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Abstract:

In this report decommissioning of offshore petroleum platforms have been investigated. It treats decommissioning in general, the process of a typical project. A variety of suitable lifting vessels have been presented, and some concepts of removal have been evaluated.

Decommissioning is important to go through with because of the environment and the use of the area after the petroleum activities ceases. Other ocean users benefit from the decommissioning because the area can be utilized when it is opened for ordinary traffic. The environment will benefit from the cessation of production because of fewer spills to sea or risk of it and being restored to a state as close to possible to original. Sometimes it is found acceptable to leave facilities behind, partially or wholly, and the marine life in the area can actually benefit from this in some cases.

A decommissioning project consists of the elements planning and approval, topside and jacket preparatory work, topside removal, jacket removal, transport, and onshore dismantling and recycling. There are two main concepts of removal, reverse installation and single lift.

The challenges in decommissioning are to make it less expensive, less time-consuming, and safer than today as well as keeping the environmental issues satisfactory. This can probably be reached by making the process more standardised to some extent, making use of new technologies like new vessels, doing less work at the offshore site, carrying out less lifts offshore, and do a lot of the dismantling work onshore. Pieter Schelte can to a great extent be the solution to these challenges.

When Pieter Schelte is used, personnel will be exposed to less risk because more work is done onshore. Onshore work is in general more inexpensive, faster, cleaner, and safer. This gives a better HSE profile to the project as well as being more cost-efficient.

Keyword:

Decommissioning

Advisor:

Svein Kristiansen

MASTERs THESIS

TMR4905 in Marine Systems
for
M.Sc. student Line Småge Breidablikk
Spring 2010

Heavy Lift Methods in Decommissioning of Installations
(Tungløftmetoder ved fjerning av installasjoner)

Decommissioning of offshore petroleum installations will have a increasing activity in the coming years. Main focus will be on top side installations, jacket structures and pipelines. Decommissioning may to a large degree be seen as an opposite process to installation and involves towing, lifting and positioning. This means that such operations require similar equipment and vessels, lead time and cost. Safety and environment are also important aspects. Lifting or refloating of substructures and top side installations may be seen as critical operations and may have potential for improved methods and innovations.

The objective of this thesis project is to study lifting and refloating methods and associated technical solutions. It should be given an overview of alternative methods both related to offshore operations and other heavy lift operations (transport). As far as possible the duration of operations and weather availability shall be discussed.

The thesis should cover following points:

a. A general discussion of the present state-of-the-art in decommissioning based on available publications and conference papers.

b. Give an overview of the decommissioning process in terms of sketches and process charts for cutting operations, lifting and transport. The presentation may be based on conventional methods for decommissioning.

c. Present alternative vessels for heavy lift operations. Both vessels dedicated for offshore operations and seaborne transport should be covered. In a comparison of the alternatives assess their respective lifting capacity, lifting and transport speed, weather availability, safety and other relevant performance parameters.

d. Undertake an assessment of the present status of the technology in view of future requirements in terms of platform weight and operational reliability (availability). Outline one or a few alternative concepts that may be more cost-effective by means of sketches and process diagrams.

The thesis shall be written as a research report with abstract, conclusions, table of contents and reference list.

During the preparation of the thesis it is important that the candidate emphasizes a well written and easily understood text. For ease of reading, the thesis should contain relevant references at appropriate places and effective use of tables and diagrams. The evaluation of the report will to a considerable degree be based on the presentation of objectives, selection of method/approach and discussion of results.

The candidate shall provide 2 paper copies and 1 DVD of the thesis.

Starting date: 20 January 2010

Completion: 13 June 2010

Handed in:

Trondheim

Svein Kristiansen

Instructor

Preface

This report is master’s thesis at Marine Systems Design at Norwegian University of Science and Technology (NTNU). The work has been done by one student during the spring term 2010 and gives 30 credits.

During the work of this report it has been hard to find detailed and good information about some of the covered topics, among others the vessel weather performance, economy, and operation times. A lot of time has been spent reading material that turned out not to be particularly relevant anyway, but it has to be done to find out. However, it has given me a better overall understanding of the topic and the industry in general.

I also experienced a laptop motherboard breakdown in the final part of the term causing a month of thesis work on an outdated laptop which was very annoying and slowed down the progress to some extent.

I would like to thank my instructor Svein Kristiansen for useful guidance during the work with this project.

Trondheim, 11 June 2010

Line Småge Breidablikk

Abstract

In this report decommissioning of offshore petroleum platforms have been investigated. It treats decommissioning in general, the process of a typical project. A variety of suitable lifting vessels have been presented, and some concepts of removal have been evaluated.

Decommissioning is important to go through with because of the environment and the use of the area after the petroleum activities ceases. Other ocean users benefit from the decommissioning because the area can be utilized when it is opened for ordinary traffic. The environment will benefit from the cessation of production because of fewer spills to sea or risk of it and being restored to a state as close to possible to original. Sometimes it is found acceptable to leave facilities behind, partially or wholly, and the marine life in the area can actually benefit from this in some cases.

A decommissioning project consists of the elements planning and approval, topside and jacket preparatory work, topside removal, jacket removal, transport, and onshore dismantling and recycling. There are two main concepts of removal, reverse installation and single lift. The elements of the project are the same whichever of the concepts are used. The vessels to be used need large lifting capacities in either concept. Especially designs that lift topsides and jacket in single lifts can improve the efficiency in the projects.

Several lifting vessels have been presented and a few concepts were reviewed regarding future requirements. The concepts were platform removal using only a traditional HLV, topside removal using HLV and jacket removal using buoyancy tanks, and removal using the new lifting vessel design Pieter Schelte. It is found that all the concepts can remove fixed platforms, but Pieter Schelte was especially well-suited. When Pieter Schelte is used, personnel will be exposed to less risk because more work is done onshore. Onshore work is in general more inexpensive, faster, cleaner, and safer. This gives a better HSE profile to the project as well as being more cost-efficient. On the downside, the vessel is not available before 2013. In the meantime the alternative with the HLV and buoyancy tanks can gain some more experience. This alternative scored the same as removal with reverse installation and is therefore not so successful in this comparison. There are however uncertainties involved and the solution with the buoyancy tanks are still interesting.

The challenges in decommissioning are to make it less expensive, less time-consuming, and safer than today as well as keeping the environmental issues satisfactory. This can probably be reached by making the process more standardised to some extent, making use of new technologies like new vessels, doing less work at the offshore site, carrying out less lifts offshore, and do a lot of the dismantling work onshore. Pieter Schelte can to a great extent be the solution to these challenges.

Table of Contents

List of figures

List of tables

Abbreviations

AWJ	Abrasive Water Jet
BTA	Buoyancy Tank Assembly
DMR	Mississippi Department of Marine Resources
DNV	Det Norske Veritas
DP	Dynamic Positioning
GOM	Gulf of Mexico
HLV	Heavy Lift Vessel
Hs	Significant Wave Height
HSE	Health, Safety and Environment
IMO	International Maritime Organisation
NDE	Non-Destructive Examination
NDT	Non-Destructive Testing
OSPAR	Oslo and Paris Conventions
PSA	Petroleum Safety Authority
ROV	Remotely Operated Vehicle
SBC	Sub Bottom Cutter
SSCV	Semi Submersible Crane Vessel
UKCS	United Kingdom Continental Shelf
WL	Water line

1 Introduction

This report is a study of decommissioning of offshore installations. The report will treat the decommissioning process especially in regards to offshore operations and lifting vessels.

There will be presented an overview of decommissioning challenges, the operations and activities involved during removal, and vessels that can be used. Some concepts will also be evaluated. Decommissioning of pipelines and wells are not emphasised.

The information this report is based on literature. The main source of information to this project will be from articles, the Ekofisk 1 booster platform cessation plan, and web pages as well as information found during the work with the project thesis autumn 2009.

2 Background

Oil and gas installations end their life with decommissioning. This means shut down of the facilities, well plugging and abandonment, and removal of the installations. When the petroleum activities started on the Norwegian continental shelf in the 1960s and the first commercial field was found in 1969, it is not likely that decommissioning of petroleum installations was thought of. Since then lots of fields have been found and facilities have been installed, and all of them will need decommissioning after shut down. Some of the installations are allowed to be partially left, but most of them will have to be completely removed. The removal requirement can be a challenge because older installations have often not been designed with decommissioning in mind. An unsuccessful attempt of removal can have consequences to the environment, third party property like pipelines and installations, or human lives. Therefore it is important to keep a high quality in the decommissioning projects.

Due to technology development, the potential of oil and gas production on the various fields have increased over the years. This has resulted in fields that were due to have closed now is still producing. Some of these at the Norwegian continental shelf can be seen in Figure 1.

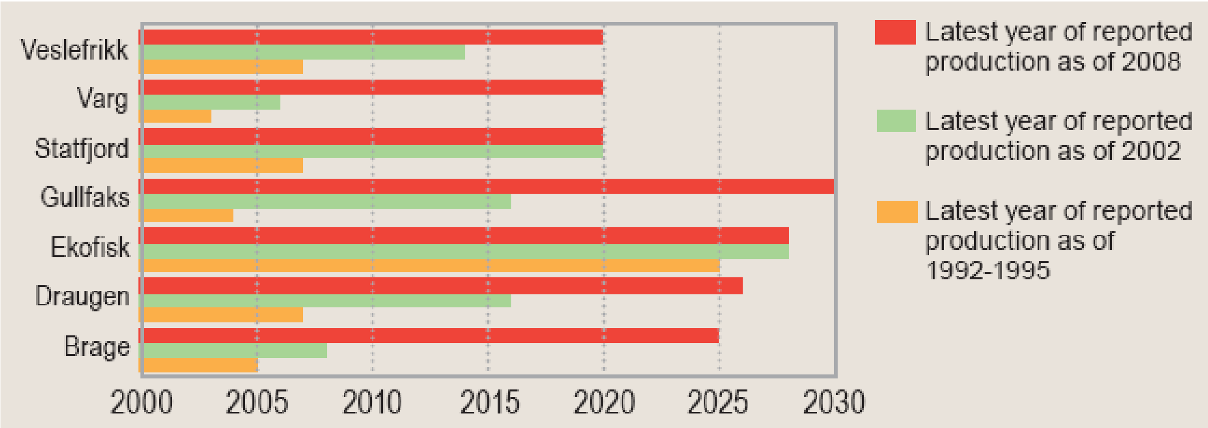

Figure 1: Lifetime for some fields, (Norwegian Petroleum Directorate 2009)

Some installations are now beyond their original design life time and measures having been taken to deal with this. However, there will come a day for all fields when the wells are empty and there is no other use for the installation. In this case the installation and wells have to be decommissioned. The installation will then be removed and disposed of, and the wells must be plugged and abandoned.

Forecasting the decommissioning of installations is quite hard as the installations keep getting their lives extended if the overall conditions are promising. Due to this, it is easier to forecast the cessation of different fields even though technology keeps extending their lives as well. Figure 1 shows a forecast of the lifetime of some fields in the Norwegian sector comparing the numbers reported in different periods of time.

From Figure 1 it can be observed that most fields got an increase in lifetime prediction as the years goes on. This is likely to be due to technology improvements and more accurate field data. This shows clearly that giving forecasts regarding this topic is hard. There are also other factors than the amount of resources left that is contributing to the decision.

Figure 2 shows the amount of fields that is due to cease every year based on the operators' own forecasts in the UK sector. This forecast changes every year so it's more like a guideline than the actual truth. This is the same observations we can make from the Norwegian forecast and from these two forecasts it can be concluded forecasting decommission projects is rather hard and is so far not very accurate.

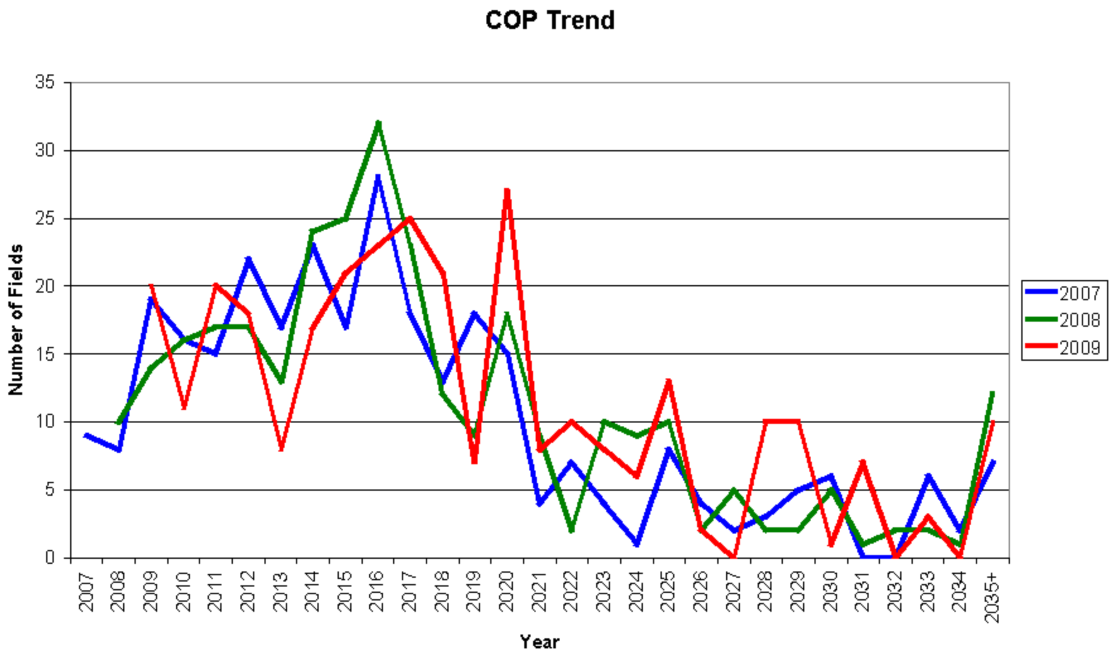

Figure 2: Cessation of Production trend, UK, (Department of Energy and Climate Change 2009)

Although forecasting the decommissioning projects is hard, it will probably be an increasing amount of decommissioning activities in the coming years as the fields are being emptied and the installations are aging. Exactly when the facilities are being decommissioned are dependent on several factors and is the reason why the latest years' forecasts have been so unreliable. Companies tend to try to squeeze out some more life time from the facilities if they find it economically favourable. Reasons for this can e.g. be the oil price making fields still profitable to operate or new technology may make it possible to keep the production going a bit longer. It can also be that the companies delay the process as long as possible because of the costs involved in the removal of the facilities.

On the Norwegian continental shelf fourteen fields have been shut down(Norwegian Petroleum Directorate fact-pages). Among these are Ekofisk vest, Odin and Frigg. Not all facilities are removed yet. Some removal activities are still ongoing and some of them are planned to be disposed before very long or put into other uses. These projects ensure useful decommissioning experience, although this experience is not much compared to other areas.

Areas with more decommissioning experience than at the Norwegian continental shelf are the Gulf of Mexico and the UK continental shelf. In UK there has been slightly more decommission activities than in Norway, but in the Gulf of Mexico more than 2000 small and larger structures have been removed according to (O'Connor, Corr et al. 2004) and that is a considerable number compared to other areas. This is probably due to the large number of structures located there as well as the maturity of the area. The experience from GOM could be possible to utilize in other areas. However, rules and regulations in GOM and the North Sea are not exactly the same as well as the conditions in the area is also different.

When it is known that an offshore installation is going to be decommissioned, there are several ways of doing it. Some ways will be excluded due to regulations because of the installations size, weight and design. Table 1 shows the different decommissioning alternatives for a typical offshore platform and belonging objects.

