points of view. As this thesis was written from an operational maritime perspective, matters related inter alia to energy production or detailed financial perspectives are covered relatively briefly. Although offshore business is not a synonym for oil and gas extraction from the seabed, it is at the present probably the most notable part of offshore operations and thus investigated relatively extensively.

2 ABBREVIATIONS

ALP	Articulated loading platform
ABS	American Bureau of Shipping
CALM	Catenary anchor leg mooring
DGPS	Differential Global Positioning System
DNV	Det Norske Veritas
DP	Dynamic Positioning
DPO	DP Operator
FSO	Floating storage and offloading unit
FPS	Floating production systems

FPSO	Floating production, storage and offloading unit
FSU	Floating storage unit
GBS	Gravity based structure
GL	Germanischer Lloyd
GPFG	Government Pension Fund Global
GPFN	Government Pension Fund Norway
HPR	Hydroacoustic position reference
HS&E	Health and Safety Executive (UK)
HSE	Health, Safety and Environment
ICS	International Chamber of Shipping
IMCA	International Marine Contractors Association
IMO	International Maritime Organization
KBAL	Knutsen Ballast Water Treatment System
KVOC	Knutsen Volatile Organic Compounds Prevention System
LOLER	Lifting Operations and Lifting Equipment Regulations
LR	Lloyd's Register of Shipping
MODU	Code for the Construction and Equipment of Mobile Offshore Drilling Units
MOM	Marine Operation Manager
MPM	Marine Project Manager
MRU	Motion reference unit
MSC	Maritime Safety Committee (of the IMO)
MWS	Marine Warranty Surveyor
NCS	Norwegian Continental Shelf
NGL	Natural gas liquids
NI	Nautical Institute
NIS	Norwegian International Ship Register
NK	Nippon Kaiji Kyokai
NOR	Norwegian Ordinary Ship Register
NPD	Norwegian Petroleum Directorate
OCIMF	Oil Companies International Marine Forum
OECD	Organisation for Economic Co-operation and Development
OOW	Officer of the watch
OPEC	Organization of the Petroleum Exporting Countries
PRS	Position Reference System

ROV	Remotely Operated Vehicle
SALM	Single anchor leg mooring
SDFI	State’s Direct Financial Interest
semi-sub	Semi-submersible vessel
SIRE	Ship Inspection Report Programme
Sm^3 o.e.	Standard cubic metre of oil equivalent
SPM	Single point mooring
STL	Submerged turret loading
TLP	Tension leg platform
USD	United States dollar
UTM	Universal Transverse Mercator projection and co-ordinate system
VLCC	Very Large Crude Carrier
WOW	Waiting On Weather

Figure 1. Deepwater construction vessel Thialf at construction site. Photo: Heerema

3 BACKGROUND INFORMATION

3.1 Key information

To illustrate the size of the Norwegian offshore industry, the key figures on the merchant fleet and oil and gas industry are presented with the estimations on available oil and gas reserves.

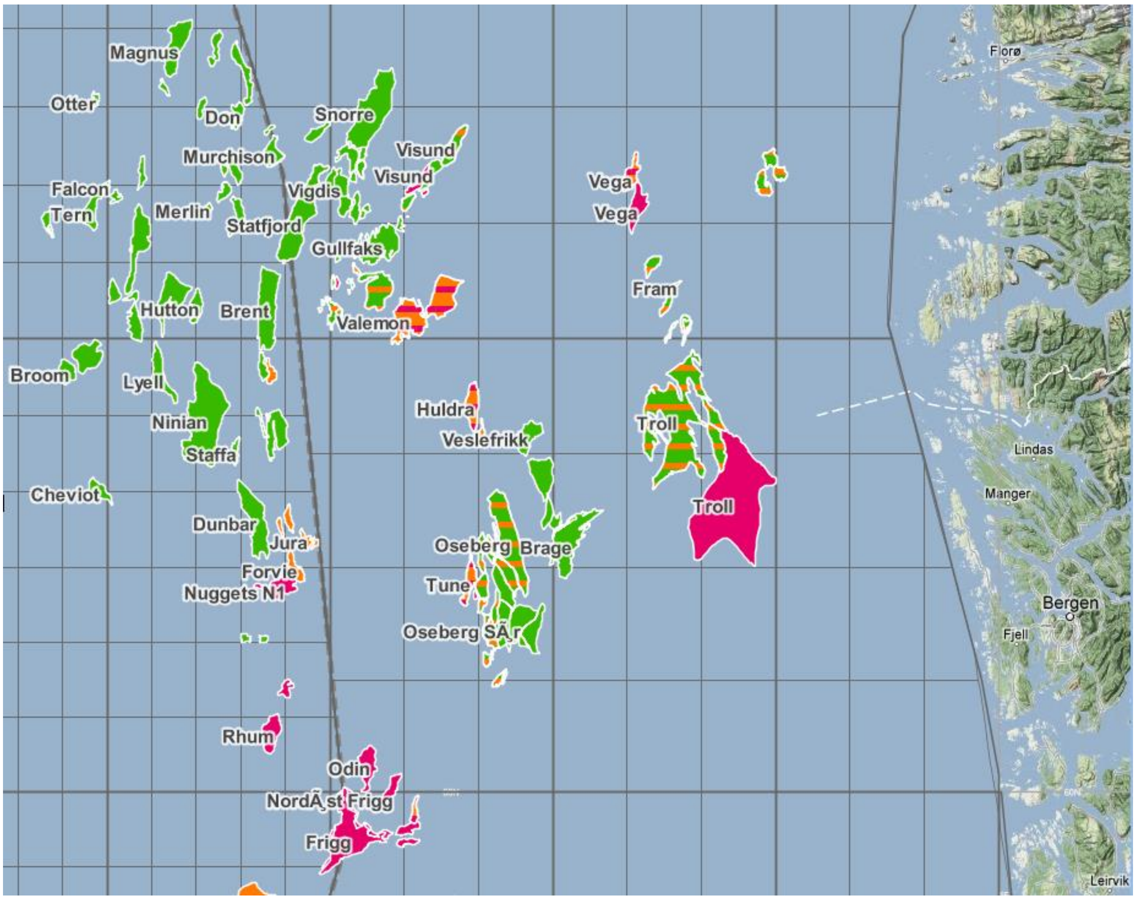
3.1.1 The Norwegian merchant fleet

There are two shipping registers in Norway, the Norwegian Ordinary Ship Register (NOR) and the Norwegian International Ship Register (NIS). The former is a regular national register and the latter is registry with some flag of convenience traits. NIS was established to prevent the flagging out of Norwegian vessels but it is also open to tonnage not owned by Norwegians. (Falkanger, Bull & Brautaset 2011, 49-71). According to Statistics Norway, in 2011 the Norwegian merchant fleet consisted of 1398 vessels of 100 gross tonnes or more, totalling 1,558,600 gross tonnes. They are divided so that the national registry had 891 vessels and NIS had 507 vessels of which 117 were foreign owned and 390 Norwegian owned. (Statistics Norway 2013).

3.1.2 Oil and gas extraction licensing

Norway licences the extraction rights out to companies. The NCS is divided to small geographically located blocks, almost rectangular in shape. The right to operate in these blocks is given with the extraction licence. Companies may have sole rights or participate in joint ventures. However, one of the companies is nominated as the responsible operator, and rivalry in the same block is made unfeasible. The fields usually are spread on the area of several blocks. The Ministry of Petroleum and Energy grants the licences based on objective, impartial and non-discriminatory basis. (Hansen & Rasen 2012, 30). State fiscal and financial involvement and role is explored more thoroughly in chapter 5.2.

Figure 2. Detail of fields and blocks of the NCS and the UK sector. Source: Norsk Oljemuseum



3.1.3 Oil and gas reserves

The Norwegian Petroleum Directorate (NPD) estimates that the discovered and undiscovered petroleum resources, including oil and gas, amount to 13.1 billion standard cubic metres of oil equivalents (Sm³ o.e.). Of these, 5.7 billion Sm³ o.e., i,e, 44 %, are now used. Unused known resources amount to 4.9 billion Sm³ o.e. and undiscovered resources are estimated to be 2.5 billion Sm³ o.e. (Hansen & Rasen 2012, 26, 137-140)

3.2 Oil and gas production and refining

Norway is not a member of the Organization of the Petroleum Exporting Countries (OPEC), an organization controlling to great extend the global petroleum policies. As an important production regulator, the OPEC decisions have great effect on world price levels. Despite not being a member of OPEC, Norway – as well as the other non-OPEC oil producing countries – has to take OPEC decisions into account and vice versa. (OPEC). According to the Norwegian Labour and Welfare Administration the largest industry in Norway is the combined petroleum, oil and gas industry. It accounts for approximately 22 % of national value creation. (NAV 2011).

3.2.1 Oil

Crude oil from the fields of the NCS is transported by pipelines or with shuttle tankers to Mongstad refinery. Shuttle tankers are crude oil tankers designed to load the crude oil from the fields and to carry the oil to a refinery. Bow loading system is fitted onboard these vessels as well as the Dynamic Positioning (DP) system allowing the vessel to load without actual mooring. (Bunes 2012). Shuttle tankers can naturally also be used to transport the crude oil elsewhere. Mongstad refinery is located in Lindås and Austerheim municipalities in Hordaland, north of Bergen, and 79 % of it is owned by Statoil and 21 % by Shell. Its annual refining capacity is approximately 12 million tonnes of crude oil. Most of the refined products are exported. The main products are petrol, diesel oil, jet fuel and other light petroleum products. Adjacent to the refinery is a Statoil operated terminal with three quays for vessels up to 400 000 tonnes. (Hansen & Rasen 2012, 131-132; Statoil e). A smaller refinery owned by Exxon, called Slagen Refinery is located in Tønsberg municipality in Vestfold at the shores of Oslo Fjord. The annual refining capacity is approximately 6 million tonnes of crude oil. The product variety of Slagen is similar to that of Mongstad, and most of the refined products are also exported. There are no pipelines from the NCS to Slagen, crude oil is brought with tankers. (ExxonMobil).

3.2.2 Gas

The gas produced in the NCS is mainly transported to shore via pipeline system owned by joint venture of gas production companies called Gassled and operated by state owned Gassco AS. There are some pipelines not included in the Gassled system. The gas from the fields is transported to shore terminals and facilities for processing. Two of the processing plants are on the Norwegian coast. These are Kollsnes gas treatment facility located in Øygarden municipality in Hordaland and Kårstø gas processing and condensate facility located in Tysvær municipality in Rogaland. Kollsnes gas treatment facility has the capacity to refine 143 million Sm³ of dry gas per day and 1.3 million tonnes of condensate per year. Kårstø gas processing and condensate facility has the capacity to refine 77 million Sm³ of dry gas per day and 6.3 million tonnes of natural gas liquids (NGL) and condensate per year. From both facilities, the dried gas is transported to receiving terminals in Germany, Belgium, France and UK. Kårstø plant is more complex and refines also variety of products which are transported to recipients with tankers, these include ethane, propane, normal butane, methyl propane and naphtha. (Hansen & Rasen 2012, 44, 127-132).

Figure 3. Kårstø. Photo: Øyvind Hagen/Statoil

3.3 Brief history of oil and gas production in Norway

Developments over the years are briefly studied here and historical cases closely related to the safety culture development are presented in chapter 8.2.

3.3.1 Search and discovery

By the end of 1950, there were little evidence or hope that oil, sulphur or coal could be found off the coast of Norway. This was even the official opinion of the Norwegian Geological Survey. The search for oil and gas in the North Sea area truly began after Paul Endacott, Vice Chairman of the Philips Petroleum Company suggested exploration efforts in 1962 and applied for permission to conduct surveys. The desire prompted from new oil discoveries made in the Netherlands. Other international oil companies soon followed. The state of Norway did not issue rights to findings to different companies in the NCS but passed legislation in 1963 claiming Norwegian sovereignty and ownership of all deposits in the NCS. The official boundaries of continental shelf areas of different North Sea states, Denmark and UK were settled with bilateral agreements in 1965. For Norway the agreement was very beneficial, as the chosen median line approach gave more area to Norway than conventional approach based on geological boundaries of the lithosphere. The border of sectors would have been closer to the Norwegian coast. Later, many of the richest deposits were found at the border of the Norwegian and UK sectors. Clear settlement of borders and rights has reduced constant disputes that trouble many other production areas of the world. The first rig, called the Ocean Traveler, was brought from New Orleans to Norway and began drilling for Esso in the summer of 1966. The first commercial discovery was made 1969 when the Ekofisk field was discovered. (Norsk Olje & Gas 2010). From early stages, the Norwegians demanded that local work force was to be utilized to great extent. This helped gaining skills on various matters related to oil drilling and producing. (Haavik 2012).