Table 1: Decommissioning possibilities for the different offshore facilities

<table>
<tr><th>Facilities</th><th colspan="6">Decommissioning possibilities</th></tr>
<tr><td>Topsides</td><td colspan="2">Onshore dismantling and recycling</td><td colspan="2">Refurbish and reuse elsewhere</td><td colspan="2">Leave in place</td></tr>
<tr><td>Substructures</td><td>Onshore dismantling and recycling (complete or partial)</td><td>Refurbish and reuse elsewhere</td><td>Reef in place (complete or partial)</td><td>Reef in offsite reef area (complete or partial)</td><td>Leave in place</td><td>Deep water disposal</td></tr>
<tr><td>Pipelines</td><td colspan="4">Remove to shore for recycling</td><td colspan="2">Leave covered in place</td></tr>
<tr><td>Cuttings</td><td colspan="2">Slurrification and re-injection</td><td colspan="2">Remove to shore for disposal</td><td>Leave in place</td><td>Leave covered in place</td></tr>
<tr><td>Seabed</td><td colspan="4">Remove debris</td><td colspan="2">Leave debris in place</td></tr>
</table>

Even if the decommissioning alternatives are those presented in Table 1, it is not so that all alternatives are available in all cases. Regulations and other conditions influence the possible choices. Most often it is the size and complexity of the structure that decides as well as the area in which it is installed. The chosen alternative has to be the best one to the environment at all times, but also economy and technical feasibility are considered. There are several solutions to how to perform the different options and some are more often chosen than others. Topsides can e.g. be taken onshore in one section or several sections, or it can be transported while still on the jacket if appropriate. For the substructures that are converted into reefs on-site they can be cut somewhere in the water column and the topmost part can be taken ashore, or it can be toppled so that the whole jacket becomes a reef. Toppling can also be an option for the whole jacket structure.

The information in the previous sections shows that there are many possible solutions in the decommissioning market, but it is difficult to foresee how the market is going to be.

3 Decommissioning

The petroleum industry has generated both energy and income to the oil and gas producing countries. However, when a field ends its producing life those who have had benefits from these resources will have the responsibility to remove the facilities according to current regulations and often this means to restore the area as close as possible to the original state. This means that there will be expenses related to the field when it is not generating income anymore and this makes it less tempting to carry through with decommissioning activities. The decommissioning is the field owners' responsibility, but the expenses are shared with the Government.

3.1 Why decommissioning

There are several factors that are important to why decommissioning has to be done, and these reasons will be presented here. The superior reason will be the environment and other ocean users. To those that are paying for the decommissioning project it is no doubt that regulations is very important as regulations decides which removal options that are available. Without clear restrictions it can be assumed that not as many installations would have been fully removed. After all fully removal is more expensive than partial removal and it has to be assumed that it could be tempting to some companies to choose other solutions if they could.

The decommissioning plans have to be approved by the Government before they can be carried out and in the OSPAR area, the member countries have to approve as well. However, this is not always enough. The Brent spar was approved for deep water disposal in the mid 90s, but this was never carried through. The public opinion should not be underrated, and in the Brent Spar case, another solution was chosen in the end because of the company reputation. Even if the deep water disposal solution was found to be less expensive than other options as well as having little environmental impact, this was not approved by the public. It turned out later that the spar contained less harmful substances than Greenpeace claimed, but it was still taken ashore for dismantling, recycling and disposal. This shows that the public opinion is also important to why decommissioning is carried out even if the environmental reasons are the background for the public's opinion. The issues regarding environmental impact do not have to be proved to influence the public's opinion. There is an aesthetic part of it as well. Even if the facilities are not visible or accessible from shore, people can think it is better with preserved scenery than one that is not. The public opinion has to be considered because it can cause trouble if it is not taken into account.

Depending on the type of facility and conditions during the production period, it will be more or less debris and drill cuttings on the seabed. It is probably nearly impossible to produce oil without having any spills to sea at all. These can be harmful to the environment and for instance drill cuttings will be located underneath the platform. However, currents can have caused them to drift some. The contents of drill cuttings depend on whether oil-based or water-based mud has been used for drilling. Drill cuttings from oil-based mud is toxic and have not been used in the North Sea since early 1980s according to (Greenpeace 1996). Even if the cuttings can be harmful locally, they can be stable and will not spread to other areas. If drill cuttings are removed from the seabed there is always a risk of spreading it when it is disturbed and a larger area can be polluted. To remove the cuttings or not will have to be considered in each case and the contents of the drill cuttings, the thickness and the outspread of the layer, and the sea conditions have to be evaluated. According to (Lakhal, Khan et al. 2009) drill cuttings are only removed for onshore disposal when solid. Other debris can probably be removed easier than drill cuttings.

There can be possible to use redundant platforms at other nearby fields if the need is present and the platform fits the requirements. This is uncommon to do for fixed platforms, but it can be done if the platform in question is designed to be re-floated for removal or if it can be removed relatively undamaged. It is not that many platforms that are designed for re-floatation, but an example of one is Maureen Alpha (Figure 3), a gravity-based steel platform that was re-floated, dismantled, and recycled. It could have been reused at another field, but there was no interest to use it on nearby fields. To take the platform onshore for refurbishing can also be an option.

Figure 3: The Maureen Alpha platform, (oilrig-photos.com 2006)

When platforms are shut-down, the equipment is still in working order. Depending on the time it takes from shut down to removal, some of it can be reused at other facilities. This is not a very common way of removing the equipment, but it could give some income if it is in good condition and it is sold. When the platforms are dismantled, it is possible to recycle most of the platforms if it is focus on reuse and recycling on the onshore dismantling site. During the work on the already mentioned Maureen Alpha, 99,5% of the platform was reused/recycled(Kristing 2004). This is very good from an environmental point of view and it contributes to sustainable utilization of materials.

Another factor to why decommissioning is important is the fisheries. Many areas with petroleum installations are interesting fishing areas as well. These areas have been closed for fishing activities as long as the petroleum activities have been ongoing. The fishing fleet will want access to the areas when the production at the field ceases. This access can only be given when it is safe to do so, and often this means that facilities have to be removed. When everything has been removed it has to be verified that the seabed is clear of any debris. After this is done it will be safe for the fishing vessels to use their gear in the area. Especially for trawlers it is important that the seabed is cleared.

Fisheries harvest the benefits of the ocean, but it has to be ensured that there is something to harvest. Although removal of the petroleum facilities gives an economic benefit to the fishermen, it is not the only value to be considered. In GOM it has been showed that various types of marine life lives on or around the platforms (Kaiser 2006).When the platform is removed the habitat disappears and the marine life does as well. It is not confirmed if the platforms generate more marine life with their presence or if it only attracts existing life. Until this is clarified it cannot be ruled out that removing jackets and taking them for onshore disposal actually leads to less marine life. To leave jacket structures behind as artificial reefs can therefore contribute to protect marine ecosystems.

Figure 4: Life at an artificial reef, (DMR 2010)

The making of artificial reefs depends on the regulations and if they permit to leave something behind to be artificial reefs. If fully removal is required, this cannot be done. In USA, both the states of Louisiana and Texas have rigs to reef- programs which permit to leave jackets or parts of jackets in designated areas. Whether platforms are turned into reefs or not, depend on the economy in the decommissioning projects and it will be done if it is cheaper than other solutions. If it is cheaper or not, usually depends on the vicinity of designated reef areas and the size of the platform. Smaller platforms close to shore can be cheaper to take onshore for disposal rather than taking the jacket to a reef area. The reason for this is that the designated artificial reef areas are usually further away from shore than the platform, at least in Louisiana (Pulsipher and Daniel Iv 2000).

As well as for the fisheries, removal of offshore installations is useful for shipping as the ship routes cannot be too near the petroleum installations. It can be assumed that removal of the installations can make shipping routes more effective. For shipping partial removal a certain depth underneath the water surface can be acceptable and the depth at which a jacket can be cut is regulated. For the fishing fleet, especially trawlers, complete removal is preferable. In some cases the topside will be removed but the substructure of the platform will be left in place. When this occurs, the substructure has to be marked with navigational aids so that the ships can pass safely. This has been done at the remaining substructures at the Frigg field and research was done to find the best way to mark it according to (Kjerstad and Bjoerneseth 2004). Another aspect to navigation is the fact that in GOM some platforms have become useful navigational references to many types of boats (Pulsipher and Daniel Iv 2000). This benefit is non-marketable and is therefore not considered among the reuse options. There are other such non-marketable benefits as well according to (Pulsipher and Daniel Iv 2000), and most of them are quite extraordinary. The most useful one seems to be that trawl-free zones can be created by placing old platforms strategically so that trawling is impossible in that particular area. That would provide a place of refuge against trawling for several types of marine life. Again, to be able to do this other alternatives than fully removal will have to be acceptable.

Altogether decommissioning is important to go through with because of the environment and the use of the area after the petroleum activities ceases. Other ocean users benefit from the decommissioning because the area can be utilized when it is opened for ordinary traffic. The environment will benefit from the cessation of production because of fewer spills to sea or risk of it and being restored to a state as close to possible to original. Sometimes it is found to be ok to leave something behind, partially or wholly, and the marine life in the area can actually benefit from this.

3.2 Some challenges in decommissioning

Decommissioning projects have to be planned carefully because if anything goes wrong it can be more costly and difficult to fix it than doing it successful in the first place. There are some uncertainties in decommissioning projects and they are among others marine growth and structural integrity because the platforms are in an unknown condition. This uncertainty becomes larger if it is a long time from platform shut-down and abandonment. Both of these are possible to minimise by doing surveys in advance. The marine growth in easily checked by ROVs and the weight of it can be estimated. The structural integrity survey is not as straight forward. Both topside and substructure have to be checked and it is especially important to check all the structure that is exposed to load during the removal. As most removals at present are done in a reverse installation manner, it is many lifts involved and the structure has to withstand the forces. This goes for lifting points, both new and old, and the structure surrounding them. If strengthening is needed, it has to be done. It can be a challenge to find all of the places that needs strengthening.

One of the greatest challenges in decommissioning is a safe working environment. Lots of activities will be ongoing at the same time especially during topside removals. The working personnel will be put at a greater risk than during projects with less time pressure and scope of work. Concurrent operations require good management to make sure that the operations cannot interfere with each other, creating conflicts and hazards. Therefore it is important to prioritise overall risk management during the whole project.

Another challenge in decommissioning projects is technology. New products are being developed, but they have to be proven in real situations to ensure commercial interest. This is especially the case with lifting vessels because there can be a lot of consequences if the lift turns out unsuccessful. Several single lift vessels have been designed, but not so many are being built. The designs suffer from lack of financing and the companies that try to carry out these projects go bankrupt. As long as there is little will to try the new concepts, it is not likely that many of them will be realised. This is a challenge because the industry wants to carry out their projects as cost-effective as possible, and that often involves spending less offshore time. Some of the vessel designs can tribute to more cost-efficient offshore operations, but it depends on who gets the benefit from the increased efficiency. The platform owner would like to do the project cheaper, but the lifting vessel owner would like an increased benefit. It is likely that single lift concepts will succeed if the end user benefits from the lowered costs and the designs prove themselves during lifting operations.

The challenges in decommissioning are to make it less expensive, less time-consuming, and safer than today as well as the environmental issues are satisfactory. This can probably be reached by making the process more standardised to some extent and making use of new technologies like new vessels.

3.3 Regulations

Decommissioning projects are regulated by international regulations, national laws and industry standards as well as that the authorities have to approve the plans. These regulations have been developed during the years and the most important in the North Sea is OSPAR 98/3. It is a decision by countries that is interested in protecting the marine lift of the North-East Atlantic. The general idea of this decision is that all facilities have to be removed, but there are some exceptions for large steel platforms, concrete installations, concrete anchor bases, and significantly damaged structures. The international maritime organisation has guidelines concerning decommissioning, but OSPAR is stricter than IMO when it comes to removal. In areas where only the IMO guidelines and not OSPAR applies more installations can be left behind unless national regulations are stricter.

National laws apply guidelines to the carrying through of the decommissioning projects. Although decisions concerning what is going to be removed are given by directions from the international regulations, the authorities want to have control of what is actually done. The laws mostly involves regulations making sure that the authorities are being informed when field shuts down, removal plans have to be approved, and the decommissioning responsibility is placed upon the field developer. In USA, the states can have their own regulations and programs for decommissioning that influences the choices of decommissioning solutions.

The laws make sure that the authorities always knows in which stage a project is, and the permission to carry out the plans are given by the authorities. In Norwegian sector an

Application for Consent has to be presented to the Petroleum Safety Authority for approval where the plan for the project is presented. Safety is emphasized especially strongly in the plans, because health, safety, and environment are very important to the authorities. Injuries to personnel and spills to the environment are not acceptable. The plans have to be approved before the work can commence. In Norway the PSA has a responsibility to supervise the removal of the installations, but they are not involved in the operations. After the modules are ready for transport and leaves the field it is the Norwegian Maritime Directorate that gets the supervision responsibility. At the onshore location different authorities supervises.

Regulations concerning how offshore operations are supposed to be performed mostly treats field development, installation, and production, and not so much decommissioning activities. Although there are laws treating this matter they are not guidelines to the operations. As long as there is no clear guides on how to carry through the decommissioning operations, the other regulations have to be followed as far as possible. Because they are not made for decommissioning activities they are not always sufficient and specific decommissioning guidelines are needed. DNV has developed a recommended practice for removal operations, DNV-RP-H102, based upon their recommended practice for marine operations.

3.4 Geographical differences in decommissioning approaches

The practice of the decommissioning process is different in various geographical areas. This will be due to engineering practice and difference in national regulations. Here, the difference between the Gulf of Mexico and the North Sea practice will be reviewed in accordance with (O'Connor, Corr et al. 2004).

Removal projects tend to finish in shorter time in GOM than in the North Sea. These differences are due to the amount of projects and the regulations concerning them. In the GOM area lots of removal work have been done and not nearly as much has been carried out in the North Sea. This multitude gives the GOM an advantage because they can use their experience from other similar projects in the same area. The regulatory framework demands a quick removal of the facilities as well. In UK it is used a more risk-based system than in the US where a more standardised approach is used. Here, it is assumed that the other North Sea area countries use approaches closer to the UK approach than the US.

In the US, the standardisation approach can be used because of the many similarities new removal projects have with the already performed ones. Together with the multitude and size of the projects the standardised approach can be justified. In the North Sea, standardisation might never become the favoured approach as the number of installations is significantly smaller than in the US and the similarities between them are generally fewer.

A risk-based system spends more time to consider and approve removal projects because all aspects of the process must be covered. This is likely to be a good method for one-off facilities that really stands out even in GOM or at large facilities in general.

The experience and regulations gives the GOM projects the possibility to be more cost-efficient than the North Sea projects as well. With an increasing decommissioning rate, the GOM method of decommissioning can be favourable also in the North Sea to make the projects more cost-effective and quickly finished. At least this could be the case in smaller and not too complicated projects.

3.5 Decommissioning knowledge

As with other industries different research is done regarding decommissioning as well as experiences from completed decommissioning projects contributes to more knowledge about the field. Some will be presented here.

As the environmental focus is characterizing the decommissioning projects, this is a focus area in the research as well. After the decommissioning of the Frøy field an environmental survey and assessment was carried out. This survey studied the health condition of fish and invertebrates. What remained after the Frøy decommissioning was covered pipelines and a cutting pile with oil content because of the oil-based mud used when drilling the wells at the Frøy field (Plisson-Saune, Beyer et al. 2005). It is the consequences of leaving the drill cutting pile at the seabed in this case that are being assessed by catching fish and invertebrate using traps and bottom trawl. Figure 5 illustrates the trap arrangement used for catching fish for the study.