Figure 4. Platforms in the Ekofisk field. Photo: ConocoPhillips Company

3.3.2 Stavanger, the Oil Capital

Stavanger became “the Oil Capital” of Norway due to its closeness to newly found fields and strong support from local political leaders. The foreign oil companies set their local headquarters there. The state owned oil company called Statoil was started from scratch in 1972 and its headquarters was situated likewise in Stavanger. As Norwegians were keen to participate and develop national know-how in oil and gas industry, Statoil aimed to gain operator responsibility of a field quickly, achieving this goal in 1981. (Kvendseth 1988, 15-18; Statoil a). The government agency responsible for regulations concerning oil industry called the Norwegian Petroleum Directorate (NPD, Oljedirektoratet) was established 1972 also in Stavanger (NPD a).

3.3.3 Demand for new vessel types

The vessels brought mainly from the Gulf of Mexico at the beginning of the oil boom in Norway were ill-suited for the prevailing environmental conditions of the North Sea. As Norwegians possessed skills on designing and building vessels for these conditions and the oil companies had knowledge of what vessel activities were required, the outcome was to design and construct new ships to withstand the harsh conditions. This approach increased the overall efficiency by enhancing safety and reducing time spent waiting on weather (WOW), a problem still interfering operations in the North Sea. After the first vessel types suited for the conditions were delivered, the development seized not. It has continued in the region ever since, and new ideas are implemented in vessel and equipment design. The simultaneous development of the capabilities of different DP systems has had great impact on vessel design as this has meant higher accuracy in offshore operations and more potential for vessel based operations. Nowadays the focus is on still on safety but also on promoting efficiency while reducing environmental effect, actually a common challenge for the whole global maritime business. (Haavik 2012; Bunes 2012).

3.3.4 Production development

The first oil was produced in 1971 when the Ekofisk field came on stream, the gas deposits also present in Ekofisk field were harnessed 1977 when it was piped to Germany. (Norsk Olje & Gas 2010). In 1971, total of 400,000 Sm^3 o.e. of crude oil from the NCS was sold and delivered (Gassco 2012). State owned oil company Statoil and the

Norwegian Petroleum Directorate (NPD), the authority to regulate the industry, were both established in 1972. The oil crisis of 1973 hit Norway regardless of the oil deposits and Norwegian shipping industry plunged to a long depression. Statfjord field was discovered 1974 and still remains as one of the world's largest offshore oil discoveries. In 1980s the search efforts to find new oil deposits shifted further north and focus on effective use of gas deposits increased. (Norsk Olje & Gas 2010). By 1980, the production levels were 125,100,000 Sm^3 o.e. and reached the peak at 2003 with 261,800,000 Sm^3 o.e. These represent total production including oil, gas, condensate and natural gas liquids (NGL). (Hansen J. Ø., Rasen B. 2012). The percentage of how much of all the oil and gas in the reservoirs can be made use of is increasing as methods evolve. However, if no new fields are found and opened for business the production levels start to decrease in the near future. (Gassco 2012).

3.3.5 Ten oil commandments

The Norwegian parliament adopted ten basic principles guiding the oil, gas and offshore industry in 1972. These principles were called the ten oil commandments and have since been the guideline to management of the NCS. The rules promote national supervision and control over all operations. Norway must remain independent of crude oil and exploitable gas must not be flared according to these commandments. The sosio-political considerations were identified when the principles were discussed and are taken into account, as well as the protection of nature and the environment. One of the decisions has led to a large company dealing in the international market emerging, the principles include that a state owned oil company (Statoil) will look after the states' commercial interests. (Norsk Olje & Gas 2010).

Figure 5. Sleipner field. Photo: Harald Pettersen/Statoil

3.4 Regulatory bodies

The offshore industry has no exemptions from otherwise binding international conventions and codes or regional and national rules, all of which are in effect. Below are outlined important bodies issuing supplementary rules related to the offshore industry.

3.4.1 The International Maritime Organization (IMO)

In addition to the international rules binding the global seafaring set by the IMO, it also issues a variety of offshore specific guidelines. Noteworthy rules include the IMO guidelines for vessels with dynamic positioning systems by the Maritime Safety Committee (MSC) and the Code for the Construction and Equipment of Mobile Offshore Drilling Units (MODU). (MODU code; MSC 645).

3.4.2 National law, government and authorities in Norway

The Maritime law of Norway is fundamentally the same as the law in Denmark, Finland and Sweden, as the preparation was carried out in co-operation. The differences are minor and predominantly technical. (Falkanger & al. 2011). In Norway, the legislative body is the parliament (Stortinget), and the executive power is divided between numerous ministries and their agencies. The main agencies are the NPD under the Ministry of Petroleum and Energy and the Norwegian Maritime Authority under the Ministry of Trade and Industry and the Ministry of Environment. Other bodies with significance are the Ministry of Fisheries and Coastal Affairs responsible for oil spill preparedness, Ministry of Labour responsible for safety and working environment and the Ministry of Health and Care Services [sic] responsible for overall health issues. (Hansen & Rasen 2012, 15.). Conceptualisation of the somewhat tangled ensemble of operators is challenging. The rules set by these organizations are incorporated to great extend to the industry's own rules and guidelines e.g. IMCA rules. Contrary to common practice of having the headquarters of national agencies in the capital city, the Norwegians have HQs of offshore related agencies' set close to the heart of the business, the NPD in Stavanger and the Maritime Authority in Haugesund.

3.4.3 The International Marine Contractors Association

The International Marine Contractors Association (IMCA) is a trade association representing companies in offshore, marine and underwater engineering. It has over 800 membership companies in over 60 countries. It functions as a self-regulating body and promotes good balance of safety and efficiency (IMCA a). It issues a large variety of detailed guidelines and rules that are applied and referred to when conducting offshore and marine operations. (Bunes 2012).

3.4.4 Oil Companies International Marine Forum

The Oil Companies International Marine Forum (OCIMF) is an association representing the interest of oil companies in the shipment and terminal phases. OCIMF was established in 1970 as a response after public concern about marine pollution started growing in the late 1960s. (OCIMF a). It runs inter alia the Ship Inspection Report Programme (SIRE) used as a risk assessment tool for tankers and barges. It may be used by charterers, operators and government bodies when it comes to tankers and barges. The system has a large database and inspection regime based on vetting inspections carried out by the oil companies. (OCIMF b). OCIMF has interest in global tanker and terminal field and offshore operations are only a small segment and many of OCIMF's member companies are not involved in offshore operations at all. However, the comprehensive guidelines issued by OCIMF are used in taker and terminal operations, offshore or not, thus making these important to offshore business as well. OCIMF works closely with the International Chamber of Shipping (ICS) and they have compiled and issued many guides together. (OCIMF c).

3.4.5 Industry standards

Hardly any industry is without standards of its own or shared with other industries, and offshore industry is no exception. The Norwegian petroleum industry has its own standards also covering offshore sector called Norsk sokkels konkurranseposisjon (NORSOK). The standards shared with others include the International Organization for Standardisation (ISO). ISO standards include the ISO 19900 series with many offshore related standards. The Norwegian petroleum industry is attempting to shift focus from NORSOK to ISO to reach internationally accepted standards whenever possible. (Bunes 2012: ISO; Standard Norge)

3.4.6 Utilizing foreign rules

To promote safety and efficiency it is simply sound reasoning to use rules that apply best in practice. Rules set by classification societies, companies or industry standards are naturally without limit of national boundaries. Use of rules and guidelines set by another state is not so self-evident nor without some difficulty. For offshore related operations an UK authority called the Health and Safety Executive (here: HS&E) has issued comprehensive rules and guidelines that can well be implemented in the Norwegian conditions. One HS&E rule implemented often in Norway is the Lifting Operations and Lifting Equipment Regulations (LOLER). Due to the location of many significant oil and gas fields at the very border of the Norwegian and UK sectors of the North Sea, one particular operation may well take place on both sides. For these reasons, it would be quite unpractical to use two different and partially overlapping set of rules. The solution is to use one set of rules and ensure that it fulfils the requirements of the other possible rules. (Bunes 2012).

4 OFFSHORE STRUCTURES

4.1 Offshore surface structures

There are several types of rigs, platforms and permanent or temporary structures used in offshore technology. Nearly all of these are somehow involved in the oil and gas extraction although some are used nowadays for other purposes, e.g. wind farm construction and service. Nevertheless, virtually all have something to do with energy production. For regular seafarers, only the parts reaching above the surface are at least somewhat familiar. This chapter explains the different basic types to improve understanding of what lies below the surface and why these structures differ so much.

When in operation, all manned platforms and other offshore structures require constant supply of material and provisions. For this a vessel class called supply vessels are used. These vessels have a large open deck space and the freight is usually in containers to facilitate easy loading and unloading at site. (Bunes 2012; Seglem 2012).

Figure 6. Supply vessel Far Skimmer. Photo: Farstad Shipping ASA

4.1.1 Fixed steel structure

Fixed steel structure is a traditional rig with a welded steel, tubular framework or jacket supporting the topside facilities. The steel framework runs to the seabed. In very deep waters, a single jacket structure is favoured. To maximize the distance between gas or oil production sections and accommodation facilities a number of separate rigs linked with bridges are used in shallow waters. In deep waters where there is only one rig structure, the separation of production from accommodation is done by stretching the structure as much as possible and locating different sections appropriately. Moving this structure type is difficult if not impossible. (Mather 2000, 3-4).

Figure 7. Grane platform. Photo: Øyvind Hagen/Statoil

4.1.2 Concrete gravity base structure (GBS)

Concrete gravity base structure (GBS) is a structure pioneered in Norway to meet the challenges caused by environmental conditions and scant steel production capabilities during the early years' oil boom. Norwegians already possessed high skills on building concrete structures due long to history of building necessary dams for hydroelectric power plants and bridges in difficult terrain. This rig type has topside with its various facilities standing on large cone shaped concrete legs. At the bottom, hollow cylindrical shaped concrete tanks are attached to the legs. These spaces are used as storage space for the produced oil or for taking ballast. The structure can be moved by emptying these spaces and towed to location. Once in location the spaces are filled and the rig goes firmly down on the seabed. The topside structure modules usually must be taken off during transit, making shifting position arduous. The weight keeps the rig well in place, eliminating the need to install separate foundations, hence the name. As this rig has vast storage space for produced oil, it requires no pipelines built to transport the oil onshore, as shuttle tanker may be used to carry the crude oil. The Troll field is constructed this way, standing the depth of 350 m and weighs 1,270,000 tonnes, making it the largest concrete structure in the world. (Holand, Gundmestad & Jensen 2000, 3; Mather 2000, 5).

Figure 8. Troll A. Photo: Harald Pettersen/Statoil

4.1.3 Tension leg platform (TLP)

Tension leg platform (TLP) is a combination of characteristics of a fixed structure and a floating object. It is a floating platform connected with steel pipes or wire ropes to foundation templates in the seabed. Tensioning winches are used to keep the connection under high tension, thus preventing vertical movement caused by waves. TLP can be moved by simply towing, but the foundation templates and the connecting pipes or wire ropes require some effort to remove ad install. (Holand et al 2000, 3; Mather 2000, 5-6).

4.1.4 Semi-submersible vessel (semi-sub)

Semi-submersible vessel (semi-sub) is a large platform or barge supported on twin hulls, resembling an out of proportion catamaran. It has immense capability to take ballast water making it an almost completely immovable object to wave action. The design does not favour installation of effective propulsion plant making most semi-subs tug assistance dependent during transit. Some vessels are fitted with thrusters and DP system to manoeuvre or to hold position. If there are no thrusters, several anchors spread to different directions are used to hold position. If the DP system is used as sole means of keeping position, it should provide the same level of safety as anchors would provide (MODU code 1989). Semi-subs are used for several different offshore tasks. In heavy lifting operations, a semi-sub offers an excellent foundation for huge cranes. Semi-subs are used as drilling exploration vessels due to the fact that their location is easy to change and great depths can be reached. In the Gulf of Mexico, depth of 2,250 m was reached with this technique. Pipelaying vessels are often based on semi-sub design as it has very favourable characteristics, i.e. good stability, good manoeuvrability and large facility space. Older semi-subs are converted to accommodation vessels or flotels (floating hotel) to be used close to fixed structures. (Mather 2000, 6-8).