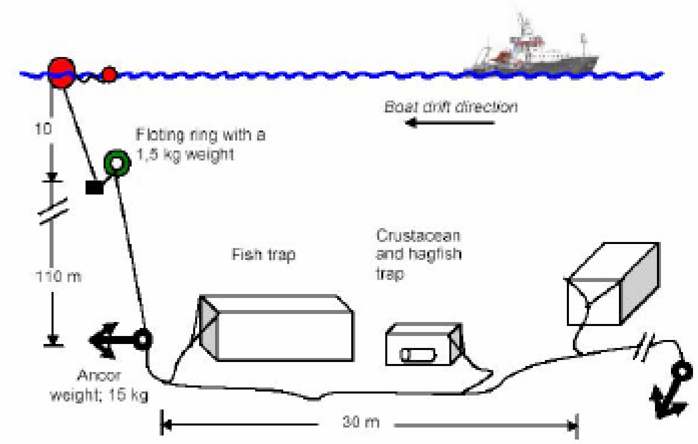

Figure 5: Trap arrangement used at the Frøy field, (Plisson-Saune, Beyer et al. 2005)

All of the studied fish was found to be in good health but the invertebrates were slightly affected. However, the overall impact was found to be limited and the effects were not showed further up in the food chains according to (Plisson-Saune, Beyer et al. 2005). This means that the decommissioning of the Frøy field has been successful and there are no current environmental risks at the field. This survey only states the conditions at the Frøy field and it cannot however be assumed that all fields that have the same amount of oil-based drill cuttings, have the same environmental condition. There are not enough available survey data for areas containing drill cuttings to make that assumption. In spite of this, the methods used at the Frøy field can be used elsewhere as they were proven to be good.

As mentioned earlier, the platform condition can be uncertain when decommissioning is about to start. Although it is a rather extreme example of unknown condition, some aspects of the decommissioning of Eugene Island 322 A drilling platform will be presented according to (DeFranco, Fitzhugh et al. 2004). The production platform that completed Eugene Island 322 A (to the left in Figure 6) was also decommissioned at the same time, but was not considered to be the challenge in this project as it was not found to be damaged.

Figure 6: Eugene Island 322 A platform complex, ***(DeFranco, Fitzhugh et al. 2004)***

The drilling platform (to the right in Figure 6) was heavily damaged during the hurricane Lilli in 2002 and this meant that the platform condition was known to be bad, but the damage was not known at the start of the project. Some of the damage that was found can even have occurred before the hurricane hit. The belonging wells had to be plugged and abandoned. Before this work could start the platform needed some strengthening so its stability during these operations was ensured. As for the decommissioning of the drilling platform, the challenge was the condition of it. Two decommissioning alternatives were considered and that was removing and dismantling, and leaving it in place as a reef. The removal option was ruled out because the heavy damage of the platform would expose the workers to unnecessary risk. After the decision to leave the platform, cutting methods had to be chosen. It was chosen to cut the platform mechanically in the water column. It was also an option to cut the platform legs below the mud line with either explosives or mechanically, but these options were not chosen due to the unknown structural condition both below and above the mud line. After the cutting, the platform was toppled into place by an assistance vessel.

Cutting operations are an important part of platform removals and some research has been ongoing in this area. In many cases in the North Sea complete jacket removal is the decommissioning choice according to regulations. In order to leave nothing behind at the seabed it is a good option to cut the jacket piles below the seabed. A tool to perform this task can be the Sub Bottom Cutter, Figure 7. The use of tools that cuts the jacket piles below the seabed will minimise the environmental impact because no remaining jacket parts will be visible, and the jacket removal will be complete. The Sub Bottom Cutter will be ready for decommission cutting missions early in 2010 according to (Sangster 2009). The cutter leaves very few marks on the structure as well. Other than the cut itself it does not damage any of the structure because a diamond wire is used to perform the cut according to (Grant 2004).

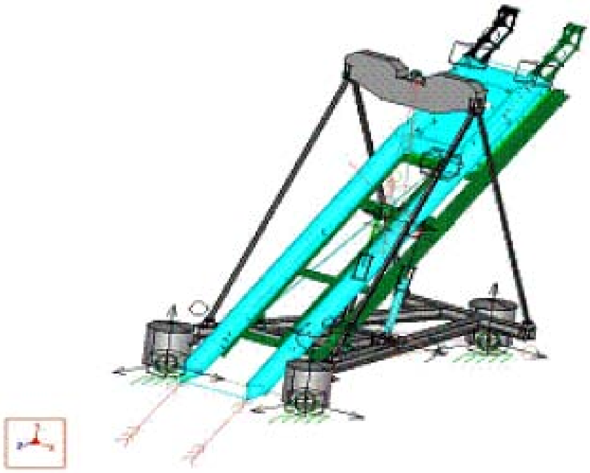

Figure 7: The sub bottom cutter, (Grant 2004)

Figure 8 illustrate where the SBC cuts and that it is controlled by an umbilical. This makes possible reuse of the structure more realistic as it will not be damaged by the cutting.

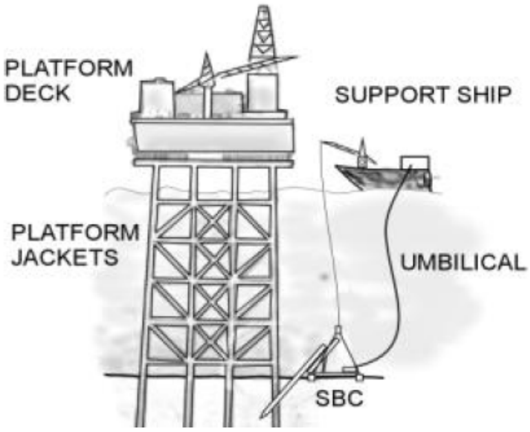

Figure 8: The SBC cutting below the seabed, (Grant 2004)

From the previous sections it can be concluded that decommissioning of redundant petroleum facilities is important to other ocean users like fishermen and from an environmental point of view. The decisions in a decommissioning project are made from many factors like regulations, the facility condition, the public opinion, and possible reuse. The ultimate challenge in these projects is to make them as inexpensive as possible. This can be reached by spending less offshore time, and using cheaper, more efficient vessels and equipment which can do the work faster, safer, and in a larger weather window.

4 The decommissioning process

This part of the report will present a typical decommissioning process and the activities involved. The presented process will be based on conventional methods for decommissioning. To present a typical process, the basis will be the decommissioning process of a part of Ekofisk 1, the Norpipe AS Booster platforms 37/4-A (Figure 9) and 36/22-A and will be given as an example. A drawing of booster platform 37/4 A can be found in appendices 1 and 2.

The offshore removal operations for the Ekofisk 1 field will be carried out in the period from 2009 to 2013, and the booster platforms have scheduled topside removal in 2009 and jacket removal in 2010 according to (Terdre 2008). The current progress of the removal operations is unknown, but the topside of Norpipe 37/4 A was lifted taken onshore in august 2009 (Sternhoff and Nordbakken 2009) and seems to be within the schedule. The rest of the platforms at Ekofisk 1 will most likely be removed within 2013.

Figure 9: Ekofisk 1 booster platform 37/4 A, (Norsk Oljemuseum)

Depending on the project in question, the decommissioning process can be different from other projects, but it always consists of different stages. We will now look at the stages involved in the removal of the Ekofisk 1 booster platforms. Apart from a planning stage including concept selection and engineering, the stages in the project are make safe-operations, hook-down, topsides removal, jacket removal, transport and offloading of topsides and jackets at shore, and onshore demolition and disposal of topside and jacket. Among these stages it is topside removal and jacket removal that are the main stages of offshore operations.

4.1 Topside removal preparatory work

Before the dismantling work itself can begin on the platforms there are some preparatory works to be done. The preparations are a part of both making the platform safe to work on and preparations for the coming cutting and lifting operations. Cutting operations are not done to a great extent during the preparatory work. However, non-critical cuts like cutting of cables and pipes between modules are done.

4.1.1 Make safe- operations

The make safe- operations are done to ensure that it is safe to dismantle the platform. This is done by ensuring safe passage on the platform by establishing and marking escape routes and securing the walkways, carrying out weight control, rigging temporary systems, and also topside and jacket inspections are done. The inspections are done to find hazardous materials and structural damage. The presence of hydrocarbons and asbestos are mapped as well as

NDE is performed in the lifting point areas at the topside. The jacket survey is done by a ROV and is a visual inspection detecting flooded members and performs a detailed inspection of the planned cutting points.

4.1.1.1 Securing walkways

As an example of the make safe- operations, the securing of the walkways will be treated further. Secure walkways are essential to the traffic on the platform. It can seem like a minor task overall, but in some cases shut-down platforms can be left in place for a significant amount of time. The integrity of the walkways as well as other parts of the platform can have changed as well as grating is not always perfect in newly shut down installations either. Secure coming and going to the worksite is important to personnel safety.

Figure 10 illustrates what is necessary to do to secure the walkways on the platform. It is important to localise all the walkways and not only those that are the main walkways to secure them. The grating on the walkways can be severely corroded and this makes a safety risk to personnel if the grating yields partly or wholly when someone is walking on it. It is also a possibility that steps can be missing from stairs and ladders. This is especially the case to the escape ways to the sea underneath the topside which are affected by waves. Damages to the walkways have to be repaired in order to make the walkways safe. Marked walkways ensure that the personnel know where they are supposed to walk when going from one place to another. The use of the designated walkways can be safer than not having walkways because there is a chance of walking into a work site without knowing it. Escape routes have to be established and these are often the same as normal walkways. However, it is very important that the escape routes are properly marked with signs and lights to provide effective escaping. It is also important to have more than one escape route, because sometimes personnel are hindered in using the primary escape route. The alternative route must also be marked.

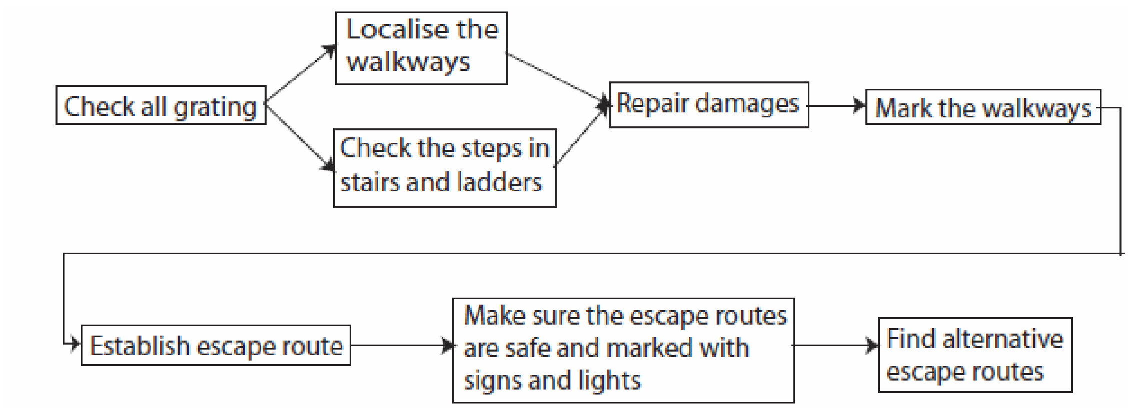

Figure 10: Steps of securing the walkways

4.1.1.2 Hydrocarbons and hazardous materials

At a platform there will be numerous materials that can be hazardous or inflammable when the removal operations commences. Hydrocarbons can still be present in pipes and equipment. When cutting operations are ongoing the presence of hydrocarbons can cause fire or explosion. Therefore it is important to detect the presence of hydrocarbons. When hydrocarbons are detected, the pipes have to be drained and cleaned before cutting and hot work commences. Figure 11 represents the process of detecting and removing hydrocarbons from the pipes.

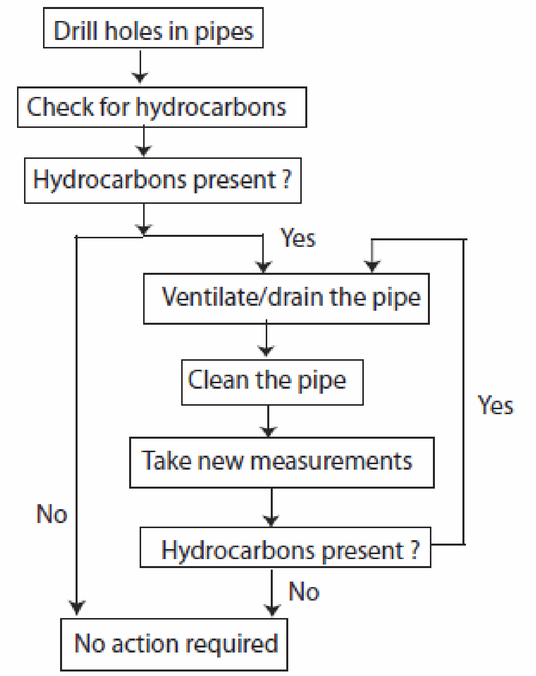

Figure 11: Removal of hydrocarbons in pipes

Testing for hydrocarbons has to be done in equipment and utility systems as well. If presence of hydrocarbons has been detected in the equipment, it can either be drained offshore or onshore. If the equipment is not drained offshore, the belonging pipes have to be blinded so that leakage is prevented during transport. When draining is performed offshore the proper procedures have to be followed. The booster platforms have presence of asbestos as well. Asbestos that is conflicting with the cutting operations will be removed. However, this is a limited amount.

4.1.2 Preparation of lifting operations

During the preparatory work it is also done preparations of the following lifting operations. The lifts will be performed using several lifting points. These points and the structure exposed to loads during the lifts must be strong enough. During the platform installation lifting points are used, and during removal those lifting aids that still are in place can be used once more if they are in good condition. The old lifting points will be prepared or new ones will be installed. NDT will have to be carried out on old lifting points according to (Det Norske Veritas 2004). Some parts of the structure will require reinforcements both for the lifting points, load bearing, and for sea fastening during transport. In addition to the strengthening of the lifting points, shackles, slings, lifting frames, and spreader bars are also being installed during the preparatory work.

4.2 Topside removal

The topside will be removed in phase one of the removal and the topside removal will follow a reverse installation concept. In the case of the booster platforms this means that the topside will be removed in modules rather as a whole. The removal of the sections will be carried out so that the removal of one section will not cause other sections to get instable. The sections to be removed have different weights and the heaviest is 2619 tonnes. Table 2 shows the sections, together with weights and dimensions.

Table 2: Topside modules for removal, (ConocoPhillips 2009)

	Modules for removal	**Weight [tonnes]**	**Dimensions L[m] x B[m] x H[m]**
1	Heli deck	120	31 x 28 x 2.6
2	3 stacks and crane boom rests	-	-
3	M10 desalter package	274	25 x 9.5 x 5.5
4	Steam generator	10	3.8 x 3.4 x 3.1
5	M3 and M4 Accommodation and Generator Module	780	29 x 29 x 12.8
6	West side laydown area	12	8 x 7.6 x 1.0
7	M6, M7, M11 pump packs and control module	2619	36 x 31.5 x 17.5
8	Caissons	20	-
9	Half of the Modular Support Frame (south part)	1141	26 x 25 x 17.5

When the topside is parted into modules the required lifting capacity for the topside removal is limited compared to lifting the whole topside in one go. This gives flexibility in the selection of lifting vessel for the topside dismantling operations. However, the lifting of the jacket can require larger lifting capacity than the topside lift. This way the lifting capacity is often selected larger than required for the topside so that the same vessel can be used in both cases. This is often convenient in any case because the vessel is already in place when the jacket removal is initiated. This reduces costs and time consumption by the mobilisation of a new lifting vessel as well as the same crew will be used which gives continuity in the project.