Figure 9. Semi-submersible crane vessel Hermod. Photo: Heerema

4.1.5 Floating production systems (FPS)

Floating production systems (FPS) are combinations of subsea structures and floating vessels. A preinstalled subsea wellhead has a hose connected to it. A vessel on the surface is connected to that hose and loaded. This technique is favoured when the field is small and it would be uneconomical to install permanent structure, or the field is isolated and pipeline connection would be costly or the depth is too great to install a conventional fixed platform. (Mather 2000, 8-14). For FPS, vessels either modified crude oil tankers and semi-subs or purpose built vessels are used. There is variance between different vessels and operation types. The units may be Floating, Production, Storage and Offloading units (FPSO), simpler Floating, Storage and Offloading units (FSO) or in the most simple form Floating Storage Unit (FSU). All have the same feature of being semi-permanently moored with a spread of anchors. Of these types, the FPSO has the strictest requirements for holding exact position due to production operated directly from the vessel. These units are all naturally considerably easier to transfer to other sites than structures directly fixed to the seabed. (Paik 2007, 3, 9-16).

4.1.6 Self-elevating jack-up

Self-elevating jack-up is an old and still widely used design. It consists of a triangular or rectangular shaped box section barge fitted with three or four moveable legs. The platform is towed for short distances and lifted on a submersible heavy lift vessel for long distances. In location, the legs are lowered to the seabed, and the hull of the structure is jacked into position well above the surface. The height of the topside can be altered using several electric motors on each leg. These platforms are primarily used for drilling operations, especially as separate gas production platforms. Another use for these is as an accommodation support platform. Depths up to approximately 120 m are reached with this technique, but plans are made to increase the depth capability. (Mather 2000, 14-15).

4.1.7 Single point mooring (SPM)

Single point mooring (SPM) was originally designed for loading and unloading of very large crude carriers (VLCC) that were too large to enter a port. For this purpose SPM are still used, but the technique has been harnessed for production service as well. The buoy is a turret type connected directly to seabed or it is a floating buoy connected to seabed with a spread of anchors. The prior is called submerged turret loading (STL) and the latter catenary anchor leg mooring (CALM). The oil from a subsea pipeline, either directly from a production facility or a subsea tank, is transferred through a swivel connector in the lowest part of the riser of the buoy to floating hoses or in CALM with a different valve connector to floating hoses. When operating with SPM the tanker connects to the floating hose and moors to the buoy with a constant thrust away (assisted by a tug) keeping distance constant or on DP mode keeps relative distance to the buoy constant without physically attaching to it. In DP the tanker is free to weathervain around the buoy with the influence of wind, tide and current situation. Tankers designed for this task are called shuttle tankers. When using physical connection and a tug the similar weathervaining function can be done manually. There are variations to the SPM called single anchor leg mooring (SALM) and articulated loading platform (ALP), the fundamental idea, however, remaining the same. (Mather 2000, 15-16).

4.1.8 Anchoring systems for surface structure

All the aforementioned structures are connected to the seabed when in operation. Some are directly installed with fixed steel or concrete structure or framework. Those structures that float, semi-subs and variations of FPS and SPM, require different means to hold the structure at desired location. This is achieved with anchor spread from the base structure to different directions. The number and type of the different anchor types used varies depending on the size and type of the structure and the seabed conditions. To facilitate a possibility to reach the structure with vessels, the anchor spread is not evenly distributed to all directions, as this would greatly interfere with safe approach. The spread is rather distributed to three or four directions with an equal angle between the directions. Each direction may consist of several anchors with their connecting chain or wire. For anchors, several different types are used, based on the soil of the seabed. The anchors must have greater holding power than the normal anchors used by commercial vessels. The anchors require to be installed by anchor handling capable vessels and are preinstalled well in advance before the structure itself arrives. The system may be catenary, where the anchor chain is not tensioned and lies partially on the seabed, or taut leg system, where the chain is tensioned and connects to the anchor at an angle. (Vryhof 2010)

Anchor handlers are vessels with relatively large open deck with powerful winches installed and a hoisting system in the aft. The deck is used to carry the anchors and chain and the winches and hoisting system is used to lower or recover the anchors. Some of these vessels are used also as tugs, enabling them to tow offshore barges or other floating offshore objects. It is possible to carry all sorts of material onboard the large open deck and thus anchor handlers may be used even as supply vessels. (BIMCO 2006; Bunes 2012).

4.1.9 Safety zones

Although the structures are called fixed, they are very vulnerable to interference from other forces than the elements. These structures cannot move away from danger and impact with vessels may be disastrous. For this reason, the safety area around these structures is great. The movements of vessels inside the safety zone is limited and controlled. Vessels permitted to enter the area advance in stages and are monitored closely. (Bray 2009; Bunes 2012; Leino 2013).

4.2 Subsea structures

All offshore surface structures have a subsea part, and these are discussed in chapter 4.1, subsea sections included. The construction of structures and installations described in this chapter are planned and executed as a Marine Operation, a concept explained hereinafter.

Survey vessels are used to determine seabed conditions when constructions and subsea installations or appropriate type of anchoring spread for a FPS are planned. Seismic survey vessels are used also to search oil and gas deposits. Large areas are covered with systematic search patterns. When a seismic survey is underway the interference from other vessels moving close may interfere with the quality of the collected data. (Bunes 2012).

4.2.1 Pipelines

In general, the offshore pipelines are built on the seabed mainly to carry hydrocarbons and not much else. The crude oil is transported from the production unit in the fields to an oil refinery with either shuttle tankers or pipelines. The gas extracted is also transported to gas refineries. In Norway, the crude oil pipelines from the fields are linked mainly to Mongstad refinery situated north of Bergen (Statoil b). The gas pipelines from the fields connect to Kollsnes gas treatment facility and Kårstø gas processing and condensate facility. The difference between unprocessed hydrocarbons is that liquid i.e. crude oil can be transported by vessels or pipelines, gas predominantly only by pipelines. From the oil refinery the products are after processing transported by vessels or land vehicles i.e. trains and tanker-lorries. (Gassco 2012). Gas processing, which is actually a relatively simple cooling process, results in products of two different forms, gas and liquid. The commercial products in liquid form consist mainly of light oil and gas condensate. In addition to cooling, the gas processing involves stages in which harmful and undesired compounds and elements are removed. The gas is transported to distant terminals with pipelines or gas tankers. The liquid form products can be transported with product tankers or land vehicles. (Hansen & Rasen 2012, 127-132; Gassco 2012).

The seabed in the NCS is gradually filling from operational or disused installations and equipment lost and unrecovered, e.g. anchors. The location in which the majority of the various apparatuses and equipment have been installed is known. For older installations, the accuracy is not always very high and the whereabouts of lost equipment may be completely unknown. To avoid further deterioration and damage to preexisting installations a thorough survey and seabed analysis is carried out on site prior to dredging and possible rock dumping begins. The survey also gives vital knowledge of the exact topographic profile along the way between the starting point and the finishing point. This is important as it provides the information on how much pumping power and how many pumping stations are required. After the seabed survey is complete and all obstacles removed, the dredging operations commence. The seabed is levelled and depending on chosen tactic a ditch is ploughed on the seabed, or support templates are put to seabed in case of an elevated pipeline. (Bunes 2012; DeepOcean 2012).

When all preliminary work is complete, the pipe is laid to seabed. It is usually assembled aboard the pipe laying vessel and lowered in a desired angle under tension. When two ends meet at sea, the pipelines are joined on the seabed using special module temporarily surrounding the ends. The module is watertight and all water is pumped out and replaced with air enabling welders to connect the ends. After completion the module is removed. New methods of mechanised underwater welding may develop fast to replace the need for divers here. DP vessels are used for all these different operation stages. The process is slow and precise and the vessels in operation require space to operate and when the pipe is lowered, the pipe laying vessel is particularly vulnerable and it cannot alter course or react otherwise. For this reason a rather large clearance is required from other vessels for safety. Vessels used in pipeline construction may be construction vessels fitted with the necessary equipment to connect the pipe sections and to lower the pipe to seabed. For pipelines with very large pipe diameter vessels specially designed for pipelaying activities are used. (Bunes 2012; DeepOcean 2012).

4.2.2 Offshore cabling

The first major application of underwater engineering and construction beyond immediate coast was the implementation of communication cables laid to seabed across the oceans. This revolutionized the speed of communication between the continents. The carriage of news was no longer wholly dependent on slow ships carrying mail. The change from the early cables that were simply lowered on top of the seafloor to buried cables has brought greater reliability. Despite the modern satellite based communication systems subsea cables still remain important, new technology e.g. optical fibre is utilized. Subsea cabling has provided means of communication for a long time, a more recent use for subsea cabling is to install electrical power cables to seabed. This enables the connection of large and scattered areas to same main power grid. The cables are laid using vessels designed for the purpose. Some are capable of deploying a device to seabed that cuts the trench and lowers the cable simultaneously. (Ramakrishnan 2008, 319-339).

4.2.3 Subsea storage tanks

The early days of North Sea oil production brought new innovations fast. The use of vast subsea storage tanks was introduced and pioneered on the Ekofisk tank of French-Canadian design. The Ekofisk tank, a large, wide concrete cylindrical tank, was constructed ashore near the city of Stavanger 1971-73 and towed to location to Ekofisk field to be submerged. The tank itself weighs 45,000 tonnes and was installed to the depth of 70 m. The concept has been used since then in the North Sea and elsewhere. Several production units may be linked to an individual tank. From the tank the contents are pumped to shuttle tanker often using some SPM variant explained in chapter 4.1.7. (Holand et al 2000, 2-3; Kvendseth 1988, 69-78)

4.2.4 Production without surface structures

A trend of dismissing use of structures reaching the surface is growing. As the production of oil and gas gradually move further north the conditions at the surface deteriorate. Snøhvit field in the Barents Sea is under development and production started 2007. Total of nine wells are to be operational 250-345 m below the sea level. All structures of the well and the pipeline connection to land is completely installed on the seabed (Statoil c). Another field called Ormen Lange, situated little more south is also without platforms. The depths at the area are 800-1100 m, substantially greater than in the Snøhvit field, entailing great engineering challenges (Statoil d). Fields with surface platforms are difficult to service and are vulnerable to the forces of nature. Installations that are completely subsea are not as vulnerable or require constant resupply and to have crews changed. Cold weather and constant storms are unpleasant, but the ice and icebergs are the cause of substantial danger when using surface platforms.

When an entirely subsea system is used, at the beginning a drilling vessel is required. After that no constant presence of man is necessary. Regular maintenance is carried out using construction vessels and remotely operated vehicles (ROV). These operations can be done mostly during the summer period when the weather causes relatively little problems. (Leino 2013).

4.3 Vessels used in most construction operations

Crane vessels are solely used to lift the heaviest loads at sea. Some have no cargo space whatsoever and others only relatively small deck space for cargo. For operations they rely on other vessels and barges. Design of the hull of different crane vessels varies greatly. Survey vessels are used to determine seabed conditions when constructions and subsea installations or appropriate type of anchoring spread for a FPS are planned. Seismic survey vessels are used also to search oil and gas deposits. Large areas are covered with systematic search patterns. When a seismic survey is underway, the interference from other vessels moving close may interfere with the quality of the collected data. (Bray 2009; Bunes 2012)

Figure 10. Construction vessel Far Saga. Photo: Farstad Shipping ASA

5 ECONOMICS

Understanding how different operators interlink to one another and what their motives are is important for everyone working in the business, including also seafarers. In this chapter, the economic interests of the public and the private sector are discussed, with emphasis on why certain fundamental decisions have been made and what boundaries the existing conditions set.

5.1 Private sector

All companies involved in maritime and offshore industry are similar to all other commercial industrial companies around the world: they are in business to make profit. For a business to succeed in the long run, it cannot simply rely on good business idea or large initial capital. Distinguished economist Michael Porter underlines in his book *Competitive Advantage* (1985) the necessity to have a clear business strategy. The strategy determines how the company in question operates and what goals it sets. He presents two strategies a company can choose to become a leader in its particular field of business, the cost leadership strategy and differentiation strategy. (Porter 1985, 1-2, 11-17, 119-152).