4.3 Jacket removal preparations

As well as for the topside, preparatory work is needed on the jacket before removal from the field. This will be done during topside removal. Loose items on the jacket will have to be removed or secured. Necessary work platforms will be installed and lifting aids like on the topside will also be put in place. Between the four platform legs it will be installed a rigging platform so that scaffolding can be built to give access to the cutting operations. Cutting tools are also being installed as well as non-critical cuts can be performed. The jacket cuts that are performed during topside removal are shown in Table 3 below.

Table 3: Preparatory jacket cuts, (ConocoPhillips 2009)

Preparatory jacket cuts
Cutting of 36” sump caisson
Cutting and removal of risers
Cutting of anodes
Preparation of external gripper area

4.4 Jacket removal

The weights of the booster platform jackets is necessary to know when the lifting operations are about to commence. The dry weights of the platforms are 4972 tons for Norpipe 37/4 A and 4376 tons for 36/22 A (Norsk Oljemuseum ; Norsk Oljemuseum). The actual weight is probably larger because of marine growth. The amount of growth is somewhat uncertain but a survey can help to find out how many additional weights there are to the jackets.

The jackets will be removed in phase two of the decommissioning project and will be removed in either one or two pieces. In the case of removal in two pieces more cuts will be performed than with the one piece alternative. Table 4 shows the activities required to remove the jacket in two pieces. Included there are many cutting operations and the cutting methods vary with the cut location. Table 5 presents the chosen cutting methods to be used in the jacket removal and where the method will be used.

Table 4: Jacket removal concept, (ConocoPhillips 2009)

Concept of jacket removal in two pieces	
1	Cutting of the inner piles of runner legs
2	Cutting of the two launch runner legs
3	Cutting of the other two inner piles and legs
4	Cutting of the corner legs of row 1
5	Cutting of the corner legs of row 4
6	Cutting of 12 bracings, horizontal plane
7	Hook on rigging
8	Cutting of the last 3 bracings, horizontal plane
9	Lifting off jacket top section
10	Cutting and removal of corner legs
11	Cutting of two corner piles of row 1, mud line
12	Cutting of two corner piles of row 4, mud line
13	Hook on rigging on the last two corner piles of row 4
14	Removal of the bottom section from the seabed

The jacket cuts in Table 4 are illustrated in Figure 12 and the numbers in the table are marked in the figure.

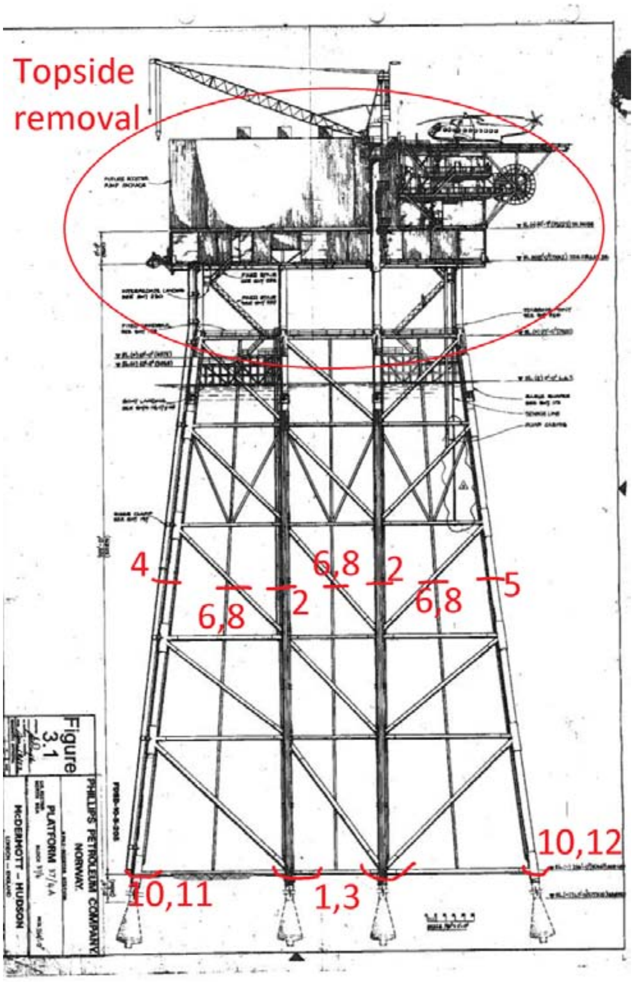

Figure 12: Ekofisk 1 booster platform jacket cuts

4.5 Cutting operations

When the topside and the jacket are to be removed in sections, cutting operations are an important part of it. Although some of the cutting is done during preparatory work most will have to be done just prior to the lifting of the sections. The topside will be cut into the modules presented in Table 2 and the jacket will be removed either as a single piece or in two pieces involving many cuts either way.

The cutting methods to be used in the different locations will be chosen as appropriate at the particular location. The methods that are relevant for the jacket removal can be found in Table 5. For most of the jacket cuts there are alternative cutting methods available. The alternative method can be used when the principal cutting method cannot be used or if it is unsuccessful.

Table 5: Jacket cutting methods

<table>
<tr><th>Cutting area</th><th colspan="2">Principal cutting method</th><th>Alternative method</th></tr>
<tr><td rowspan="2">Jacket legs and piles</td><td>Primary cut</td><td>Secondary cut</td><td>External AWJ</td></tr>
<tr><td>Internal AWJ</td><td>External AWJ at the corner legs</td><td>Diamond wire cutting</td></tr>
<tr><td>Launch runner (c/w jacket leg)</td><td colspan="2">Diamond wire cutting</td><td>Diamond wire cutting of bottom section + internal AWJ</td></tr>
<tr><td>Braces</td><td colspan="2">External AWJ</td><td>Diamond wire cutting</td></tr>
<tr><td rowspan="2">Caissons and Risers</td><td colspan="2">External AWJ</td><td rowspan="2">-</td></tr>
<tr><td colspan="2">Diamond wire cutting</td></tr>
<tr><td rowspan="3">Ancillary cuts</td><td colspan="2">AWJ</td><td rowspan="3">-</td></tr>
<tr><td colspan="2">Diamond wire cutting</td></tr>
<tr><td colspan="2">Chop saw</td></tr>
</table>

Figure 13 is a picture of a tool for cutting of piles and caissons and is using the abrasive water jetting method to make the cut.

Figure 13: AWJ tool for cutting of piles and caissons, (Kaiser and Byrd 2005)

For the topside dismantling and removal, there are several cutting methods to choose from as well and that is an advantage as there is lots of cutting needed. Cold and hot cutting methods are among the possibilities. The choice of hot or cold cutting methods depends on where the cut is made. If there is a risk of fire or explosion when heat is applied, a cold method will be preferred. But if there is no risk of fire, hot methods can be used according to (Kaiser and Pulsipher 2004). Table 6 shows examples of some common hot and cold cutting methods for the topside removal.

Table 6: Topside cutting methods

Cold cutting methods		Hot cutting methods
Method	*Example*	*Method*
Abrasive cutting	Diamond wire, grinding	Torch cutting
Pneumatic tools	Saw, drill	Arc gouging

Other methods than those referred to in Table 6 can be used as well, but the cold methods are more important than the hot because of the potential fire hazard during the cutting. Even though hydrocarbons already have been removed from the platform during the topsides preparatory work, other materials can catch fire if it is hot enough. That is why cold methods are preferred. The chosen method, abrasive cutting methods or pneumatic tools, will be used in the cases where each method is best suited. No matter which method that is chosen the necessary precautions and safety measures must be taken.

Figure 14: Illustration of diamond wire cutting of a deck leg, (Kaiser and Byrd 2005)

Figure 14 shows diamond wire cutting of a deck leg. Diamond wire cutting systems are quite versatile and can be fitted to cut many sizes and types of structures. This makes it a very useful method for topsides removal. The system can be fitted onto ROVs and it can be a useful under water cutting method as well.

4.6 Lifting operations

A central part of the offshore operations is to carry out the lifts. The lifting vessel removing the booster platforms will be a traditional heavy lift crane vessel. According to (ConocoPhillips 2009) the lifting vessel will either be Thialf or Hermod, both HLVs. Both vessels have the required lifting capacity. According to (Terdre 2008) both vessels will be used in the removal of the platforms at Ekofisk 1. Thialf will be used when dynamic positioning is required, that is when pipelines and seabed installations can be damaged by the anchor handling operations and Hermod will be used when anchoring is possible. Figure 15 shows Hermod lifting a small jacket structure.

Figure 15: Hermod lifts a small jacket structure, (Terdre 2008)

When the lifting vessel arrives onsite mooring arrangements have to be made. Both Hermod and Thialf use three anchors at each corner. All these anchors need to be put in place and anchor handling vessels will assist the HLV during this process. Thialf can use DP as well to keep its position during lifts. For personnel access between the HLV and the booster platforms a gangway will be installed from the HLV to the booster platform.

The anchor handling operations have to be done within a suitable weather window. When the anchors are in place, the HLV is ready to commence the lifting operations. However there is still a weather window to pay attention to. When the wind picks up to 6-7 Beaufort (Kaiser and Pulsipher 2004) the anchors normally will be taken up, but this depends on the sea conditions as well. There are also rules for in which conditions the gangway between the HLV and the booster platforms has to be removed. The lifting operations have to be within an approved weather window to ensure safe lifting.

When the lifting vessel is in position and moored it is ready for the lifting operations to commence. However, it has to be made sure that the lifting is safe. Therefore everything has to be checked and inspections have to be carried out. During a lift operation there are several stages. Preparations have to be done before the lifting can start. After that it is a pre-lift stage, lifting stage and an after lift stage. During the lifting stage, the load transferring is critical and checks will have to be carried out. Crane boom and hook movements have to be monitored as well even though not so critical the load transferring, and then there is the end of the lift with the lowering and release of the load.

It is during the pre-lift stage that the monitoring, safety and alarm systems are controlled as well as the sea fastening is undone. It is important to the safety during the lift that these systems are working. It is also very important to avoid falling objects during the lifts by doing inspections to detect potentially falling objects before the lift commences. Figure 16 illustrates what have to be done to commence the lifting.

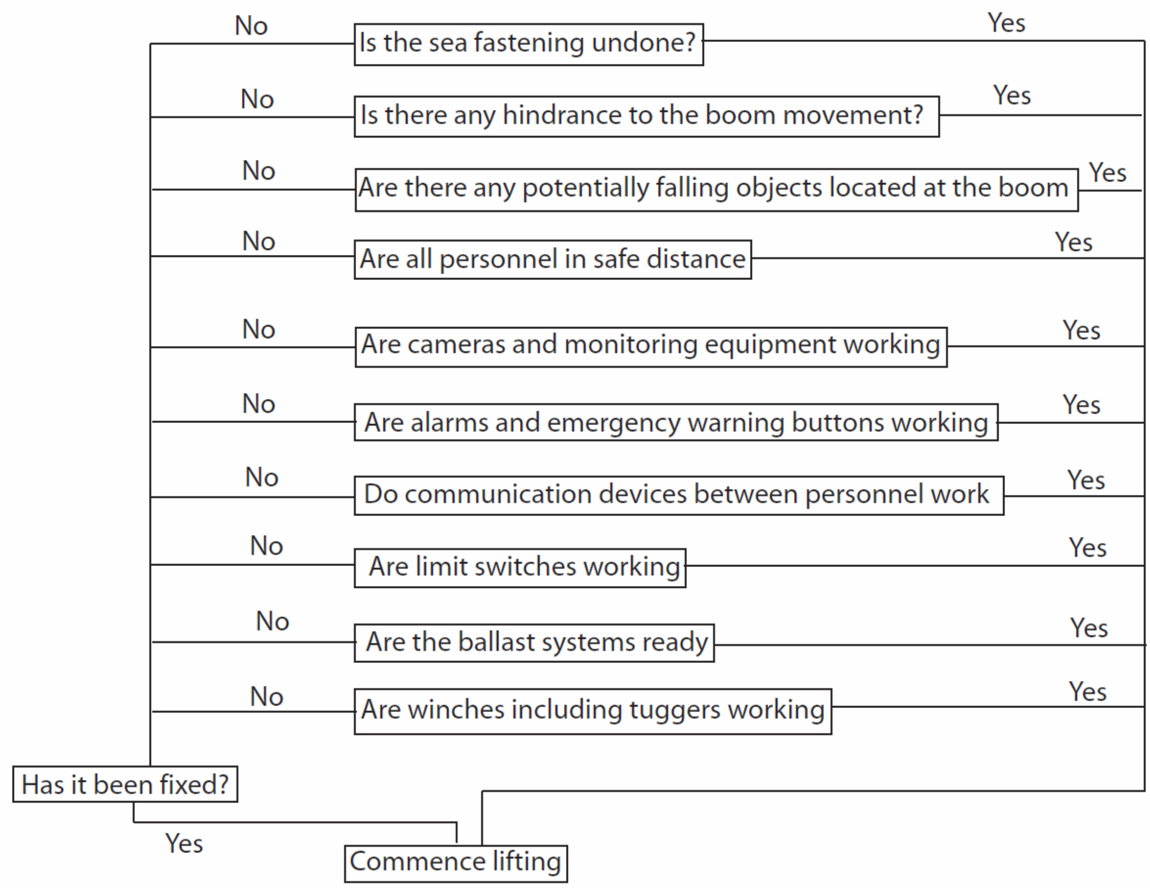

Figure 16: Pre-lift check list

The load transferring stage of the lift is very important and is the situation when the load is transferred to the crane when the lifting begins. This stage is in the very beginning of the lift and if the lift is going to be cancelled it has to be at this point. Figure 17 illustrates the check list that will have to be gone over during the load transferring.

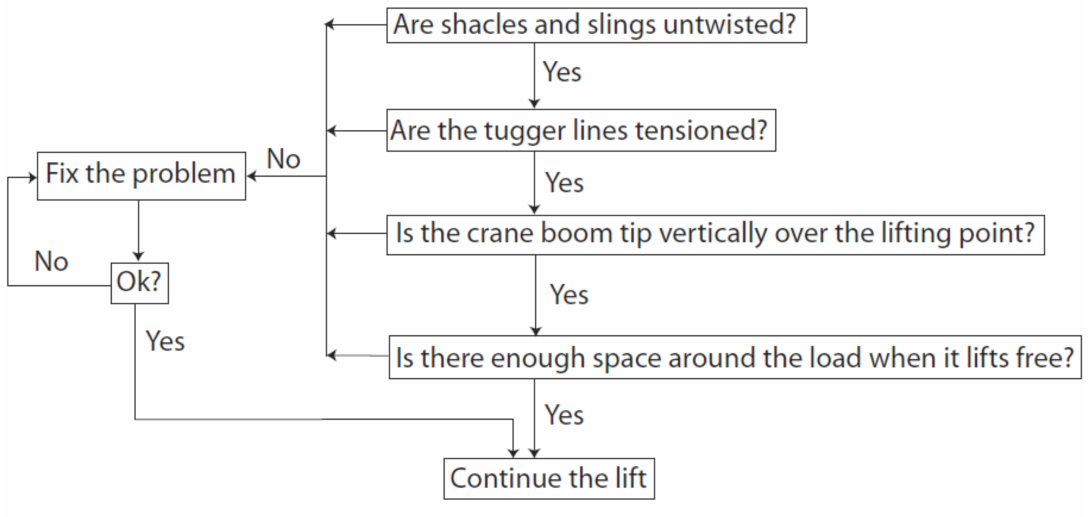

Figure 17: Load transferring check

If the load transferring check list is not completed or taken into account, the lift can turn out unsuccessful. Shackles have a design load direction and it is important that both shackles and slings are not twisted when it is loaded or they may not be able to withstand the applied load.

Tugger winches are used to assist in the lift by controlling the load and preventing it from undesired motion and their wires will have to be tensioned before the lift. The crane boom tip has to be vertical over the lifting point. If this is not the case, the section to be lifted may begin to skid when the crane start to lift. This can lead to damage to other sections or to personnel and equipment. The section to be lifted has to have enough free space around it. The reason for this is that if the load bumps into something it can damage whatever it hits as well as the crane can get loads that it is not designed for. If any of these problems are present they have to be sorted out before the lift can be carried out.

When the crane is carrying the load, there are still issues that have to be checked. Figure 18 presents some of these. In addition the weather and sea conditions will have to be monitored during the lifting operation as well as the crane vessel have to have heel and trim within the allowed limits.

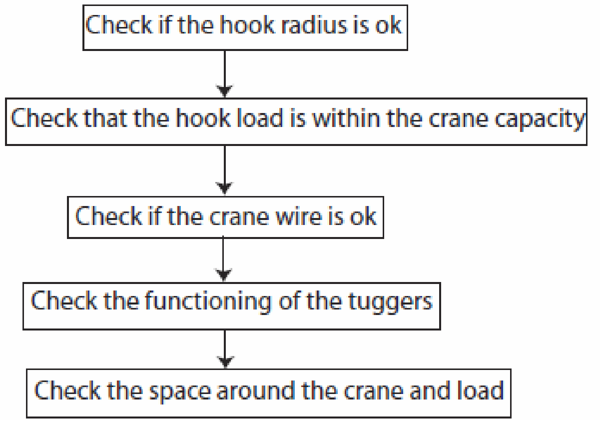

Figure 18: Boom and hook movement check

The hook radius have to be checked and by this it means that the reach of the hook have to be within the radius requirements both for the hoisting and the lowering part of the lift. The applied load cannot be larger than the crane design capacity, and it has to be made sure that it is within this capacity before the lift commences. The crane wire has to be whole and undamaged, and run freely. The tugger winches are assisting during the lift and they have to be able to feed out and take in wire as required to be able to help to guide the load like required. As well as for the other stages of the lift there has to be enough space around the crane and its load as well as safe spots must be identified where the personnel can stay during the lift.

The lowering of the load onto the lifting or transport vessel has to be done as quickly as possible when the conditions are checked. This is due to the motions of the vessels. The deck has to be strong enough to withstand the impact of the put-down of the load. This is checked on beforehand during the preparatory work.

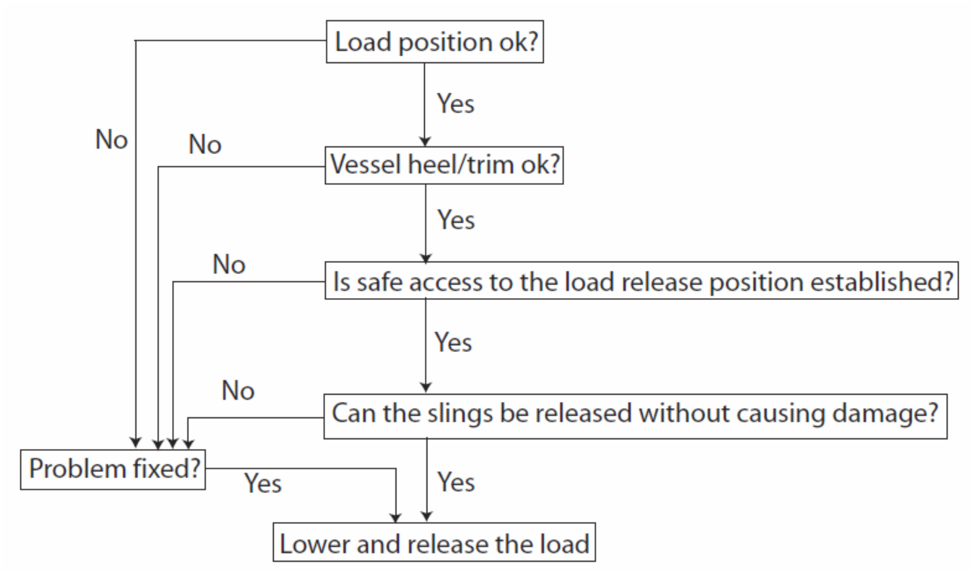

Figure 19: Lower and release check list

Figure 19 shows the check list needed for the lowering and release part of the lift. The load has to be in the correct position vertical above the target area before it is lowered. The vessels heel and trim have to be checked as well and if it is not satisfactory it can be sorted out using ballast if it is not the wave conditions that are the problem. If the sea conditions are the problem one would have to wait for the right moment to put the load down. When releasing the load from the hook the slings used can fall down at the structure below. It has to be made sure that they cannot shit fragile equipment or people when they are released from the crane hook. The stability of the vessel must be ensured as well.

4.7 Transport

The platform sections can be transported to the onshore location in several ways and the alternatives are transport on the crane vessel, self floating, as cargo on a barge or ship transport. The jacket and topsides of the booster platforms will be transported to the onshore demolition site on the HLV and some will be on cargo barges. The HLV cranes will be used to unload the barge and HLV when onshore location is reached. The booster platforms will be taken to an onshore location about 2 days sailing away from the field. Figure 20 shows a topside module from the Ekofisk 1 field being transported on the deck of Hermod.

Figure 20: A topside module from Ekofisk 1 being transported by Hermod, (Førde 2009)

When the load is put down on the deck of the cargo vessel it has to be secured for the transport. Directly after the put down is have to be temporary secured, and according to (Det Norske Veritas 2004) it has to be secured against sliding and overturning until the proper sea fastening is complete.

The full sea fastening has to be done before the transport of the modules. The sea fastening is done in the same weather conditions as the lifting operations and has the same limits ensuring among several factors, safe personnel working conditions on deck. Because of this it is an advantage if the sea fastening can be done as time efficient as possible. While as much work as possible has been done on beforehand, the full sea fastening operation can be done more quickly. It can also be the case that the transport of the platform section can start before full sea fastening has been achieved if the most recent weather forecast is promising in regards to good conditions.

Whether the transport can commence prior to complete sea fastening depends on the type of transport and if the operation is weather restricted or not. A weather restricted operation has to be finished within 72 hours. If the transport is regarded a ship transport, it can commence before full sea fastening is achieved if the weather conditions do not lead to unsafe working conditions to the personnel. Too much vessel motion can cause unsafe working conditions on deck. If the transport is on an unmanned barge, sea fastening has to be complete. If the transport is on the HLV, transport can commence with temporary sea fastening. However, change in vessel motion has to be considered. If the jacket is transported by self-floating and have buoyancy elements installed, the jacket still have to be afloat even if one buoyancy element is damaged or lost.

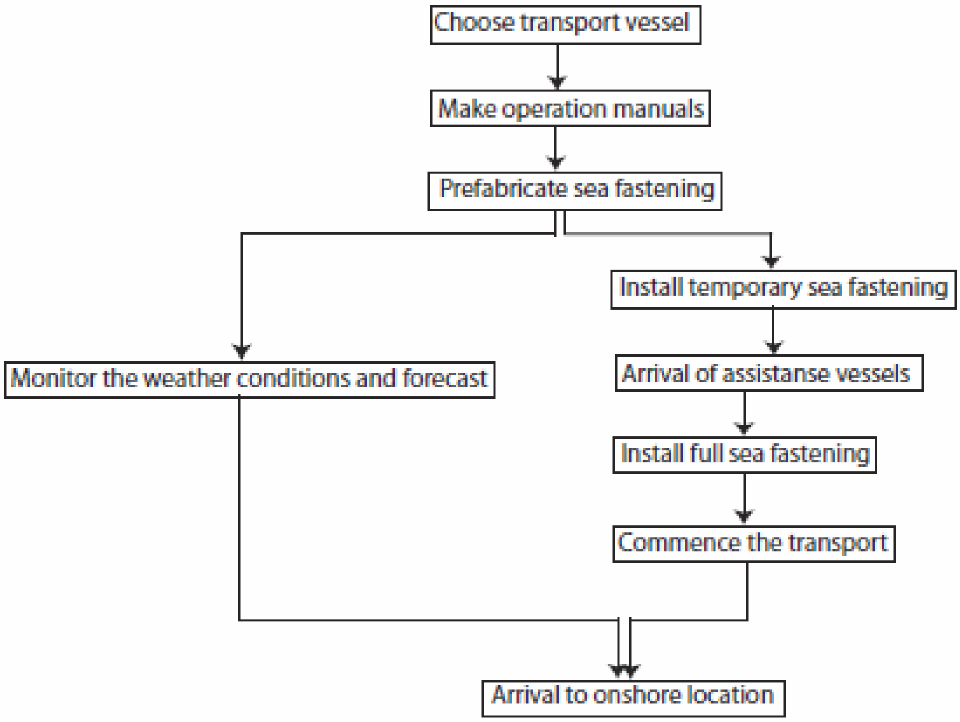

Figure 21: Offshore to onshore transportation

Figure 21 illustrates the transport from the offshore site to shore. The transport of the platform parts can be done using several alternatives as mentioned above. The choice of transport vessel is one of the first tasks that have to be done when it comes to planning the transport to shore. Operation manuals are needed as well and whether or not the operation is weather restricted is one of the aspects needed in the transport planning. How to monitor the weather and find the best weather forecast also has to be decided. It is an advantage to the offshore operation time if as much as possible of the sea fastening has been done in advance. Therefore those sea fastening measures that can be made on beforehand will be made prior to the offshore arrival of the cargo vessel. Full sea fastening will be installed offshore before the start of the transport. The transport can be assisted by towing vessels.

When the onshore site has been reached, the lifting operation described previously can be reversed. Other methods like skidding or trailers can be chosen as well. However, in the Ekofisk booster platforms case, lifting operations will be used. Figure 22 shows Hermod lift a module ashore.

Figure 22: Hermod lifts the 37/22 heli deck ashore, (Sternhoff and Nordbakken 2009)

4.8 Decommissioning overview

Above, the elements in a decommissioning project have been gone through and Figure 23 illustrates the stages in such a project. The figure is a summarisation of the previous chapters which were more detailed. It shows the main stages of a decommissioning project with the planning stage, both the topside and jacket preparatory work, topside and jacket removal, and onshore dismantling work. These stages have several elements in them and some of them are present in the figure.

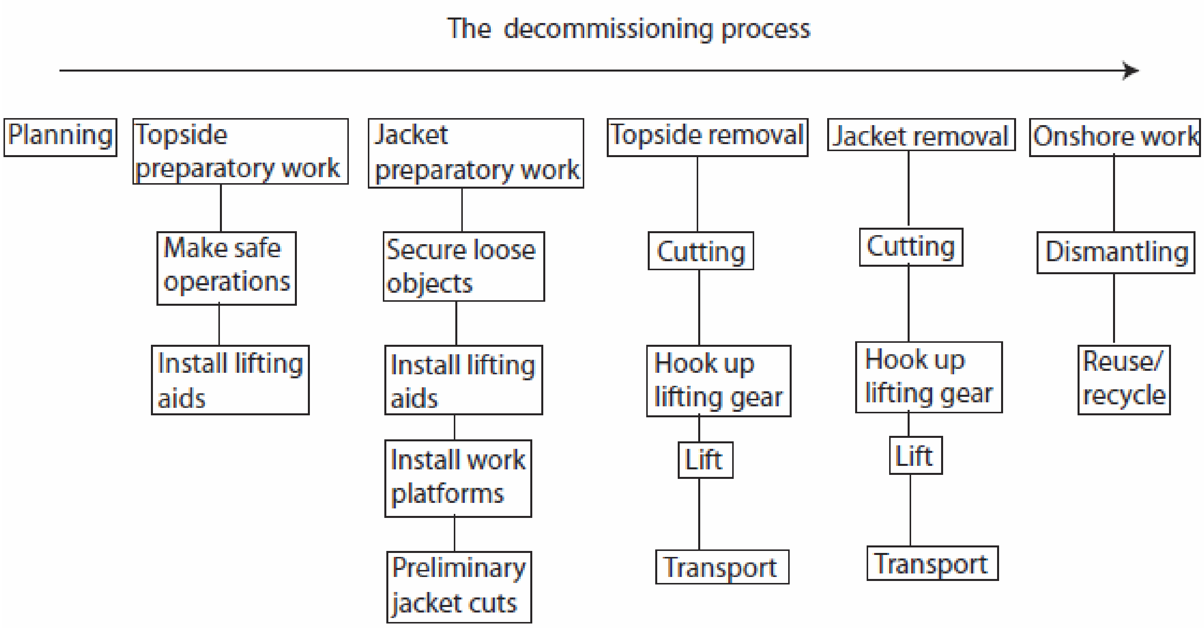

Figure 23: The overall decommissioning process

5 Decommissioning vessels

The vessels used for removal of jackets and topsides, depends on the size and weight of the items to be lifted. But it is also a matter of the type of dismantling, i.e. single lift or reverse installation. If single lift is used, larger vessels have to be used. Today, the largest heavy lifts crane vessels are Thialf and Saipem 7000. These are semi-submersibles and can lift 14200 tons and 14000 tons respectively. At the moment heavy lift vessels like these and smaller are the preferred lifting tool when removing jackets and topsides in the North Sea. Vessels like Blue Marlin are interesting in an offshore lifting point of view. However, it will not be presented here because a float over- operation is required and this is not very convenient in jacket removals. In the following sections suitable vessels for decommissioning will be presented and it has been tried to present a variety of vessel types.

5.1 SSCV Thialf

Thialf is a semi-submersible crane vessel and is one of the largest of its kind in the world. Only Saipem 7000 is near it when it comes to lifting capacity. The vessel is used in a variety of operations like installation of topsides, pipelines, and moorings among others as well as it has been used in several removal projects. Vessels like Thialf are typically used in projects that are using the reverse installation concept during removal. It can still lift topsides and jackets without cutting them into smaller modules, but that depends on the platform in question and how it was installed. The Frøy platform that was removed in 2002 located in a water depth of 120 meters is an example of a case where both the topside and the jacket were lifted off in single lifts using Thialf according to (Heerema Marine Contractors 2010; Total E&P Norge AS 2010).

Figure 24: Thialf in action, (Hereema Marine Contractors 2009)

Thialf has good stability at lifting draught, because the hull shape gives it a greater water line area at this draught. Some of Thialf's most important data are presented in Table 7. From this we can see that Thialf can lift more in a tandem lift than it can have on the deck for back-loading. This is usually not a problem because most projects so far have been far smaller. However, if more back-loading capacity is required, it is possible to hire another vessel, e.g. a cargo barge, to transport the load to shore.