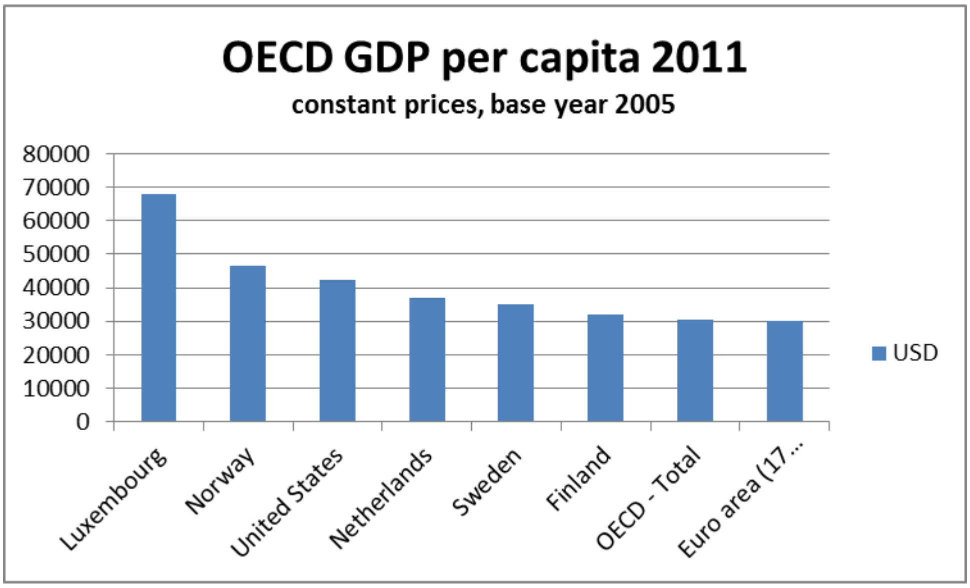
According to Porter, choosing the cost leadership strategy involves cutting costs to a minimum on all or selected parts of the company value chain. This means concentrating on large production volumes, limited product variety, using well known and cheap manufacturing technologies, operating in cheap labour countries. Basically, a company tries to do business with lower costs – and larger profit marginal – than its rivals. A company’s strategy is successful if it succeeds in offering goods or services to clients with lower price than the competitors while still having a sufficient margin of profit. To be able to choose this strategy, the market for goods or services produced must be relatively large and steady, market needs do not change rapidly. In maritime business, some shipyards fall into this category as well as the majority of shipping companies around the world. (Porter 1985, 11-17, 62-64).

If a company aims to succeed using differentiation strategy, it rejects the concept of attempting to be the cheapest although naturally trying to keep the expenses reasonable. Here the strategy is set to be able to offer highly specialized goods or services that can outmatch those offered by competitors. It can even be some completely new form of product or service not offered by any other company. The aim is to be unique and remain so, the approach should not be easily copied by competitors. (Porter 1985, 11-17, 119-130).

There is, according to Porter, also a third generic strategy besides cost leadership and differentiation, called focus strategy. It targets only segment(s) of industry and tries to have cost or differentiation advantage in that segment, it has characteristics from the two other strategy types. Companies with focus strategy could possibly be identified in the Norwegian offshore business, but speculating this is somewhat unrewarding and unnecessary for comprehension of the chosen approach of offshore companies. (Porter 1985, 15-16).

According to latest available annual OECD data from 2011, Norway has the second largest gross domestic product (GDP) per capita within OECD region, superseded only by Luxembourg. Norway's GDP per capita 2011 was in constant prices (reference year 2005) 46734 USD and in current prices 61047 USD. The diagram below presents how it relates to some competing countries. (OECD).

Figure 11. OECD GDP per capita 2011. Source: OECD



Being a land of such a high GDP per capita while maintaining a welfare state similar to other Nordic Countries, it is impossible for Norway to compete with cheap labour or production costs. This together with the fact that offshore industry in North Sea region is innovation driven makes it natural for companies to choose the differentiation strategy.

5.2 Public sector

The public sector here is the state of Norway. The municipalities and regions, however, receive also tax income and may have investments in the offshore industry. The state is the most versatile operator in the offshore business as it legislates, governs, owns directly and invests on market basis to private companies.

5.2.1 Tax and licencing income

The state of Norway has collected the surplus of income from taxes and licence fees from companies operating in the area controlled by Norway to a special fund called Government Pension Fund Global (GPFG). The name changed at the beginning of 2006 as part of a larger public pension fund rearrangement. The previous name of GPFG was Petroleum Fund of Norway, and still it is often referred to as The Oil Fund (or Oljefondet). It is used as a fiscal policy tool to help control the country’s long term strategies. Putting money aside to a fund reduces the inflation rate and decreases the inefficiency of administration and short term thinking in budget policy. Over the years, the fund has gathered vast sums of money and invested it to bring even more profits at a moderate risk. (GPFG 2013).

The GPFG differs significantly from regular pension funds as it has no defined liabilities in the future, i.e. its capital is not earmarked for pensions specifically. For that purpose there is another state fund called Government Pension Fund Norway (GPFN) functioning more like a regular pension fund. The objective is to use GPFG capital for the benefit of present and future generations, even after income from oil has eventually ceased. As a state fund, the short term policy of maximizing profit by questionable ethics fits poorly to operating methods. Ethical guidelines for investment were set 19 November 2013, and companies involved with unethical production are excluded, such as producers of tobacco or cluster munitions as well as companies producing in occupied territories or with record of environmental damage or abuse of human rights. (GPFG 2013; GPFN 2013).

At the end of the third quarter 2012, GPFG investments were distributed to 60.3 % in equities, 39.4 % in fixed income and 0.3 % in real estate, with the total value of 3723 billion NOK (approx. 654 billion USD) at the end of the third quarter 2012. During that quarter, the return was 162 billion NOK. (NBIM 2013).

5.2.2 State ownership and investment

Statoil merged in 2007 with Norsk Hydro's oil and gas division. The new company was called StatoilHydro for a short time, now the name is again Statoil ASA. The company operates in the market with private companies, but is under great interest of the Norwegian public sector as it still remains under state control despite other minor shareholders. (Statoil a). As an owner, the state of Norway can influence the industry standards and methods by exercising persevering ownership policy with clear focus. Other international companies forced to compete with a regionally important state owned company have to adjust their business methods to match Statoil methods. (Leino 2013).

Widening the public investment to petroleum sector companies other than Statoil began in 1985 with the establishment of the State's direct financial interest (SDFI) arrangement. Statoil's share of licences it held in the NCS were split, one half to Statoil and the other half to SDFI. The state invests directly to various other oil companies and receives its share of the revenues from the sale of production. In November 2012 the SDFI had direct financial interest in 146 production licences, some in very large fields and had interest in 13 different joint ventures for pipelines and onshore facilities. The SDFI is managed by state owned Petoro AS. (Petoro 2010; SDFI 2012).

6 CLUSTER

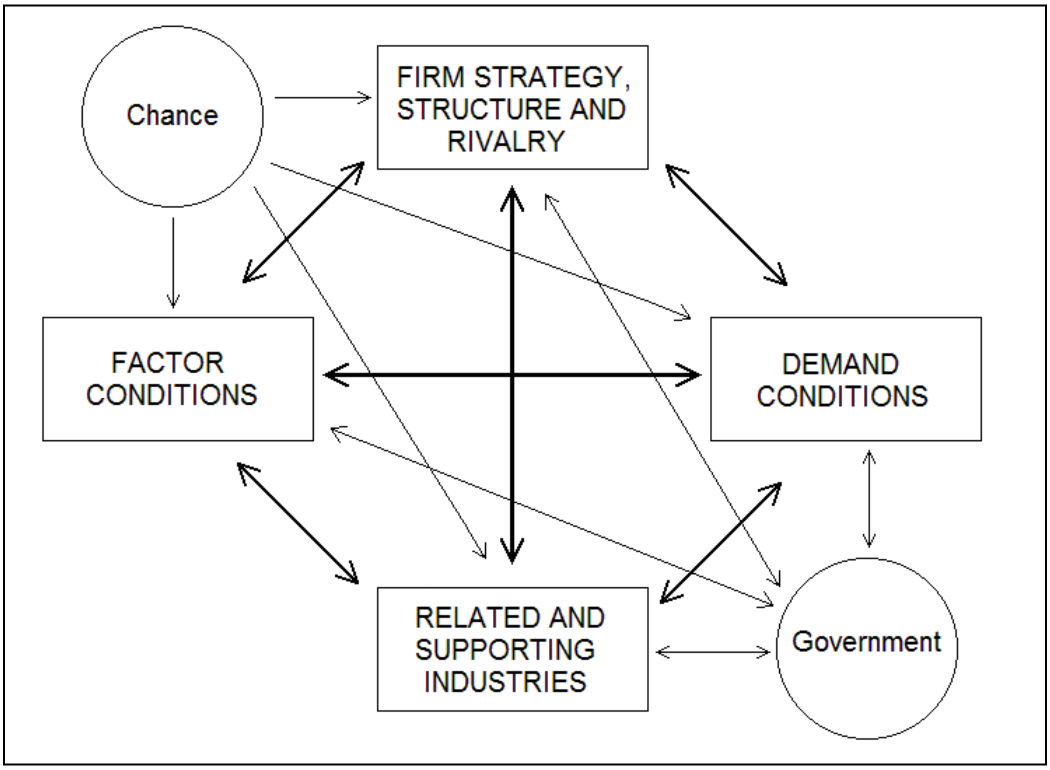
6.1 Instrument for conceptualization

Although clusters are often associated purely with economics, here they are separated as an independent chapter to make room for its wider explanatory nature. Cluster is a term first presented by Alfred Marshall in his book *Principles of Economics* in 1890 as "concentration of specialised industries in particular localities". The final breakthrough for the cluster theory was made by Michael Porter in 1990 with *The Competitive Advantage of Nations*. Two different cluster theories are presented briefly. The cluster is seen to be beneficial for all involved in it, business and public interests alike. The cluster theory can also be used to understand how different aspects are affecting one another and to identify what can be done to assist a cluster to develop to full potential. (Kuah 2002, 206-208, 210). In Norway the existence of a maritime cluster and a petroleum and gas cluster can be identified without difficulty. For offshore business it may be possible to identify a petro-maritime cluster as well (Haavik 2012). This cluster type has not yet made a breakthrough, but deserves to be noted. The maritime cluster and petroleum clusters are nonetheless well established and very interlinked in offshore business.

6.2 The diamond model

According to Porter the strongest competitive advantages emerge from geographically localised clusters. To discuss and study the determinants of national advantage Porter has presented as a tool, a model referred to as the diamond model. It consists of four key conditions: factor conditions, demand conditions, related and supporting industries, and firm strategy, structure and rivalry. When these determinants are studied the achievement of international success, or lack of it, of a nation can be understood. The system consisting of the separate determinants create the context in which the companies operating in a country compete. Companies of a nation gain competitive advantage from accumulation of specialized assets, common industrial knowledge and increasing commitment in a working system. Porter argues that there are two other variables besides the four conditions, i.e. chance and government. (Porter 1990, 69-130)

Figure 12. The diamond model. Source: Porter 1990.



Factor conditions investigate what is the nation's position in different factors of production. The different factors range extensively, for example the presence of skilled labour force, knowledge resources, natural resources, capital, state of the infrastructure or international rivalry are all regarded as factor conditions. (Porter 1990, 73-85). Norway is a Nordic Country with stable society, highly educated work force and developed infrastructure. The key for the presence of offshore and business is the natural resources present in the NCS. Difficult terrain throughout the land has caused settlements to thrive in coastal areas and favoured sea as means of transport and provider of nutrition. The terrain and geographical location are historical reasons for seafaring expertise, and the demand for fossil fuels and the possession of them has given Norway very favourable factor conditions. The know-how has been gained rapidly and the situation has changed so that the expertise is no longer imported but rather exported.

Demand conditions study the influence of domestic demand for the service or product the industry is providing. Three significant attributes can be identified: the nature of buyer needs, the size and growth of home demand, and the mechanisms by which domestic preferences are transmitted to foreign markets. (Porter 1990, 86-100). As offshore currently operates mainly on oil and gas production, the domestic demand in Norway is very low compared to production levels. The size and growth is challenging, as it is wholly dependent on the new findings. The demand for produced and refined oil and gas products in the foreign market is, however, very high. The foreign market preferences are equal to the domestic ones. Maritime perspective of offshore business is bright, as oil companies as buyers require new vessels and equipment to meet the growing challenges in production. There are various services these buyers require continuously need e.g. supply, construction, subsea work. The specialist vessels operate not only within the boundaries of the NCS, but on rest greater North Sea area, some highly specialized vessels operate globally. The domestic demand therefore can be transmitted easily to meet the foreign market demands.

Related and support industries are suppliers and similar industries to the examined industry. The level of availability of domestic suppliers and their level of international competitiveness are important. The presence or absence of highly competitive suppliers or a related industry providing common knowledge affects the conditions where the examined industry operates. (Porter 1990, 100-107). The oil and gas industry has partially relative industries in energy production and construction. The hydroelectric power plants require specialized skills also used in offshore construction. The maritime business in Norway is definitely a related industry to offshore industry and it has good competitive status. The maritime business can be also regarded as a supporting industry. The shipyards with their supply chain in Norway can definitely be regarded as support industry. These shipyards are specialized and effective, building and repairing vessels and platforms. The steelwork of newbuildings may be completed elsewhere and brought to Norway to be finished, this is to keep the costs reasonable.