Table 7: Thialf specifications, from (Heerema Marine Contractors 2007)

Vessel name	Thialf
Type of vessel	SSCV
Owner	Heerema Marine Contractors
Dimensions	
Length overall	206,6 m
Breadth	83,4 m

Draught	Max heavy lift	31,6 m	Transit	12,5 m
Accommodation	685			
Deck load capacity	Max 12000 tons, (15 tons/m^2)			
Transit speed	Max	7 knots	Back-loading	6 knots
Main hoist	7100 tons			
Auxiliary hoist	907 tons			
Whip hoist	200 tons			
Crane outreach				
Main hoist	Up to 31,2 m			
Auxiliary hoist	36 – 79,2 m			
Whip hoist	41 – 129,5 m			
Max tandem lift	14200 tons, at 31,2 m			
Lifting speed	-			
Crane outreach				
Main hoist	Up to 31,2 m			
Auxiliary hoist	36 – 79,2 m			
Whip hoist	41 – 129,5 m			
Max tandem lift	14200 tons, at 31,2 m			
Lifting speed	-			
Max hook lowering	Main (2990 tons)	351 m	Aux	460 m
Maximum lifting height above work deck level	Main	95m		

5.2 HLV Oleg Strashnov

This section will present the HLV Oleg Strashnov which is planned for delivery in June 2010 according to (IHC Merwerde Offshore & Marine 2010). The owner company Seaway Heavy Lifting Ltd. has another HLV as well, the Stanislav Yudin. I have chosen to present Oleg Strashnov because it will have the double capacity compared to Stanislav Yudin. It does not need assistance from Neftegaz 66, an anchor handling tug/ supply vessel, either. It will also be delivered shortly as well as using the same proven concept as Stanislav Yudin.

Figure 25: Oleg Strashnov

Oleg Strashnov is a mono-hull heavy lifting vessel and is showed in Figure 25 as well as some of its specifications are presented in Table 8. The hull is constructed with both transit speed and lifting stability in mind. At transit draught it has the capability to obtain a transit speed of 14 knots. It is also able to lift of 800 tonnes at this draught making it possible to operate in shallow waters. The high transit speed can be obtained because of the narrow hull at transit draught. The widest part of the hull is 47 meters to ensure heavy lift stability, but at transit draught the breadth in the water line is smaller. The high speed and the fairly large lifting capacity of the vessel make it a good alternative for many offshore lifting operations and it is the largest of the mono-hull lifting vessels according to (www.shl.nl 2010).

Table 8: Oleg Strashnov specifications, (Seaway Heavy Lifting 2007)

Vessel name	Oleg Strashnov					
Type of vessel	HLV, mono-hull					
Owner	Seaway Heavy Lifting Ltd.					
Dimensions						
Length overall	183 m					
Breadth	47 m					
Draught	Max heavy lift	13,5 m	Transit	8,5 m		
Accommodation	Max 395 persons, double cabins					
Deck load capacity	10 tons/m^2					
Transit speed	Max	14 knots	Back-loading	-		
Main hoist	5000 tons					
Auxiliary hoist	No. 1	800	No. 2	200		
Whip hoist	110 tons					
Crane outreach						
Main hoist	Up to 32 m					
Auxiliary hoist	Up to 72 m					
Whip hoist	-					
Max tandem lift	-					
Lifting speed	-					
Max hook lowering	-					
Maximum lifting height above water level	Main	102m	Aux. 1	134 m	Aux. 2	110 m

5.3 Pieter Schelte

So far quite traditional lifting vessels have been presented. Now a new concept will be gone through. The Pieter Schelte is a platform installation and decommissioning and pipe laying vessel. The building of the vessel was decided in 2007 and it has a planned delivery in 2013 according to (Allseas 2010).

Figure 26: Pieter Schelte, (www.allseas.com 2009)

The vessel is designed using two tankers that are joined into a catamaran, and it is designed to use the single lift concept. The lifting capacity will be larger than for traditional lifting vessels. The topside lifting capacity will be 48000 tons and for jackets it will be 25000 tons and this increases the lifting capacity from today's limits. This can be useful in the future when larger platforms will be decommissioned. The natural projects for Pieter Schelte will be topsides and jackets that are too large to be lifted in a single lift with today's vessels. When it comes to the size of the topsides that can be handled they have to fit into the bow slot of the vessel. This requires no more than 51 meters distance between the jacket legs. When it comes to weather requirements it can lift topsides and jackets in up to 3,5 meters significant wave height(Allseas 2010) and this is quite good compared to other vessels. As for so many heavy lift vessels, as much as possible of the preparatory work will be done by other vessels prior to the onsite arrival of Pieter Schelte. This is mainly to save money because the heavy lifting vessels are more expensive than the other vessels involved.

Table 9: Pieter Schelte specifications, (Allseas 2010)

Vessel name	Pieter Schelte			
Type of vessel	Catamaran			
Owner	Allseas			
Dimensions				
Length overall	382 m			
Breadth	117 m			
Draught	Max heavy lift	-	Transit	-
Bow slot	122 m x 52 m			
Accommodation	571 persons			
Deck load capacity	-			
Transit speed	Max	14 knots	Back-loading	14 knots
Max topsides lift	48000 tons			
Max platform leg spacing	51 m (to fit in the bow slot)			
Max jacket lift	25000 tons			
Jacket height	>70 m			

5.4 Versatruss

Versatruss uses a truss system to perform single lifts. It is especially good for topside lifts and jacket lifts are uncertain (Byrd and Velazquez 2001). Trusses and winches are installed on two barges and during lifts the barges will be placed on opposite sides of the platform. Underneath the topside, winch wires will be connected and trusses are hooked on further up on the topside sides. The barges are pulled closer to each other using the winches and this causes the lift as the trusses are forced upwards.

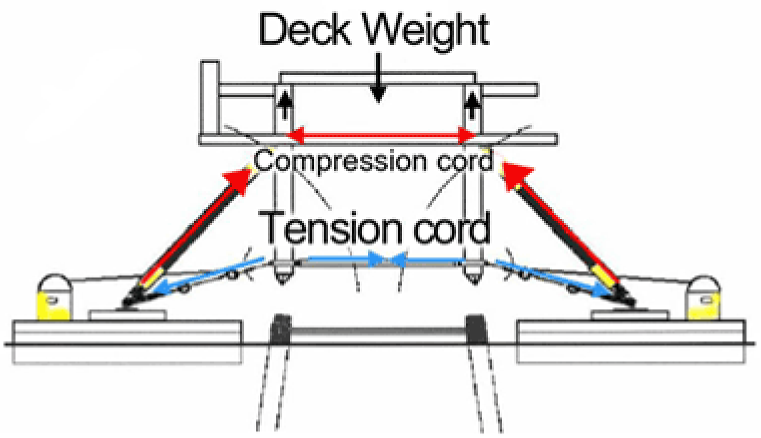

Figure 27: Versatruss concept, (Versatruss Americas)

Afterwards the topside can be lowered onto a cargo barge and will be taken to shore. It can also be transported in the lift position between the barges like a catamaran setup. Figure 28 illustrates this setup. The catamaran setup has shown to be stable. The transport can also be arranged with a cargo barge and the versatruss in a trimaran setup and this is stable as well.

Figure 28: Topside lifted by the versatruss system, (Cash 1998)

The Versatruss system is not that much used, but in 1997 a topside of 1350 short-tons was lifted (Cash 1998) as well as a 6100 short-ton topside was lifted in 1999 (Devine 2000).

Although not proven yet, the Versatruss system has a large potential for lifting capacity as standard parts are used for it and the size of it can be increased. According to (Devine 2000) it will be possible to lift 25000 tons with the Versatruss system only by increasing the dimensions. The system can be installed on conventional barges which makes the construction time of the system shorter than for other lifting vessels. The Versatruss has a small draught also during lifting and this is useful in shallow waters close to shore.

Table 10: Versatruss system specifications, (Cash 1998)

Vessel name	-			
Type of vessel	Barges fitted with a truss system			
Owner	Versatruss Americas			
Accommodation	0			
Deck load capacity	-			
Transit speed	Max	-	Back-loading	8-10 knots
Max topsides lift	6100 - 25000 tons			
Max jacket lift	25000 tons			

5.5 Jumbo Javelin

Another mono-hull lifting vessel is the Jumbo Javelin built in 2004 from Jumbo Shipping. The company has another similar vessel, Jumbo Fairplayer. These are equipped with a dynamic positioning system. The company also have two vessels without DP that is otherwise similar. The lifting capacity is on the smaller side compared to the other vessels that have been presented so far with a maximum of 1800 tons load using two cranes of 900 tons in a tandem lift. All the same, it can be used in the lifting of smaller platform sections which after all have to be lifted too or the larger modules can be parted into smaller sections. However, for larger platform removals the vessel will probably not be the only vessel and it will more likely be an assistance vessel, doing the smaller lifts.

Figure 29: Jumbo Javelin, (Vuyk Engineering Rotterdam B.V 2010)

Table 11: Jumbo Javelin specifications, (Huisman - Itrec 2003; Jumbo Offshore 2009; Jumbo Shipping 2009)

Vessel name	Jumbo Javelin			
Type of vessel	HLV, mono-hull			
Owner	Jumbo Shipping			
Dimensions				
Length overall	144,21 m			
Breadth	26,7 m			
Draught	7,5 – 8,1 m			
Accommodation	20 (max 50)			
Deck load capacity	7 – 12 tons/m^2			
Transit speed	17 knots			
Main hoist	900 tons			
Auxiliary hoist	No. 1	37,5 tons	No. 2	37,5 tons
Sling handling hoist	2 x 10 tons			
Main hoist outreach	Ca 25 m at 900 tons			
Max tandem lift	1800 tons			
Lifting speed	2,3 m / min (for similar 800 ton crane)			

5.6 Buoyancy tanks

Buoyancy tank assemblies can be useful when removing jackets and they are clamped onto the jacket corner legs. The tanks presented here were designed by Aker Solutions, and they were used successfully during a jacket removal at the Frigg field. Three vessels were used to install the tanks on the jacket (Total E&P Norge AS 2008) and it took approximately 20 hours to install each of the tanks (Rodseth and Olsen 2009). The BTAs that was used in that case can lift jackets with weights from 6000 to 18000 tons depending on the jacket legs and their floatability according to (www.offshore-mag.com 2009). Figure 30 is a model of the BTAs installed at the Frigg field DP2 jacket.

Figure 30: BTA installed at the jacket, (Total E&P Norge AS 2008)

The re-float at the Frigg field was done with a jacket of about 9000 tons plus 2000 tons of marine growth and grout according to (Total E&P Norge AS 2003). If bigger tanks are needed it should not be a too big challenge to build tanks to fit the requirements. Figure 31 shows a model of the buoyancy tank. When the tanks are being used a certain water depth is required during the tow, because the jacket will always have a certain draught. Near the onshore demolition site a suitable deep water location to put the jacket on the sea bed.

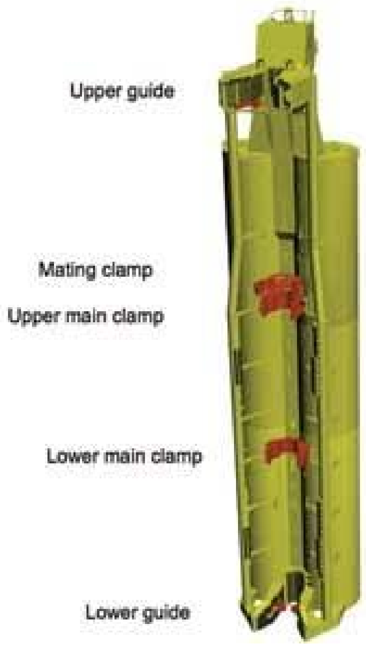

Figure 31: Buoyancy tank model, (www.offshore-mag.com 2009)

To use the BTAs, preparatory work has to be performed both in and above the water. This involves clearing the jacket corner legs of marine growth, anodes, and additional steel like pile guides. In addition, there is needed some excavation around the piles around the seabed as well as some of the piles have to be cut. Weldments have to be installed on the jacket legs so that loads can be transferred from the BTAs to the jacket. These are some of the tasks that have to be done to prepare for lifting a jacket using the BTAs according to (Total E&P Norge AS 2003).

5.7 Other vessels

In the following section it will be presented some concepts that have not yet been realised. Some of the concepts might not ever be seen in operation. However, the concepts themselves are interesting, but the amount of available information is often limited.

5.7.1 Twin Marine Lifter

The first vessel on the list is the Marine Twin Lifter from SeaMetric. The vessel development has come very far, but in January 2010 the company went bankrupt. A vessel was supposed to be delivered in 2009 according to (Ree 2009), but this was never done because of delays at the Chinese ship yard as well as financial issues.

Figure 32: Twin Marine Lifter, (gcaptain.com 2007)

The Twin Marine Lifter can lift both topsides and jackets and uses a single lift concept to do so. The lifting capacity will be 20000 tons according to (Marintek 2009) and the design have potential to lift more as well if that is requested. The lifting system consists of two vessels positioned on opposite sides of the platform. Each vessel has several lifting arms hinged to the vessels and together these lift the object. The lifting arms use a principle of leverage using ballast and buoyancy tanks inside the lifting arms to control the lifting force, and each lifting arm can lift 2500 tons according to (Marintek 2009). For transport, the pieces will be lifted onto a cargo vessel.

The system can perform lifts in sea states with wave heights of 2 meters according to model tests performed by Marintek (Marintek 2009). One advantage of the Twin Marine Lifter is that the lifting operations will be unmanned so that there is very low risk to personnel.

5.7.2 MPU Heavy Lifter

Another concept is the MPU Heavy Lifter and it does not seem to be anywhere near to being built at the moment. The building of one of these vessels had commenced at Keppel Verolme, Netherlands, but when the owner company MPU Offshore Lift went bankrupt in 2008 the building ceased (Hand 2008).

Figure 33: MPU Heavy Lifter, (Hellestøl 2007)

The MPU Heavy Lifter is a u-shaped semi-submersible concrete rig that lifts using ballast water. The vessel has one concrete column in each of its four corners and during the lifts ballast water is taken out and in of these columns. The vessel is designed to lift both topsides and jackets using the single lift concept. The lifting capacity is not a fixed number and it depends on the load that will be lifted and its height above water. This is due to the ballasting of the vessel. With a height above water of ca. 25 meter, 14000 tons can be lifted and the maximum capacity is 38000 tons (Nestvold 2002). However, this maximum load is with a height of only 6 meters, and this is very unlikely in real scenarios so the real maximum capacity is probably more like 20000 tons (Hellestøl 2007). The capacity will be larger for jackets than for topsides because of the height above water issue.

The rig has a DP system for positioning during the lifting operations, but it needs assistance during transport, and for long distance transports it can be carried by a heavy lift ship according to (Www.offshore-mag.com 2007).

5.7.3 Marine Shuttle

The next vessel in question is the Marine Shuttle. This has not been built either and the reasons for this are unclear.

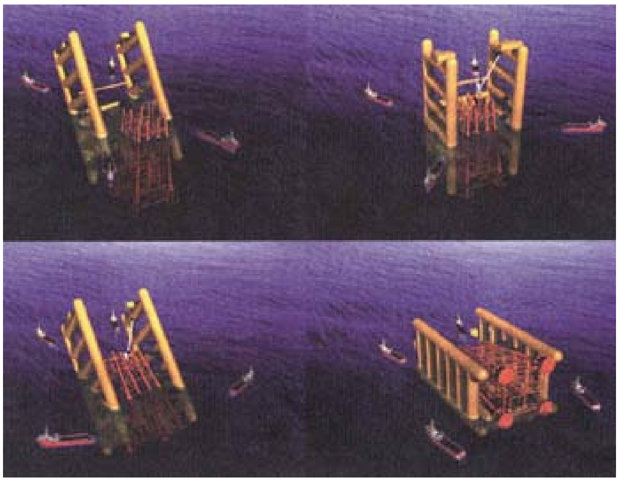

Figure 34: The Offshore Shuttle in action, (Www.offshore-mag.com 2007)

The Marine Shuttle uses ballast water to perform the lifts, but the concept is different from the MPU Heavy Lifter. However, it is a u-shaped structure as well. The shuttle uses water ballast to lower, rotate and lift. The Marine Shuttle is designed to lift topsides up to 25000 tons (Www.offshore-mag.com 1998), but can lift jackets as well as showed in Figure 34. During the jacket lift the shuttle will be rotated and lowered alongside the jacket and to lift the shuttle is de-ballasted. For topsides removal it will be positioned under the topside and de-ballasted to lift the topside. The sea state during the lifting operation can be 2-3 meters according to (Www.offshore-mag.com 1998).