Firm strategy, structure and rivalry peruses the conditions in which the companies are created, organized and managed, as well as the nature of domestic rivalry. The goals and strategies chosen by companies differ greatly between different nations. The national advantage is to a great extend result of the choices of approach on competitive advantage within the industry and individual companies. The pattern of how rivalry within the domestic market performed determines the process of innovation, thus affecting the prospects concerning international success (Porter 1990, 107-124). The choice of strategy to gain competitive advantage for the Norwegian companies operating in offshore business is differentiation (see chapter 5.1). Rivalry between companies exists, and due to dynamic development the competition is on safety, precision and reliability of how operations are conducted. For international market the demand for an approach similar to Norway is gradually growing as new areas in difficult conditions coming for development, e.g. extreme depths and arctic waters.

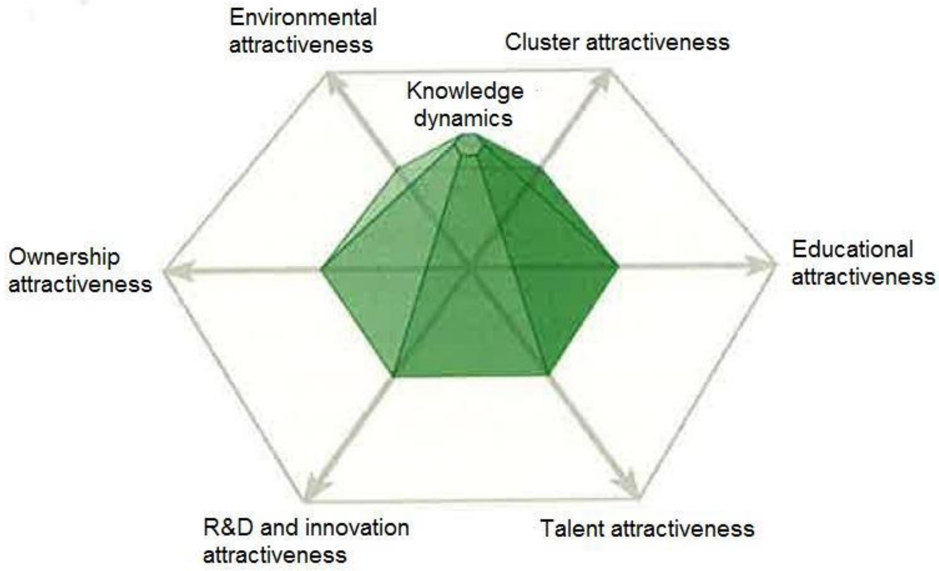
Chance has a role despite how well all other aspects succeed, and it may have a crucial role in how industry prospects develop. Chance can affect almost any variable, but among some significant examples have been identified. Acts of pure invention, discontinuities in technology, significant shifts in financial markets, foreign political decisions and wars can all be regarded as chance, as the industries in question are virtually unable to predict these. It is nevertheless important to appreciate that chance may interfere or promote the industry. (Porter 1990, 124-126). Attempt to state present day and future examples of chance in the Norwegian offshore would be absurd. Historical perspective, however, reveals some examples, inter alia chance had a role in the initial oil discovery.

Government can have a positive or a negative role in how well its industries can develop their respective advantages. The investments on education fitting for industry needs, enactment of antitrust policy, subsidies, adjusting taxation, and financial investment on companies are all examples of how a government can shape the circumstances of the industry in question or the related and support industries. (Porter 1990, 126-128). The government in Norway has invested consistently in education suited to oil and gas industry and offshore and maritime industry needs without neglecting other educational paths. The oil and gas companies have to compete for licences and maritime segment of offshore industry has numerous companies competing, thus the evolution of a harmful cartel is unlikely. The state owns some companies partly or completely and is also able to affect the market in the capacity of owner.

6.3 The emerald model

In their recent book *Et kunnskapsbasert Norge* (A Knowledge Based Norway), Torger Reve and Amir Sasson present a cluster model called the Emerald Model. As this model is developed in and based on Norway, it ought to be well suited to illustrate the cluster and its benefits there. The Emerald Model is a model drawn to picture form. It has six sides in hexagon form and an extra dimension at the heart. The six sides or corners represent different forms of business attractiveness required to form a true cluster. These are environmental, ownership, R&D (research & development) and innovation, talent, educational and cluster attractiveness. The extra dimension is situated in the centre and is called knowledge dynamic. (Reve & Sasson 2012). The corners and applicability and suitability for offshore business in Norway are described below in steps.

Figure 13. The emerald model. Source: Reve & Sasson 2012



Environmental attractiveness measures how well the industry can meet future environmental challenges and requirements, i.e. its capability to renew, adapt and become a pioneer. (Reve & Sasson 2012). Due to the technical challenges in the NCS and natural favouring the differentiation strategy presented prior, the maritime and offshore industries are well prepared to meet the environmental challenges.

Ownership attractiveness peruses the ownership policy and overall management from the aspect of how well the economic possibilities of the common knowledge in the industry are recognized and utilized. As in choosing the competitive strategy the amount of capital is not the crucial factor, the potential possibilities of common industry knowledge has to be made good use of. (Reve & Sasson 2012). Commitment and differentiation strategy work favourably here. The size of the companies in offshore related business in Norway varies from large corporations (the oil companies, state companies) to medium sized (shipping companies, docks, refineries) to small (subcontractors, suppliers, planning agencies). They all have different immediate and long term needs but can all take advantage of the common knowledge.

Research & development and innovation attractiveness studies the share of research done in an industry in relation to its size. Usually there is more research and development input in high-tech than in low-tech industries. (Reve & Sasson 2012). The extraction of oil and gas becomes all the time harder and new solutions in more challenging environment are continuously demanded. In energy sector wind farms are spreading to favourable sea areas and prototypes harnessing wave energy may become a normal way to produce electricity. The installation works, cable laying and maintenance of these are increasing and require research input from offshore industry as well. In general this attractiveness is well met in Norway. As for innovations, an example can be found later in chapter 11.

Talent attractiveness defines how good the particular industry is at attracting the best qualified workforce. How well the industry can compete of competent personnel determines greatly the future of that industry. A growing high-tech industry needs global competence and has to be desirable for prospective workers. This attractiveness section partly overlaps with the educational attractiveness, as the industry needs access to manpower from educational facilities together with international recruitment. (Reve & Sasson 2012). Norwegian salary level and stable society aid the companies in this talent harnessing, people abroad wish to come and Norwegians hesitate to leave if there is no better bargain available.

Educational attractiveness means how much and what kind of effort is put to primary and specialist education. The aim is not just to offer attractive study paths but also to bring talented students from outside the region. The requirements for educational attractiveness are filled if the educational system is able to sufficiently supply the industry with competent staff. (Reve & Sasson 2012). In Norway, the vocational institutes and universities are educating people for the maritime and the oil and gas sectors as well related sectors, such as environment or construction. The educational facilities are attempting to get interested students from abroad to study in Norway to achieve these objectives. (Haavik 2012).

Cluster attractiveness is determined on whether a critical mass of companies working is present and on the amount of variety and internationalisation. (Reve & Sasson 2012). The vast amount of different companies operating in offshore related business in Norway, many of which operate globally and some owned by international owners ensure that the critical mass is reached.

The knowledge dynamic at the heart of the emerald represents the knowledge linkage to related industries. It surveys how dynamic the cross-learning is and how much new industries and new markets emerge from this linkage. Offshore wind power is suggested to be an outcome of this phenomenon and one that has great potential in Norway. The government can influence the corners of the emerald presented above but has little influence on the knowledge dynamic. (Reve & Sasson 2012).

7 DYNAMIC POSITIONING

7.1 Definition

Dynamic positioning (DP) is defined in the IMO MSC circular 645 as: *"Dynamically positioned vessel (DP-vessel) means a unit or a vessel which automatically maintains its position (fixed location or predetermined track) exclusively by means of thruster force."* (MSC 645). Actually it is a system that also controls the heading along with the position (Bray 2009, 3). The same circular divides the DP system to three subsystems: power system, thruster system and DP-control system (MSC 645). There are many publications presenting the DP system, and this thesis only presents a few basic details about the system, applications, and new changes to the training scheme.

7.2 Description

In this chapter, the word thruster refers not only to tunnel and azimuth thrusters, but also all rudders and propulsion systems, main propulsion included, as the DP system takes advantage of them all. The DP system is used by virtually all offshore vessels and also some other types of vessels e.g. cruise vessels (to avoid anchoring), research vessels, military vessels and dredging vessels. Some of the offshore vessels, even those perceived as structures e.g. semi-subs, may lack main propulsion altogether, relying on tugs for transit from one place to another, but still have thrusters and DP system installed.

A vessel at sea has six grades of freedom. Three are controlled by DP system (surge, sway and yaw) and three can only be observed and cannot be controlled (heave, pitch and roll). DP makes it possible to keep very accurate geographical position, or to move and change heading with high precision. This can be done gradually or in a predetermined way. The core of the system is a computer that has the necessary software and mathematical model of the vessel installed and it uses data from different sensors and gives orders for thrusters and propellers. The mathematical model is simply a representation and description of the vessel, as accurate as possible, for the DP system to use when comparing sensor data and calculating thruster output. The DP system receives its sensor data from motion reference units (MRU) giving information on heave, pitch and roll. Wind sensors informs on wind situation. Vessel heading is derived from gyro compasses. (Bray 2009, 3-7, 17-18; IMCA a).

7.3 Projection and co-ordinate system

Instead of regular geodetic systems used in navigation inter alia WGS 84, the prevailing system in offshore business and DP operations is the Universal Transverse Mercator projection and co-ordinate system (UTM). It is a flat paper projection covering a local zone with 6° width of latitude, hence there are 60 zones in the world. The positions are not stated using latitude and longitude, they are given in Northings and Eastings [sic] stated in metres. The system has no negative values and gives very precise geographical location. (Bray 2009, 60-61) As the UTM co-ordinates are zone dependent, the zone is stated together with the co-ordinate values. This system is not suited well for normal navigation, but works great on tasks requiring high precision. Perceiving the UTM system may initially be a difficult task. For normal navigation even DP vessels use regular co-ordinate systems. When only a relative position is required, all co-ordinate systems are almost obsolete during operation.

7.4 Forces affecting the vessel

The forces affecting the vessel are divided in DP respect to two categories, wind and current. Wind is self-explanatory, current however here refers to not just sea current, but also to forces caused by waves and all other possible forces affecting the vessel. The wind can be measured with the wind sensors and the current is only calculated by the computer from the difference of how much thrust is required to hold wanted position to how much wind affects. (Bray 2009 17-18). The need to know how different environmental forces are acting is essential to be able to assess how much margin is left. Foreseeable problems are minimized with planning, and contingency plans are made beforehand for different incident scenarios. When operating near other vessels or fixed structures, the side where approaching takes place is considered thoroughly. If a drift-off occurs due to loss of power, the vessel is to drift away from others, not towards them. An escape route is determined in advance in case some other vessel has problems performing. (Bray 2009 47-50).

The DP computer is able to provide a consequence analysis on-line for worst-case single failure mode. The computer assesses the environmental forces and measures thrust required to hold position and then compares the thrust requirement to thrust power available if any major part within the system fails. When more power is used than would be available if failure occurs, the system triggers an alarm. The DP operator (DPO) may safely seize operations or continue after assessing the risks of possible drift-off. (Bray 2009, 28-29).

7.5 Development of DP systems

The first working DP systems were onboard vessels used for drilling in great depths in the 1960s. Development accelerated in the 1970s and by the 1980s DP was being used more and more on different offshore vessels. (Bray 2009, 1). The early systems were ununiformed and management of DP systems lacked consistency. (IMCA a).

The issuance of IMO rules and guidelines by various organizations, inter alia IMCA, the DP concept has reached a framework and can be developed effectively. Despite relatively long history and established status the DP system is improved constantly. To learn from mistakes and incidents related to the use of DP systems in vessels IMCA maintains a database of incidents. Companies sent their reports to IMCA, which collects individual reports and analyzes the incidents. This practice helps identifying common problems and potential hazards, which can then be addressed rapidly. (IMCA b).