5.7.4 GM Heavy Lift

The GM Heavy Lift is a concept of which there is little information, and it is probably not close to being built at this point. It uses the single lift concept when lifting and is designed to lift up to 12000 tons according to (Byrd and Velazquez 2001). It is a semi-submersible rig that is fitted with a u-shaped extension, (Byrd and Velazquez 2001). This extension is very good at removing topsides. It will need towing for transport, but have a DP system (Byrd and Velazquez 2001) so that anchoring is not required.

5.7.5 TPG 500 IDV

Technip- Coflexip already has a jack-up platform design called TPG 500 that is used for a production platform and it is used among others at the Elf Elgin field (www.decomplatform.com). The TPG 500 IDV will use the same design as TPG 500 and it will be fitted with the required deck modules to carry out lifting operations. One of its advantages compared to other decommissioning vessels is that it will be fixed to the seabed while lifting (www.decomplatform.com). This reduces dynamic response problems due to weather conditions. The lifting capacity will be 14000 tons and maximum water depth is 120 meters (www.decomplatform.com). The water depth limitations restrict the use of the vessel and make it useless in deeper waters.

Figure 35: A variant of TPG 500, (Technip 2008)

6 Vessel comparison

The previously presented lifting vessels will now be compared to each other. The vessel concepts presented in section 5.7 will not be a part of this comparison. There is little information about them and they are not going to be available in near future anyway. However, the marine shuttle operations can get time-consuming when the jacket that will be lifted is too big to fit inside the u-shape or if the jacket is too heavy. It is not known whether or not this is a disadvantage compared to other vessels.

6.1 Lifting capacity

The first property that will be compared is the vessel lifting capacity and Table 12 contains the capacities for the different vessels.

Table 12: Vessel lifting capacities

Vessel	Main hoist lifting capacity [tons]	What is lifted	Removal concept
Thialf	2 x 7100	Topside/Jacket	Reverse installation
Oleg Strashnov	5000	Topside/Jacket	Reverse installation
Pieter Schelte	48000	Topside/Jacket	Single lift
Versatruss	6100 – 25000	Topside	Single lift
Jumbo Javelin	2 x 900	Topside/Jacket	Reverse installation
BTA	6000-18000 (four tanks)	Jacket	Single lift

From these lifting capacities we can see that the potential lifting capacity of Pieter Schelte is far greater than any of the other vessels and Jumbo Javelin has by far the smallest capacity. Even though the Jumbo Javelin has a large lifting capacity for its type it could not have lifted all the modules in the Ekofisk booster platform case were the largest module was approximately 2600 tons. It is likely to be too small for most decommissioning projects. The vessels will have satisfactory lifting capacity for most decommissioning projects except for Jumbo Javelin.

The choice of vessel with regards to lifting capacity depends on the removal concept and whether or not both topside and jacket are to be removed. Of the above mentioned single lift concepts only Pieter Schelte is well-suited for both topside and jacket lifts. It is most common to use vessels like Thialf when the decommissioning is undertaken as a reverse installation project. It can however lift topsides and jackets in single lifts if the structures can handle the applied forces and the lifting capacity is large enough. Of the vessel that most often uses reverse installation good examples are Thialf and Oleg Strashnov. The lifting capacity of Thialf is superior. However, this large capacity is not always required and vessels like Oleg Strashnov could have been used instead. The choice of vessel can probably be subject to availability.

6.2 Transit speed

Transit speed can be a quite important contributor to the project economy and the time spent on transport impacts the overall cost. There are two kinds of situations where speed has to be considered, pure transit and back-loading, i.e. transport of platform sections. Transit speed influences the vessel mobilisation time and the vessels possibility to cover larger distances efficiently. Back-loading speed is most important when the lifting vessel is used for the transport of platform parts. This is normally done for most single lift vessels and sometimes for HLVs. Back-loading speed is important to the total operation time when the vessel needs to perform more lifts onsite after the transport.

Table 13 presents the transit and back-loading speeds for the different vessels, some are given and some are not, some are assumed. For Thialf the speeds are given. For Oleg Strashnov and

Jumbo Javelin the back-loading speed is not given, but as they are ships that also can carry deck load to the field when used for installation, it can be assumed that transit speed and back-loading speed for these two vessels are about the same. The assumption for Pieter Schelte is the same. The buoyancy tank transit speed is rather low, but the tanks will be towed horizontally to the site and likely at a higher speed. The versatruss system is installed onto ordinary barges and these are not usually designed with the most efficient hydrodynamic shape. Therefore similar speeds to the back-loading can be assumed for the ordinary transit.

Table 13: Vessel transport speed

Vessel	Transit speed [knots]	Back-loading speed [knots]
Thialf	7	6
Oleg Strashnov	14	-
Pieter Schelte	14	14
Versatruss	-	8 – 10
Jumbo Javelin	17	-
BTA	-	2,5

There are three vessels that are on the high side when it comes to transport speed, Oleg Strashnov, Pieter Schelte, and Jumbo Javelin. This gives them an advantage compared to slower vessels. For Pieter Schelte it is essential with high speed compared to other vessels as it is a single lift vessel that will be used for transport of the platform pieces to shore as well. This way it can take the cargo to shore and come back to the field ready for new lifts in an acceptable time period. The other vessels can load the pieces onto cargo barges or similar for transport if more lifts are required shortly after another. It can be assumed that Thialf's speed is similar to other vessels of its type and the Versatruss is slightly faster than the semi-submersibles. The BTAs have the slowest back-loading speed of all the concepts. However, this is natural as the jacket is transported vertically in the water. This limits the speed in which the jacket and tanks can be towed.

6.3 Cargo capacity

In decommissioning projects the vessel cargo capacity is more important for returning platform sections to shore than for any other purpose. Single lift vessels often carry the platform parts to shore themselves while the others use other vessels/barges for transport. Therefore the back-load capacity of the single lift systems is assumed to be the same as the lifting capacity of the vessel. There is little point in the ability to lift more than what can be carried to shore on the vessel if the vessel have to take the cargo to shore.

Table 14: Back-loading capacity

Vessel	Back-loading capacity	
	Total [ton]	**[tons/m^2]**
Thialf	12000	15
Oleg Strashnov	-	10
Pieter Schelte	48000	-
Versatruss	6100 – 25000	-
Jumbo Javelin	-	7 – 12
BTA	6000 – 18000 (four tanks)	-

It is probably not the back-loading capacity that decides whether or not a vessel is chosen for a decommissioning project or not. The single lift vessels can take to shore the same they can lift and the others can use cargo barges for the transport if necessary. All vessels have a good cargo capacity per area so it should not be a problem in most cases. Thialf with its large lifting capacity will have to get help from another vessel/barge for the transport if the whole lifting capacity is utilized.

6.4 Onsite positioning

How the lifting vessels are getting into position on site can be important for the total operation time. Traditionally lifting vessels have been using anchors and need anchor handling prior to the lifting operations. This is more time consuming than if anchor handling could have been avoided. Vessels similar to vessels like Thialf, Oleg Strashnov and Jumbo Javelin are often using anchors.

Table 15: Onsite positioning

Vessel	Positioning aid
Thialf	DP or anchor
Oleg Strashnov	DP or anchor
Pieter Schelte	DP
Versatruss	Assistance vessels for positioning, mooring to the platform
Jumbo Javelin	DP
BTA	Assistance vessels for positioning, then clamped onto the jacket

None of the above-mentioned concepts need anchor handling onsite which is time saving compared to vessels that needs it. However, the Versatruss system and the BTAs need vessels for towing to site and positioning on site. The versatruss system will be in place in less time than the BTAs because the BTA positioning is more complex. The BTAs need to come from horizontal to vertical position. Then they have to be clamped onto the jacket legs and secured, and this operation has to be done for all of the four tanks. That is clearly most time-consuming than the other alternatives.

6.5 Sea-keeping considerations

One of the challenges not only for decommissioning projects but for all projects that involves heavy lifts is the weather conditions. Waiting for the weather can be expensive and it is not very productive either. Normally heavy lift operations is done in sea states with significant wave heights of 1,5 meters and less. It is possible to design vessels that handle a larger weather window than traditional HLVs. It is claimed that Pieter Schelte will have the possibility to carry through lifting operations in significant wave heights up to 3,5 meters (Allseas 2010) because of its big size. According to (Andresen 2004) a limit will be set at 2,5 meters of significant wave heights because of general safety aspects. The good properties of Pieter Schelte during lifting will have to be proven in trials before being put into offshore service. The versatruss system is so far proven during topside installation in transport state with weather conditions with 50 mph wind speed and squalls of six-foot seas (Devine 2000).

With this in mind it can be assumed that it can operate in normal heavy lift operation conditions and for the other vessels considered here it can be assumed the same limits as well.

Table 16: Sea-keeping properties

Vessel	Max Hs [m]	Hull type	Hull properties
Thialf	1,5	Semi submersible	Greater WL area at lifting draught
Oleg Strashnov	1,5	Mono-hull	Greater WL area at lifting draught
Pieter Schelte	3,5 (2,5)	Catamaran	-
Versatruss	1,5	2 x barge	Catamaran setup during lift and back-loading
Jumbo Javelin	1,5	Mono-hull	-
BTA	1,5	-	-

From Table 16 it can be seen that most of the vessels is likely to be able to operate in the same weather windows with an exception for Pieter Schelte that can operate in a larger weather window because of its large size. The vessel is not yet delivered so it has to be emphasized that the given operational limit may not be entirely as good as the real limit.

When it comes to the hull designs there are different types represented and some of them have features that can be useful during the different operations. Both Thialf and Oleg Strashnov have an increased width at heavy lift draught. This increases the water line area at this draught and increases stability as well as it is possible to keep a higher transit speed with a more slender hull at transit draught. The versatruss system has proven to be stable in the catamaran and trimaran setup during transport, at least in the above mentioned conditions.

6.6 Operation time

The effectiveness of the operations impacts the project economy. For single lift vessels the time to perform the first lift and the total operation time are important aspects. For most projects the total operation time is the most important of these aspects and it can be compared to other HLV performances. Single lift vessels will be able to remove topsides quicker than when reverse installation concept is used. Factors that contributes to the overall operation time is according to (Andresen 2004) the distance to shore, offloading time, and reconfiguration of the lifting system for jacket lift or topside lifting points. If these are unfavourable for the single lift vessels the advantage of making the first lift faster than the others will be reduced compared the HLVs.

When it comes to the HLV cranes' lifting speeds, they can be unknown. This is the case for Thialf. For Hermod, a similar vessel with smaller capacity, the lifting speed is known. According to (ConocoPhillips 2009) Hermod's two main hoists can lift 4000 and 5000 short tons at 4,3 m/minute. Similar lifting speed can be assumed for Thialf. The lifting speed is also known for the cranes on Jumbo Javelin and the lifting speed is 2,3m/min. The lifting speed alone does not predict the time consumption of the lifting operation. Also important are necessary preparations, transport arrangements, and how many objects are being lifted.

Table 17 shows the planned schedule for a jacket removal at the Frigg field. The actual installation of BTAs in the Frigg project was 20 hours per tank and the jacket tow to shore was two and a half days at 2,5 knots speed. The preparation time and the lifting time are unknown.

Table 17: Frigg DP2 jacket removal, the planned schedule of activities, (Total E&P Norge AS 2008)

Activity	Planned Start	Planned Finish
Phase 1 - Preparation work above-water and subsea	07.05.08	17.06.08
Phase 2 - Buoyancy tank assembly installation	18.06.08	12.07.08
Phase 3 – Float up and tow	12.07.08	24.07.08

The time required to prepare the platform prior to lifting operations with the different concepts is unknown. Table 18 is an attempt to rank the different concepts in terms of the required preparatory work.

Table 18: Ranking of the amount of required preparatory work before lifting, from the least to most

	Ranking of required preparatory work
1	Pieter Schelte
2	Versatruss
3	Thialf
3	Oleg Strashnov
3	BTA
3	Jumbo Javelin

Pieter Schelte requires the least preparatory work because it is going to lift topsides and jackets in single lifts. Cutting is required of the piles fixed to the seabed and to separate the jacket and topside as well as strengthening of the topside if necessary. For the Versatruss system cutting is needed to separate topside and jacket as well as lifting points has to be prepared. The single lift systems use several lifting points and this give less forces on the structure which is the reason why platforms that consists of modules can be lifted in a single lift. It is assumed that the remaining concepts require about the same amount of preparatory work. It is easy to imagine that the concept of using BTAs requires less preparatory work than the other remaining concepts because they use the single lift concept, but actually quite a lot of preparations are needed.

Lifting speed is only known for Thialf and Jumbo Javelin and is shown in Table 19. It can be assumed that Oleg Strashnov has about the same lifting speed as Thialf rather than the same as Jumbo Javelin because of the crane size.

Table 19: Lifting speed

Vessel	Lifting speed [m/min]
Thialf	4,3
Oleg Strashnov	4,3
Pieter Schelte	-
Versatruss	-
Jumbo Javelin	2,3
BTA	-

Even though the lifting speed information is inadequate, it can be assumed that the single lift systems do not lift any slower than the others.

6.7 Economy aspects

The ever important factor in industry projects is economy and the vessel choice can influence the project economy. There are several factors that influence the project economy that come of the vessel choice. It is the manning, the total operation time, the vessel day rate, and more. All of these factors are hard to know for sure, but the following will be an attempt to get an overview of the situation.

It can be assumed that BTAs and the versatruss system are cheaper to manufacture than any of the lifting vessels. This is due to the difference in size as well as that the versatruss uses fairly standardised components. The day rates will be subject to the popularity of the chosen concept as well as the availability of the vessel type. When it comes to the BTAs, more can probably be built if they turn out successful. Thialf that can lift heavy and has only one competitor for the heaviest lifts is likely to have one of the highest day rates. To keep the costs down it is beneficial to do as much of the preparatory work as possible before the arrival of vessels like Thialf. Oleg Strashnov will probably be a vessel with high day rates because of the high lifting capacity. It can keep high transit speeds and lifts at the same speed as Thialf, making it better than Thialf and similar vessels when the lifting vessel also transports the lifted objects to shore. Jumbo Javelin has probably lower day rates than the vessels with larger lifting capacity. The smaller size gives it a disadvantage because more lifts will probably have to be undertaken unless the platform is very small. Pieter Schelte is a large vessel with large lifting capacity and will probably have high day rates. However, the weather window is larger than for the other vessels as well as the transit speed is good. High day rates can probably to some extent be made up for by the weather window and transit speed.

6.8 Safety

When it comes to safety there are several factors involved. It is safety to the vessel, environment, and personnel. When it comes to the safety of the vessels it has to be assumed that they all are seaworthy and have approved sea-keeping properties in given the weather conditions. When it comes to environmental safety it comes down to the risk of spills and losing parts when lifting. This can however be avoided with high quality preparations. Well proven concepts are easy to trust because they have worked many times before and they will probably work many more times. This can favour long existing systems ahead of new systems. Existing systems also do not experience run-in errors like new systems can either.

Personnel safety will be further treated. The required manning to carry out the operations contributes to the safety. When many personnel are working it can be hard to keep track of where everyone else is working and what they are doing. Vessels that require less onsite preparatory work to carry out the lifts can be safer to the personnel because there are fewer workers required and less concurrent operations. When much preparatory work is required, there will be many concurrent operations, and the work has to be carefully planned. This is especially the case when the reverse installation concept is used where lots of the worker safety is impacted by the planning on beforehand and the good management during the operations.