7.6 Position referencing

The DP systems requires accurate data from position referencing systems (PRS) to determine exact location and execute proper thrust to stay in the wanted position or to move there. A large variety of different PRS are available and these systems can be absolute or relative. The DPO has to determine which PRS are used and how much weight is given to those chosen. There is not always available all different PRS and as all have individual advantages and disadvantages, the ones best suited are used. Just one PRS is never sufficient, at least two separate are required for all DP operations and for some three for redundancy (Bray 2009, 86). A diligent DPO and persons planning an operation must remember that the actual position cannot be more accurate as the data from PRS, but can be less accurate. (Bray 2009, 31-32, 57-86).

7.6.1 Above the surface methods

Satellite based PRS is a DGPS but it could also be based on the Russian Glonass or the delayed Galileo system of the European Union. A regular GPS location is not reliable enough, differentiation signal is a must. From these systems an absolute geographical location is determined. (Bray 2009, 61-69). PRS giving relative location are devices installed on the vessel and a counterpart, such as a platform or other surface object. These systems include optical laser based Fanbeam and CyScan (Bray 2009, 69-71) and microwave based Artemis, RADius, RadaScan. For some of these the counterpart is passive. (Bray 2009, 80-82).

7.6.2 Below the surface methods

Hydroacoustic position reference systems (HPR) are used for position fixing using transponders put to seabed and signal from them is received by the vessels transducer. If the transponders are installed permanently to exactly known locations, then they give also an absolute location instead of just a relative one. The possible ROV may have also a transponder installed so that the DPO is continuously aware of its position. (Bray 2009, 71-79). A purely mechanical PRS is called a Tautwire. It consists of a clump weight lowered to seabed with a tight kept cable. The position is calculated from the length and angle of the lowered cable. This system gives the vessel little area to move. (Bray 2009, 82-85).

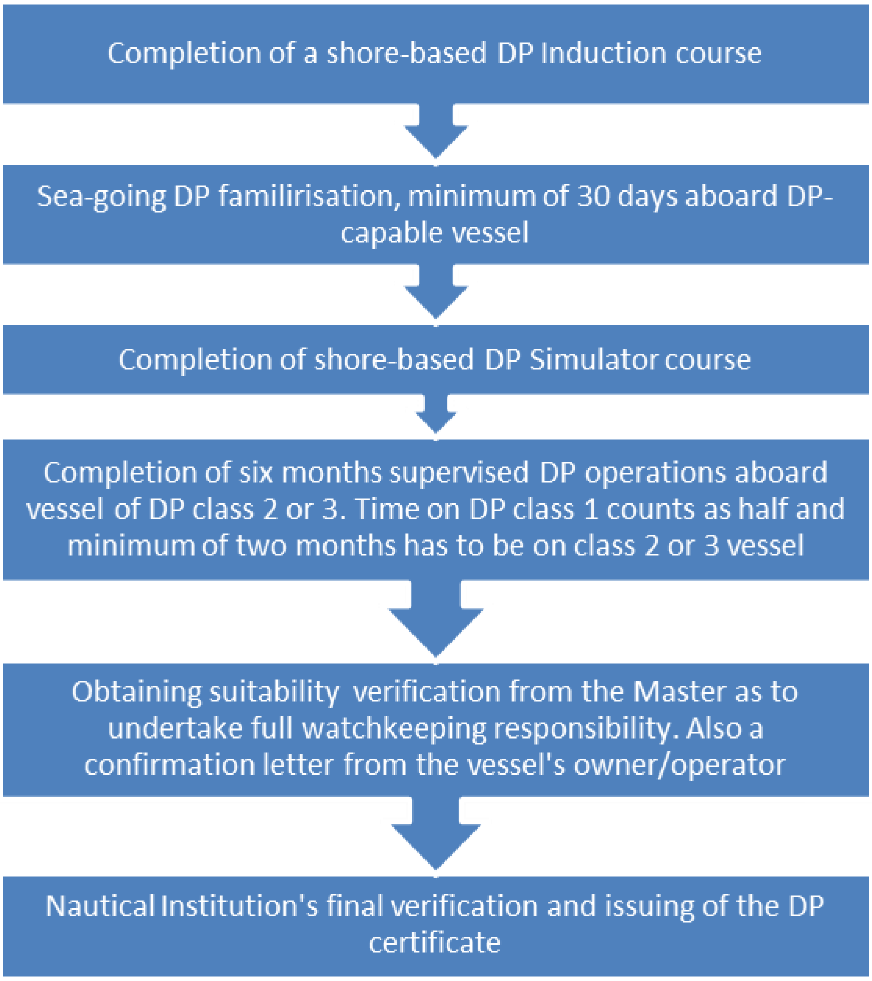
7.7 DP operators and training

The person operating the DP systems, the DPO, is required to go through a training scheme controlled by the Nautical Institute (NI), a non-governmental organization (NGO) located in the UK and holding a consultative status at the IMO. Its scheme is accepted worldwide and it approves all the training facilities and issues the DPO certificates. (Bray 2009, 98-103). The IMO Circ 738 “*Guidelines for Dynamic Positioning System (DP) Operator Training*” recommends using the guide of IMCA, “*M117, The Training and Experience of Key DP Personnell*”. All these interlinking rules of different bodies are incorporated to the training scheme (Bray 2009, 101-102; IMCA c)

Usually the DPO are the watchkeeping navigating officers or the Master of a DP vessel. This is natural as the bridge tends to have at least two officers working simultaneously, one operating the DP system and the other functioning as the officer of the watch (OOW). They change places during watch and for that reason both require appropriate STCW certificates and DPO certificates. It is, however, possible to have engineers who go through DP training scheme, but they must obtain also STCW competence for engineers. Whether a person aboard a DP vessel is a DPO or not, good knowledge of the DP system of that vessel is required as DP system is very integrated to all other systems of the vessel, and engineers, electricians, engine ratings have to know how and what parts are interacting. (Bray 2009, 98-99).

The training scheme is being updated, inter alia the former DP basic and DP advanced courses are changed to courses called DP induction and DP simulator, and the entry requirements are changed to meet the STCW Manila amendments. The main aspects of the six phases of DP Training Scheme to obtain an unrestricted DPO certificate are briefly presented in figure 9.

Figure 14. Six phases of DP Training Scheme. Source: Bray 2009



To start the training scheme, a person has to hold an appropriate STCW certificate or be in the process of training to obtain that certificate. Before starting the DP simulator course, a person has to hold the appropriate certificate. (Bray 2009, 98-103).

Future will bring changes to training. Of classification societies at least DNV is expected to introduce a scheme competing with the NI scheme. This is to take place at the beginning of 2014. Major changes will include less sea time required before issuing certificate and DP specialization on ship and operation type. (Johansen 2013).

7.8 DP classes

DP systems are divided to three different equipment classes depending on their capabilities and the level of redundancy. These IMO approved categories are used with their own notations by the classification societies. IMO class 1 has the lowest level of redundancy and class 3 has the highest. Many operations require some specific minimum class level from vessels participating. (Bray 2009, 21-22, 26).

The different notation a DP vessel receives varies depending on which classification society has approved the system. The contents and demands are similar. IMO classes with the equivalents of Det Norske Veritas, Lloyd's Register, American Bureau of Shipping, Germanischer Lloyd and Nippon Kaiji Kyokai are presented below. Other classification societies have their own notations. (Bray 2009, 25-28; IMCA c).

	IMO equipment class	1	2	3
Class notations	DNV	AUT	AUTR	AUTRO
	LR	DP (AM)	DP (AA)	DP (AAA)
	ABS	DPS-1	DPS-2	DPS-3
	GL	DP 1	DP 2	DP3
	NK	Class A DP	Class B DP	Class C DP

Table 1. DP Class notations. Source: Bray 2009, IMCA d.

8 SAFETY CULTURE AND TRAINING

This chapter is focused on safety culture and its development. Education and training is also presented here, with exception of DPO training which is discussed in chapter 7.7.

8.1 Development of the safety culture

One of the most interesting features of the Norwegian offshore industry lies in the development of the safety culture. Although based on well established businesses, the old petroleum industry and ancient maritime business the offshore sector in Norway has not accepted the culture and standards of those base industries, but has overtaken and developed its own level. The quintessential reason is financial instead of humane compassion. There are many factors leading to this: the delays, fines, compensations to be paid, and increasing insurance fees amount to sum too vast to be paid often. (Bunes 2012; Leino 2013). The equipment, different structures, and vessels are extremely expensive and harm to these together with offhire time burden the coffins of owners too much. The fear of an environmental catastrophe – or actually the negative effects to reputation, fines and compensations – uphold the will to avoid such accidents occurring. For whatever the motive for development in safety related matters, in the end they tend to work for benefit of the health and safety of workers, and the safety of property and the environment. (Bunes 2012).

8.2 Learning from mistakes

The companies having vessels in offshore business try to minimize the amount of accidents and incidents. No positive outcome is achieved with a culture of fear in regard to making mistakes. Mistakes happen and those are to be learned from, not to be hidden and covered up. Potential hazards are constantly tried to be eliminated by risk assessment and safe job analysis, but it is impossible to predict accurately all that can happen or go wrong. Whenever an accident has happened or almost occurred, corrective measures are taken to prevent same happening again. Non-compliance reports and systems are used to eliminate potential hazards, larger incidents or accidents that occurred are investigated by investigation group. The reporting systems are easy to use and cases are looked into. (Bunes 2012; Leino 2013). Two major accidents having vast repercussions are presented below.

8.2.1 Ekofisk Bravo platform blowout 1977

First uncontrolled blowout on the NCS occurred 22 April 1977 at the Ekofisk Bravo platform in the North Sea. The blowout lasted out of control for eight days. The well became under control and halt only after American professional well-killers were flown in to assist. The blowout was in the headlines all over the world and became the biggest media event in the Norwegian history. None of the personnel onboard the platform was killed and the damage to nature was eventually little, as lot of oil slick dissipated before reaching coast. Total of 9,000 - 9,500 tonnes of crude oil was later estimated to have been discharged to sea, the initial estimates were higher, approximately 20,000 tonnes. Despite minor environmental damage and no loss of life, the warning, however, was taken seriously. The special commission of inquiry criticised the operator’s control of the well and emergency response preparedness as well a number of other conditions not found satisfactory. The debate over possible environmental impact with oil and gas production heated up. One of the results was the postponement of exploration drilling north of the 62nd parallel. (Kvendseth 1988,133- 142; Norsk Olje & Gas 2010; Store norske leksikon).

8.2.2 Alexander L. Kielland disaster 1980

The most severe disaster in the Norwegian oil history occurred 27 March 1980 in the Ekofisk field neat Edda platform. Alexander L Kielland, a flotel with five support columns collapsed and overturned after one of the columns broke off. The reason for the column to brake was determined to be fatigue cracking in a steel brace. The rig had 212 people onboard at the time of the accident. The turnover was rapid and despite major salvage operation involving nine naval vessels, 71 civilian vessels, seven planes and 19 helicopters from Norway, Denmark, Germany and the UK only 89 people were saved. 123 people perished. New and stricter safety standards for the whole NCS area were issued, emergency response routines were improved, and more efficient rescue equipment was developed. The inquiry also suggested better co-ordination between different official regulators by reducing their number. This disaster had a great impact on Norway becoming forerunner in the safety issues related to offshore operations. (Norsk Olje & Gas 2010; NPD b; Safety – Status and Signals 2013).

8.3 Training and working

The Norwegian maritime studies are governed by the same IMO conventions as the rest of the world. The difference compared to many other countries is the vast size of the fleet owned by the Norwegians, a fact affecting positively to the future career possibilities of the students. As there is not enough Norwegian manpower for the fleet a lot of foreign seamen find work aboard Norwegian vessels. The suitability of competencies and certificates issued outside Norway differ, for most part those are accepted. As offshore vessels require officers with DPO competence the DP training is an advantage. Some consignors may impose strict demands on DP competence of the crew. Some special courses may be required and a lot depends on the flag state of the individual vessel, e.g. a course on Norwegian law may be required if sailing on NIS flagged vessel. (Haavik 2012, Leino 2013). The oil and gas industry has constant demand of workers for various tasks. Although the offshore sector represents only 35 %

of jobs within the whole oil and gas industry it still is relatively large sector. Currently the demand is high especially for engineers. (NAV 2011).

9 FROM DIVERS TO PREPLANNING AND ROV

9.1 Work carried out subsea

All constructions and installations put down below the surface have been constructed and assembled as complete as possible onshore. There is, however, virtually always need to do some actual stages of work subsea, and there is also usually need to monitor the proceedings. After original installation the subsea structures require periodical maintenance. The actual work may be welding or other type of mechanical joining of different parts, connection of cables, replacing parts or inspection work. Originally the subsea work could be done only by divers, but nowadays ROV are available.

Construction vessels are used to carry installation parts and large pieces of equipment and are equipped with one or two cranes capable of handling very heavy loads. These vessels can be fitted with pipelaying equipment and used as a pipelaying vessel. Many construction vessels have a ROV hangar bay or two to facilitate possible need to have ROV operations carried out subsea.

9.2 Divers

The problems related to the use of divers in subsea operations have been evident since the start of subsea oil and gas excavations. There are limits to how deep a human can dive and how long that person can operate continuously. These limits have been stretched greatly over the years, partly due to better equipment and improved gas mixtures, and partly because of the increased risk-taking due to growing demand. As the limits were pushed perhaps too fast beyond reasonable, the negative impact on divers' health became obvious. The use of divers is quite expensive due to diver and supporting crew salary expenses, special equipment and relatively low work efficiency ratio. (Bunes 2012; Leino 2013).

As the safety limits within which the divers can operate safely remain limited for indefinite future while the need for work done on subsea installations increases together with increasing depths, the development for methods that requires no human presence on-site became evident. (Bunes 2012). Two different approaches to this are taken and they are not in conflict. Firstly, all structures that are to be installed subsea are planned and constructed onshore in such a way that subsea work is minimized. Secondly, Remotely Operated Vehicles (ROV) have been developed to supplement and to replace human divers.

Diving support vessels are used for construction and other subsea work done with divers. These vessels can support the divers and subsea equipment. Often the larger diving support vessels are also construction vessels and are capable of holding large amounts of equipment and possible installation parts. Crane is used to lower supporting systems like diving bells. For deep water operations large diving vessels carry pressure chambers for divers to live for long periods of time. This enables the divers to remain in the high pressures of their working area even when resting. Vessels designed to carry divers often have a so-called moon pool inside to send and recover divers and diving systems straight from the vessels bottom without interference from wind and waves. (Bunes 2012; DeepOcean 2012).

9.3 Preplanning and minimizing subsea work

Good preplanning is essential for the reduction of the difficult, time consuming, expensive and potentially hazardous subsea work. Structures to be installed are planned at engineering companies specializing in offshore work. All structures are built as complete as possible onshore, and in case of very large structures in blocks that can be easily fitted with each other on-site. (Bunes 2012).

The amount of maintenance required during the lifespan of a structure depends greatly on how well it is designed to function, of how good the construction materials are and how much attention was given to the maintenance perspective during the initial designing process. Investment on planning increases the lifespan and reduces trouble with maintenance as in every field of business. In very costly subsea work, the planning efforts can save vast sums.

On the surface, the North Sea has been quite a busy sea area for centuries, but after oil and gas were discovered, solid objects, such as rigs and offshore loading terminals emerged, also the sea bottom has become congested with different installations, anchoring systems and pipelines. The available space is limited and already all new operations require precision not to harm what has been already installed there. Environmental awareness is growing all the time, and in addition to have all residues harmful to nature removed from the decommissioned structures, also the need to have these structures removed and properly scrapped has risen. New structures are designed whenever possible in such way that they are easier to be removed after decommissioning than those that were installed decades ago. (Bunes 2012).

9.4 ROV and its applications

ROV is basically a diving robot that has special abilities and characteristics depending on the design and can be operated remotely from the supporting vessel. (Bunes 2012). ROV is composed of at least a propulsion system consisting of thrusters enabling movement in all directions and a camera for transmitting live image to the operator and an umbilical cord connecting the ROV with the support vessel. This ROV type is simply a diving camera good for underwater inspection work or supervising some other operation. Usually ROV are equipped with several cameras, good floodlights and manipulators (“robots hands”). The ROV-operator uses different features to do the designated task, guides the ROV, chooses camera image, adjusts lighting conditions and does with the manipulators the same tasks a diver would do. (DeepOcean 2012). ROV support vessels carry ROV in special hangars and have the necessary systems to support the ROV and have space to accommodate the operating crew. Vessels can launch and recover ROV from the sides and some have a moon pool with similar idea to those constructed in diving support vessels. (Bunes 2012; DeepOcean 2012).

9.5 Benefits in use of ROV instead of divers

There are several obvious benefits for using ROV instead of divers. ROV is a completely mechanical instrument, thus it can be designed to withstand extreme pressures. Divers can function efficiently only a limited period of time before rest is needed, whereas ROV can work constantly. The operator safely on-board the support vessel only has to be relieved by another operator. In harsh current conditions, the diver has to use much energy to be able to stay still while the ROV can operate with same precision as long as the propulsion thrust is adequate. If the subsea work requires moving long distances, e.g. an inspection of a pipeline, it is also possible to manoeuvre the vessel together with the same speed and direction as the ROV fitted with an acoustic transponder. With divers this is virtually impossible.

An important factor is that the diver is a human being whose life and health is at stake, ROV is only a robot – albeit expensive – but it cannot be hurt and in case of accident or rapid change in the environmental conditions can be abandoned and recovered much later. Machines can be fixed when wrecked, humans cannot.

10 MARINE OPERATIONS

10.1 Definition

Marine Operations are not defined as such in any IMO convention or rule, but they are an established term describing some offshore related operations and defined by DNV in their document RP-H101 *Risk Management in Marine – and Subsea Operations* as follows:

“Non-routine operations of a limited defined duration carried out for overall handling of an object at sea (offshore, inshore and at shore). Marine Operations are normally related to handling of objects during temporary phases from or to the quay side or construction sites to its final destination or installation site. Marine operations include activities such as load transfer operations, transport, installation, sub sea operations, decommissioning and deconstruction, rig moves and pipe laying".

The definition above is quite comprehensive and excludes routine operations such as supplying rigs, personnel transportation or loading of crude oil from offshore source. Hence, not all offshore operations are Marine Operations, but all Marine Operations are offshore operations. All Marine Operations are planned and executed under the standards and rules set by the authorities and the classification societies.

Every Marine Operation can be seen as an individual project. Whether to have a rig moved or to have an object installed subsea, it nevertheless requires individual planning especially made for that particular operation. As Marine Operations are non-routine by nature, possible experience from previous similar operations is utilized, but the plans cannot be copied from other projects as there are always variables changing. Marine Operations differ from many other types of work carried out in the Maritime business in general or on routine offshore operations on the role and number of different participants. For all Marine Operation, the minimum of three different parties can be identified: the client, the contractor and the Marine Warranty Surveyor (MWS). (Bunes 2012).

Within the Norwegian area, generally DNV rules are used, but other classification societies' rules may be applied as well. (Bunes 2012). Besides only determining what Marine Operations are, they have also issued guide for planning and execution of Marine Operations and detailed standards for all different types of Marine Operations such as Load transfer (H201), Sea Transport (H202), Rig Moves (H203), Offshore Installation (H204), Lifting (H205), Subsea (H206). (DNV a). Currently there are major changes to the structure of DNV rules covering this field and names and codes of the standards may soon be outdated, e.g. the DNV Rules for Planning and Execution of Marine operations also referred in this thesis. However, the principles will not change. The national rules and industry standards are to be discussed at the early stages of planning, as explained in chapters 3.4.5 and 3.4.6, and it may be possible in some cases to choose which rules are applied.

10.2 Parties involved and their roles

In this chapter, the main parties always involved in a Marine Operation as well as some possible subcontractors and service providers are presented. The responsibilities of participants are set in the classification societies' rules, the following are in accordance with the DNV Rules for Planning and Execution of Marine Operation. There may be supplementing rules and guidelines set by the client or authorities that may alter these roles a little. (Bunes 2012).

10.2.1 Main parties

The Client is a company that has a need to have a particular operation carried out, e.g. it has a rig to be moved, a pipeline laid, or an offshore structure decommissioned. In contracts and procedures compiled for the Marine Operation the client is often referred as the Company or in some cases – to make things difficult to perceive correctly – the Operator. It hires another company called the contractor to plan and actually execute the operation. Client may have their own standards the contractor has to follow or aspirations about how the work is to be done. The client obtains insurance for the operation and is the assured party. (Bunes 2012; DNV b).

The Contractor is a company specialized in planning and executing Marine Operations, a certain kind of engineering company. Contractors may offer services for all kinds of Marine Operations or may concentrate on just some operations. These firms come in all sizes, they can be large with business outside Marine Operations field, plenty of employees and plenty of own equipment and expertise, or they may be small companies using many subcontractors. Depending on the degree of difficulty of the operation, there may be greater or lesser need to acquire expertise and equipment outside own firm. The Contractor appoints a manager to lead and oversee the planning and execution, this person is usually called the Marine Project Manager (MPM), Marine Operations Manager (MOM) or similar. Although the title of this manager varies, the role does not. (Bunes 2012; DNV b).

Marine Warranty Surveyor (MWS) is an independent third party whose responsibility is to ensure that the terms of the Marine Insurance Warranty Clause of the insurance are not breached. The MWS should assure that all provided documents are in compliance with existing rules and standards, and that all equipment is in proper working conditions prior to start of operation. After satisfactory completion of all preparations the MWS issues a Marine Operation Declaration, a document giving permission to continue the operation. In addition it is for the MWS to see that the operation is performed in accordance to plans. Some operations may require the MWS to be present all the time and some not. If the preparations or the operation itself are not conducted in a satisfactory way, the MWS shall reject the issuance of the Marine Operation Declaration or stop the operation from proceeding until proper corrective measures are taken. The MWS does not lead the operation but has great power to ensure that it is executed safely. (Bunes 2012; DNV b).

10.2.2 Additional possible parties

The operation may be so large and difficult that the resources of one main contractor are not sufficient to carry out the project on their own. Also, if the contractor is a small company it may need to use subcontractors virtually always.

Typically, at least one vessel has to be hired from a shipping company unless the contractor has a suitable vessel for some reason already on time charter. The need may be for one or several vessels depending on the type of work to be done. Hiring a vessel from a shipping company is similar to normal freight market. The chartering type may be for a short time work a voyage charter of a kind. If a structure is to be installed to sea bottom relatively close to the coast or a large structure has to be towed, a voyage charter may be used. If, however, the project is long involving consecutive voyages, e.g. installing suction anchors for a floating storage far away from a coastal base, it could require the use of time charter. (Bunes 2012).

The Marine Operations often require either divers, ROVs or both. For both the subcontractor providing whichever service may also have a support vessel at their disposal, owned or chartered, and they can sell both the subsea capability and the support vessel services for the contractor or the contractor may hire subsea and vessel services separately. Often some offshore vessels are capable to support divers and have ROV hangars reducing possibly the amount of different vessels required, e.g. construction vessel can lift and install structures with the help of ROVs based on the very same vessel. (Bunes 2012).

The lifting of extremely heavy objects at sea requires cranes designed for this task. Sometimes it is possible to have a crane installed onboard a vessel or barge and sometimes a special crane vessel have to be chartered. These crane vessels are problematic as there are not many operating due to limited market. For the same reason these vessels operate even more globally than other vessels normally related to Marine Operations. If there are several projects around the world simultaneously underway, it may be impossible to acquire a suitable vessel hired. (Bunes 2012).

Onshore planning and engineering phase of the operation may demand for expertise to be bought from other engineering companies. That work can include calculations, seabed analysis or construction or altering of equipment. In new ways of approach how to execute an operation the situation may require laboratory tests and analysis done elsewhere. When working outside the North Sea the need for interpreters increase, as well as the need to have a good local agent with wide contacts. (Bunes 2012). Also in some parts of the world the local legislation may require to have a certain percentage of people involved in the execution to be local people hired for work.

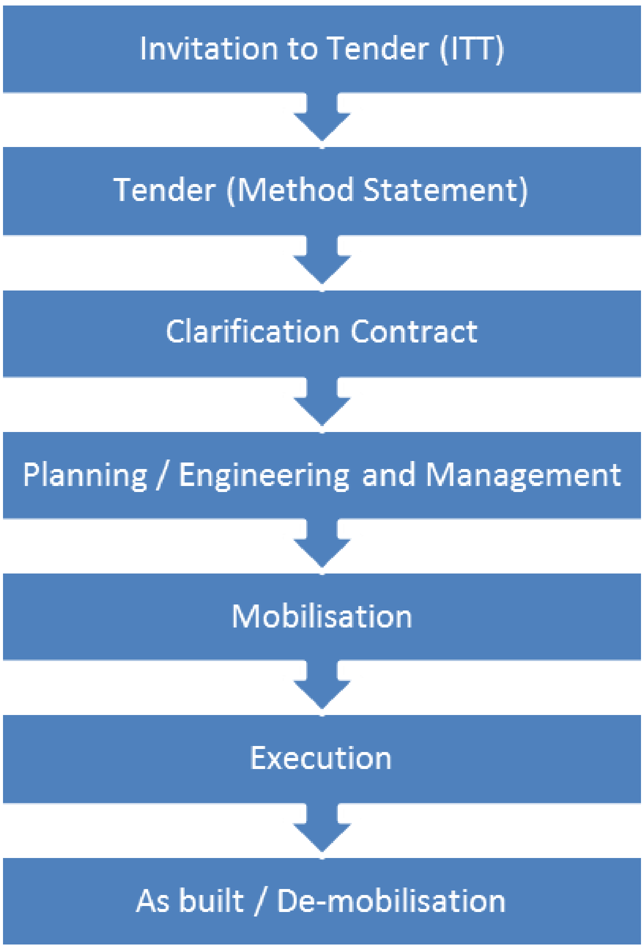
Brazil is one of such countries, and the example is partly copied from Norway, for Norway demanded that domestic workers were to be used to great extend in the NCS. This decision brought lot of work for the Norwegians and helped to gain knowledge rapidly. (Haavik 2012).

To be able to have all subcontractors and services available and plans ready inside the time window set in the contract between the client and the contractor may be difficult. The more there are participants, the more variables. Prices and availability of some subcontracting services change rapidly. Achievement of safe execution and profitability objectives simultaneously may prove to be a true challenge. (Bunes 2012).

10.3 Life cycle of a Marine Operation

To illustrate how a Marine Operation proceeds, it must be divided to different stages. Lecturer of Marine Operations, Marine Coordinator Svein Bunes, has compiled from open sources and own experience a seven-step system:

Figure 15. Life cycle of a Marine Operation. Source: Bunes 2012



Invitation to Tender (ITT) is given by the client when the client decides to have some operation carried out. It is up to the client to choose how and to how many potential contractors this invitation is given. Clients often wish to use known and well established contractors, often prequalified and reviewed. ITT will outline generally what is requested to be done, but it may have also very specific requirements. (Bunes 2012).

A contractor who has received ITT will issue a tender to the client within given deadline if interested. The tender is constructed according to the ITT requirements and usually includes a Method Statement containing technical information of how the contractor plans to execute the operation. Also in the tender information concerning the pricing (fixed or open for negotiations) and the time schedule. (Bunes 2012).

During Clarification stage the Client and the Contractor try to clarify all items unclear to other party and try to ensure that both parties have a uniform idea of how the operation is to be carried out. The commercial issues will also be settled during this clarification process and finally a contract is drawn up. (Bunes 2012).

Planning / Engineering and Management stage includes all the planning and engineering required for safe execution of the operation. A competent person is assigned to be the manager for the project, the title of that person varies, it can be e.g. Marine Project Manager (MPM) or Marine Operation Manager (MOM). All the relevant rules and guidelines are to be identified, qualified people assigned for planning, required subcontractors must be hired (vessels, tugs, ROV services, special engineering services etc.), manual for the operation has to be compiled. Risk assessment is carried out well in advance. As the execution is a non-routine operation of expensive hardware utilizing special equipment and a lot of manpower it is absolutely necessary to identify all risks in advance and to reduce those risks to acceptable minimum. Proper timing for execution and familiarization of different participants might be challenging. (Bunes 2012).

Mobilisation is the activities related to preparing resources for execution, all participating personnel, equipment and vessels included. Personnel are familiarized, necessary loading and installation of equipment is carried out and final tests done. Health, Safety and Environment (HSE) briefings are carried out. (Bunes 2012).

Execution is the part where the actual planned work is done. Operational procedures compiled for the project consist of necessary information for all participating personnel, including step by step procedure, work plans, flow charts, sketches and drawings. For emergency situations an emergency plan is made in advance to cover the whole execution stage. As participants from many parties are involved and for many of them position specific manuals and documents are made, a special bridging document is used to link participants and procedures together. The number of different documents involved is great, therefore consideration on how they are compiled for different purposes reduces frustration during execution. The person in charge of the operation is the Marine Project Manager, taking into account the fact that vessel(s) participating in the execution has their Master(s) and Master's authority and responsibilities cannot be removed. The Marine Warranty Surveyor is in most Marine Operation required to be present during the whole execution and approves individual stages during the operation. Although the MWS does not lead the work, he/she can stop it if not done according to approved plans. (Bunes 2012).

As built / De-mobilisation is partly done during execution and finished immediately after that. Documents stating and proving what was done are compiled in accordance with the contract. This may involve survey logs, positioning fixes, ROV logs, recorded videos etc. De-mobilisation covers all activities involved in returning rented equipment, releasing participating subcontractors, handing over chartered vessel(s). (Bunes 2012).

Other ruling bodies whose rules and guides are to be taken into account beside authorities, classification societies, client, MWS are the International Marine Contractors Association (IMCA) and standards by ISO and NORSOK. The use of guidelines set by foreign states may be applied, e.g. the LOLER rules of HS&E of the UK. In some cases also rules and limitations given by trade unions and oil companies require special consideration. (Bunes 2012).

11 INNOVATIONS

11.1 The demand for development

The conditions for extracting oil and gas from the NCS become harder and new methods have to be developed (Gassco 2012). The requirements set for safety issues and environment are becoming tighter for offshore industry and the whole global maritime business. New regulations on sulphur emissions from vessels are a good example of tightening rules. Large part of the NCS is within the present boundaries of the Sulphur Emission Control Area (SECA) covering the Baltic Sea, the North Sea and the Channel area. All vessels, regular cargo vessels as well as offshore vessels, are bound by these rules. The vessels are required to use fuel with very low sulphur content or remove the sulphur from the exhausts. The price of crude oil per barrel continues to rise due to diminishing reservoirs of fossil fuels and more expensive extraction methods. This increases the desire to eliminate all losses of hydrocarbons during extraction and processing. The rapid developments within the industry require unprejudiced thinking and flexible solutions in the education and training segment as well. This chapter introduces some of the innovations and presents some approaches to illustrate the attitude existing in the Norwegian offshore business towards development and how some ideas may benefit the global maritime business in general.

11.2 Innovation from thinking outside the box

The Knutsen OAS Shipping AS is a Norwegian shipping company specialized in tankers. They own and operate shuttle tankers carrying crude oil from offshore production fields to refineries, product and chemical tankers to carry refined products and liquefied natural gas tankers (LNG) from processing plants to receiving terminals. (Seglem 2012.) The loading of crude oil using continuously the same diameter piping onboard the vessel causes in evaporation in the dropline due to pressure decrease as the liquid form crude oil rapidly falls down. This leads to gas rich with organic compounds mixing with the inert gas within the ullage space. When the tank gradually fills with liquid the inert gas now containing organic compounds is discharged via mast risers and/or P/V valves. Per Lothe, director of Knutsen Technology claims, that the forming of gas within the dropline can be minimized with a simple method, just increase the diameter of the dropline compared to the rest of the piping is applied. At the bottom of the dropline, the piping is constricted again, and a pool of a kind accumulates at the bottom, and crude oil only in liquid form flows through. The system is called Knutsen Volatile Organic Compounds Prevention System (KVOC). (Lothe 2012).

The KVOC may help reduce the loss of valuable hydrocarbons to the atmosphere, but the benefits are limited to tankers and land based piping where droplines exist i.e. storage facilities and terminals. The future innovation consequent upon this discovery has much larger effects. According to Lothe, Knutsen’s researchers turned the idea upside down thinking that the phenomenon could be put to good use. By constricting the dropline diameter compared to rest of the piping a significant decrease in pressure can locally be induced causing the liquid moving inside the piping to boil in ambient temperature. The IMO is attempting to protect the marine environment from non-native and harmful material e.g. bacteria, viruses, protozoan and even plants brought by vessels within their contaminated ballast water. The use of ballast water is essential to vessels and cannot be stopped, thus the ballast water has to be treated so that all harmful substances are eliminated. The rapid boiling destroys effectively biological material by ripping the structure apart. Knutsen has constructed prototypes for vessels to enable ballast water treatment during transit, they call the system KBAL. The artificial boiling is enhanced with the use of UV light. The benefits of KBAL are its simple structure of the system, no need for filters and low operation costs. The ballast water treatment regulations bind the whole global maritime business, and the financial potential for working solutions is great. (Lothe 2012).

11.3 Simulator centre founded on extensive collaboration

Simsea AS, a simulator centre located in Haugesund, Norway, has an interesting ownership profile and is presented as an example of collaboration between the educational establishments, offshore industry and public interests. The owners come from different background representing the interests of companies, educational establishments and local authorities. Among the owners are a major DP system manufacturer Kongsberg, Stord/Haugesund Univeristy College, and numerous offshore shipping companies. (Johansen 2013; Simsea).

Fifteen instructors work for shipping companies also partners of Simsea. Instead of regular 1 on – 1 off system, these people do their work rotation in a system divided to three parts consisting of one part onboard a vessel, one part as simulator instructor and one part on leave. This arrangement benefits the shipping companies, Simsea, instructors and those participating on Simsea's courses. This way the shipping companies are integrated to the daily running of their investment and have a good knowledge of what new is coming. It also helps to arrange flexibly courses for the crews of the owners. For Simsea it is beneficial to have staff that are also working at sea as officers and maintain a grip of the actual work, Simsea gains access to up to date operational and technical experience. For the instructors this system allows more time to spend ashore with normal working hours, an attractive solution for those wishing for some reason to work at sea, but not full time. The real winners with the arrangement are the participants of various courses organized by Simsea, they gain much from instructors that have both the simulator knowledge and up-to-date real work experience. (Johansen 2013).

11.4 Supply vessel with hybrid energy system

The FellowSHIP project has produced a hybrid powered offshore supply vessel called Viking Lady, fitted with fuel cell power packs. The vessel was delivered 2009, has dimensions L=92.2 m, W=21.0 m, D=7.6 m with dead weight of 5900 t and it is owned by Eidesvik offshore. It is the first commercial vessel with fuel cells designed specifically for maine use. The combination of fuel cells and combustion engines run on LNG. (FellowSHIP a). The fuel cells convert chemically stored energy of the fuel directly to electricity with a controlled reaction with oxygen of the atmosphere. It could be used with some other fuel as well, e.g. hydrogen, methanol of biogas. As LNG is a good fuel type for marine combustion engine as well as for fuel cells, and as it is readily accessible in Norway, it is an ideal solution for fuel for a vessel of this kind. The project is quite long-term, the first phase began 2003 with feasibility study and initial design studies. The current phase in 2013 involves the commissioning and testing of hybrid systems and compiling of standards & rules for hybrid energy systems. (FellowSHIP b). Even tough the vessel is designed for NCS conditions the knowledge and competence required for the project is gathered from wide background, e.g. Wärtsilä is involved as a partner, as well as DNV and Eidesvik Offshore ASA. The different partners gain knowledge and can test new ideas and are able to influence what the standards for the future shall be. (FellowSHIP c). This power system concept may become common for some vessel types, even outside the offshore industry. The growth in the use of LNG as fuel for vessels becomes more attractive and

LNG bunkering terminals spread out, enabling bigger market areas for vessels powered by LNG, but also these hybrid vessels.

Figure 16. The Viking Lady, hybrid powered supply vessel. Source: FellowSHIP

12 CONCLUSIONS

The offshore business in Norway is extensive and versatile. The harsh environment combined with high safety demands and high overall labour costs make it an interesting segment within the global maritime business. The prevailing conditions force the offshore business, or cluster, to be highly dynamic. In the NCS area and the greater North Sea area, the profits are not obtained by trampling upon the workers' rights or with low regard for the environment, situation which is quite different to many other geographical areas where oil and gas is produced. Profits can be made but they are distributed to smaller companies and the society and not only major companies operating world-wide. The offshore business is also not only about oil and gas, it is also part of the growing sector of renewable energy. For seafarers, these above-mentioned facts represent good job opportunities with decent wages and little trouble with ethics.

For seafarers not working in the offshore industry, it is also important to have basic understanding of what is involved in it, for virtually all seamen come across platforms, survey vessels, and constructions vessels. It might be easy to see these offshore operations only as a nuisance for normal commercial seafaring with their requirements for extensive exclusion areas and unyielding protocols. To appreciate the requirements all seafarers should try to understand why offshore related operations are carried out the way they are. All platforms and offshore vessels undergoing operations at sea are very vulnerable, even a vessel seemingly free to move away might actually be unable to do so. The operations are also very precise and e.g. the acoustic positioning systems are easily interfered by propeller noise as are the seismic studies.

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