Table 20 ranks the various concepts' level of experience, manning, need for preparatory work and concurrent operations. The manning requirements are based upon assumed amount of offshore work and the accommodation possibilities aboard the vessels. It is assumed that when the vessel can accommodate lots of people, those people are likely to be needed to carry out the preparations and lifting operations. It is also assumed that the amount of preparatory work and concurrent operations depends on each other and the time schedule. For removal operations with Pieter Schelte the topside and jacket will be separated and the topside may need strengthening to withstand the lifting forces. In those cases where the topside needs comprehensive strengthening the preparatory work will require lots of manpower. This does not necessarily mean that there are lots of concurrent operations going on at different places on the topside. If most of the preparatory work has been carried out before the lifting vessel's arrival, fewer personnel are needed.

Table 20: Factors that influences safety

Vessel	**Level of ...:**			
	Experience	**Manning**	**Preparatory work**	**Concurrent operations**
Thialf	Proven	High	High	High
Oleg Strashnov	New (larger version of proven concept)	High	High	High
Pieter Schelte	New	Medium	Medium	Low
Versatruss	Limited in decommissioning	Low	Medium	Low
Jumbo Javelin	Limited in decommissioning	Low	High	High
BTA	Limited	Low	High	Low

Thialf is well proven which enhance the safety level, but it requires high manning, much preparatory work and concurrent operations which reduces the safety level. Oleg Strashnov is in almost the same category as Thialf, but it is new. It is however, a larger version of another lifting vessel, the Stanislav Yudin, which is proven in heavy lifting and there is no reason why Oleg Strashnov will not be too. Pieter Schelte is new and the concept is new as well. The manning can be high, but the preparatory work and the amount of concurrent work is less than for Thialf even if the accommodation capacity is high. It is therefore ranked a bit safer for personnel than Thialf and Oleg Strashnov. The versatruss system scores well in manning, preparatory work and concurrent operations. It is not much used in decommissioning, but the factors that contribute to the overall safety level considered here are good. Jumbo Javelin has small lifting capacity so it has not been used much in decommissioning, but the manning of the ship is low which indicates that the vessel cannot provide personnel to do all the preparation work itself. Other vessels will therefore have to take part in the operations and the total manning will probably be on level of Thialf and Oleg Strashnov. The overall personnel safety will probably also be about the same as with Thialf. When it comes to the BTAs the experience is limited having being used during one jacket removal. Lots of preparatory work is needed, but with a proper schedule there is no need for that many concurrent operations, and the manning requirements will be low. This gives a high safety level in total.

6.9 Overall

Now several aspects of the vessels have been presented and there is no answer to what is best. Whether or not a vessel is chosen for a job depends on the project in question and the planned use of the vessel. Regardless of this, a summarisation will be given.

Thialf and similar vessels are well-proven in offshore lifting and in decommissioning as well. Compared to the other vessels the transit speed is perhaps its disadvantage. However, the large lifting capacity is sometimes required even in projects that follow the reverse installation concept.

The versatruss system provides good redundancy due to several lifting booms and not only one or two like in traditional HLVs. The lifting operations can be reversed easier than with traditional HLVs. Unlike the other lifting systems it is moored to the platform.

It is assumed that the Jumbo Javelin can lift both topside and jacket with a reverse installation approach. It will however be too small for most projects and some of the modules that will be lifted might have to be cut smaller of the original modules into smaller pieces due to low lifting capacity.

Pieter Schelte has a large lifting capacity and the best weather window of all the concepts considered here, making it a good alternative if the platform can be removed in single lifts.

When it comes to the BTAs they are tried on the Frigg field in the North Sea, so it should be a feasible solution in other areas as well. They are also cheaper to manufacture than to build new lifting vessels. Even though the transport to shore is slow and there is a need for assistance vessels to get into position and during the tow, they can still be a good alternative for jacket removals. But a lifting vessel will have to lift the topside.

The decommissioning challenges regarding economy and the weather windows are related to the vessels involved. The decommissioning season is rather short because of the weather restrictions that apply. Project economy is influenced by day rates and time required for offshore operations. So there are benefits in reducing the offshore operation time and increasing the weather window in which the operations can take place. Pieter Schelte seems to be a step in the right direction when it comes to extending the weather window. The overall time consumption depends on many factors and these can be vessel dependent, but the field distance to shore is not. If it is relatively short distance to shore, the single lift concept will have an advantage because the transit to shore can be done quite quickly. Even when a lot of preparatory work is needed the first lift can be done by single lift before the traditional HLVs could have done it. The short transport time will then make sure that the jacket can be lifted out in one piece long before it could have been done with HLVs and the reverse installation method. There are several factors influencing the time consumption as well and it has to be considered in each project to find the best suited vessel to be involved in the operations.

7 Future requirements

Future requirements in decommissioning are based upon the location, size and number of platforms, the standards and regulations, available equipment and vessels, and previous experience.

7.1 Regulations and standards

Today there are international regulations as well as national and area specific regulations concerning decommissioning of offshore petroleum facilities. The international regulations are decided by IMO and they specify that offshore facilities are to be removed, but certain facilities can be left. The IMO regulations often function as a basis for national and area specific regulations which can be stricter. In the North Sea area there are the OSPAR regulations which state that all the facilities are to be removed. There are exceptions for installations heavier than 10000 tons and others that are hard to remove. This is stricter than the corresponding IMO regulations.

It is not unlikely that the above-mentioned regulations will be changed in the future and that they will require the removal of even larger structures. There has been an increased consciousness about the environment and resource use for several years, and the general comprehension is that it is not ok to dispose of waste everywhere. On this basis there is no reason to assume that the regulations will be less strict. On the other hand there will be more and more facilities needing decommissioning and it can turn out expensive to remove all of them. The reason for this is that there is no income from the field anymore when it has reached the end of its life time. The money needed to carry through the removal will have to be taken from somewhere else.

In addition to international and national regulations, standards treat matters in most industries, and they are important in making sure that a certain quality level is reached. There are many standards that cover offshore industry, but there are few that cover the decommissioning stage. Often standards concerning installation will be used during removal, and as far as possible these will be met. Together with the national regulations this ensures the safety during the operations. It is likely that those standards that are made already will be developed and that new ones will be made as well.

7.2 Equipment

In order to optimise the decommissioning process the equipment involved can be one of the keys to more effective operations. There is already good equipment used for removal. Examples of this are diamond wire cutting tools which can do topside cutting as well as being fitted onto ROVs to do underwater cutting. Nevertheless, the range of decommissioning equipment can always be improved. An example of newly developed equipment for decommissioning is the SBC mentioned in section 3.5. When the SBC is ready for commercial use, it will be a step towards a complete range of well-suited decommissioning equipment.

When it comes to vessels used during removals there are at the moment mostly traditional HLVs available, but especially the new Pieter Schelte is an interesting contribution to the lifting vessel fleet. Other designs have been developed as well without being built. The BTAs is interesting for jacket removal especially because they can be built to suit the required lifting capacity. However, a deep water site is needed at shore to do the dismantling. The vessel and equipment choice depends on what is available in the area and how well suitable it is for the job. This will be the case in the future as well.

7.3 Challenges

Decommissioning challenges depends on the size and location of the platforms and the challenges are not likely to become any fewer in the future. The petroleum industry moved into increasingly deeper waters. This required larger platforms and many are fixed to the seabed. The larger platforms are more expensive and difficult to remove. Floaters and subsea installations are not considered here. According to (Lakhal, Khan et al. 2009) about 470 installations at UKCS await decommissioning at some point. This goes for 10000 km of pipelines, 15 onshore terminals, and 5000 wells as well. The number on Norwegian continental shelf is generally lower than this. According to (Pulsipher and Daniel Iv 2000) there are 39% large platforms in the North Sea/North Western Europe and 11% in GOM. That is when a platform is defined as large when it is larger than 4000 tons. There are large platforms in other areas as well and by current international regulations these do not have to be fully removed. Area specific regulations may apply. In the North Sea these have to be removed because of the OSPAR regulations. However, 23 very large concrete platforms have an exemption from the rules (Pulsipher and Daniel Iv 2000) and will be left in place. The regulations might be changed in the future in other areas to be stricter than they are now.

When decommissioning concept is chosen, there are several considerations to make. The platform removal alternatives are given by regulations, but how to carry out the decommissioning so that it complies with them can different from case to case. Previous experience from similar projects is important in choosing the way of doing it. It is often convenient to choose about the same solutions that have worked in earlier projects of similar type. However, this experience will be varying and depends on the number of platforms having been decommissioned in the area. In the future this experience will have increased because more platforms will have been removed. The GOM area has much of this experience already at least in shallower waters.

Presently there are a limited number of heavy lift vessels that can lift larger platform modules and the single lift concept vessels will be a welcome contribution to the fleet. When Pieter Schelte is delivered and when it gets some experience and proves its capabilities, it is likely that the scepticism that seems to follow new concepts will decrease. The number of heavy lift vessels can prevent projects from being executed at a desired point in time, because the vessels are involved in installation and other projects as well. Therefore there is a need for more heavy lift vessels and preferably those that can operate in a wider range of weather than the traditional HLVs. In many ways Pieter Schelte seems to be a good alternative because of its lifting capacity, the single lift, and the improved weather performance. Other new designs can still be introduced, even if those mentioned in section 5.7 are not close to the realization.

Currently it is possible to improve the carrying through of decommissioning projects. Basically this means to do them as cost-effective as possible and at the same time complying with current regulations. This can mainly be achieved by doing less work at the offshore site, carrying out less lifts offshore, and do a lot of the dismantling work onshore.

8 Future decommissioning concepts

The most common method of platform removal using traditional HLVs will be challenged by future concepts and some of them are quite close to being a real competitor to the HLVs and their reverse installation concept. However, the HLVs are likely to be involved in removal operations in all future because they are proven in such operations as well as some installations have to be removed using the reverse installation concept. It depends on the build and geometry of the platform which concept is best suited. Now, two concepts will be reviewed here that are good alternatives to SSCV lifting only and that can be more used in the future. The first concept chosen is already tried out with success and that is topsides removal using a HLV and buoyancy tanks will perform the jacket lift. The second concept will be removal using Pieter Schelte which is designed with decommissioning in mind as well as other tasks. The delivery is planned in 2013 so this option is not available yet, while the concept using HLV+BTA is. The chosen concepts are chosen because they are quite recent and promising developments as well as being able to lift jackets and topsides reasonable efficiently. Single lift systems like Pieter Schelte and the BTAs are designed to take part in removal of medium to large platforms and because of this they are well-suited for the future requirements in offshore removal.

In order to present the promising concepts for future removal, they will be compared to removal using only a HLV. A case is chosen to do the consideration of the future concepts versus the traditional. The case will be the removal of a platform with topside of 26000 tons and a 13000 tons jacket in the North Sea. It is assumed that the topside can be lifted in one piece by a single lift system. It is also assumed that by use of a HLV like Thialf or Oleg Strashnov it will be a similar amount of topside lifts like the Ekofisk 1 booster platforms treated earlier where the topside were removed in 9 modules. It is assumed that the lifting vessels are located in the North Sea or nearby areas when they are mobilised as well.

Finding out how cost-effective a removal concept is requires accurate data. As such data is not available. The comparison will be undertaken using assumptions about which of the concepts that require most or least resources. It is also assumed that a time consuming process also generates the largest costs.

8.1 Traditional removal concept

The traditional removal concept is usually a concept in which a HLV of the semi-submersible type is being used and the removal is done in the reverse installation order. Although HLVs can lift topsides in single lifts when the topside can withstand the loads, the lifting capacity is limited even for the largest vessels. In a case with a topside of 26000 tons the lifting capacity of any of the traditional HLVs is not enough anyway and it will be removed in modules. Most removals are done during summer because the weather conditions are best at that time. The HLV weather window is limited and there is a challenge to increase this as well as the preparatory work is extensive with its many cutting operations. On the other hand the HLVs are experienced in the decommissioning process and they are useful in those cases where the topside cannot be lifted in one piece. In this case it is assumed that the HLV can operate at DP to avoid lengthy anchor handling operations.

8.2 Removal with HLV and BTA

The next removal concept consists of topside removal using HLV and jacket removal using the BTAs. The HLV used can be a SSCV like Thialf or similar or a mono-hull like the new Oleg Strashnov which have good capacity. One of the advantages of the BTAs is that they can be modified to fit several sizes of jacket legs so that they can be modified to fit larger jackets than what is tried out so far. The size of the BTAs compared to a ship or semi-submersible vessel makes it way more affordable to custom fit the BTAs to each jacket. This is a huge advantage in the North Sea where many platforms are one-off and different from each other. The BTAs have already proven themselves in a real project even though the experience is limited. There is no reason why it should not work on other jackets as well.

8.3 Removal with Pieter Schelte

The last concept to be reviewed is removal using the Pieter Schelte. The vessel has a large lifting capacity and there is a motion compensation system for the lifting operations to eliminate some of the wave response, (Allseas 2010). Topside lifts is carried out using the vessel's bow slot and it is large enough to fit most platforms. This makes it possible to lift most structures in a single lift, but if it does not fit, it will have to be lifted in modules. The lifting method does not require the accurate topside weight and this is an advantage because less time can be spent on calculating the weight compared to other methods. To lift the topside, clamps are used to attach the lifting vessel to the topside and these have to fit to the object. These have to be prepared in beforehand according to the geometry and will be a part of the Pieter Schelte mobilisation. Pieter Schelte can operate in a larger weather window than other lifting vessel. In addition to this the light ice class ensures that the vessel can operate in many areas. This can be a great future advantage if more facilities are installed in colder waters.

8.4 Comparison

All of the concepts presented here will be able to remove the case platform and others. Now they will be compared to each other with a view to the different aspects involved in a decommissioning project. The comparison is presented in Table 21 where the different concepts are given a score from 1 to 3 for each of the involved activities. The lowest score is the most time-efficient and is therefore the most cost-effective. This is a simplification as the time consumption and the cost of the different activities are not equal in the first place. It can however be an indicator.

When it comes to mobilisation it was assumed that the vessels already were localised in the North Sea area and all the concepts are given an equal score. This is done because the HLV does not need any adjustments, but its transit speed is on the slow side. The HLV + BTA concept is likely to have the same mobilisation time as the HLV only as the HLV is used first and the BTA can be adjusted when the HLV is being used. At last, Pieter Schelte has a good transit speed, but the clamps need some adjustment to fit the platform in question. For all the concepts as much of the preparatory work as possible will be done before lifting vessel's offshore arrival to keep the costs down. However, Pieter Schelte requires less preparatory work than the others which needs about the same amount of preparatory work done. When it comes to rigging activities most rigging is required for removal using HLV. Pieter Schelte needs the least amount of rigging and the HLV+ BTA is in between. All these concepts require a lot of assistance from vessels other than the lifting vessel. The main reason for this is the preparatory work which is done prior to the lifting vessels arrival onsite as well as that the BTA needs to be positioned by three vessels.

Weather downtime can be costly in all offshore operations and Pieter Schelte has the largest weather window of these concepts. Pieter Schelte has a large accommodation capacity, but when preparatory work has been done before its arrival much of the accommodation capacity is redundant and the manning requirements will be lower than for the other concepts. The installation of the BTAs requires less manning than HLV jacket removal so even if the involved HLV requires lots of manpower to carry out the topside lifts it is still lower than for the HLV only concept. The manning requirements are also subject to the amount of preparatory work required. Single lift systems use less lifts to remove topsides and jacket so Pieter Schelte is best when it comes to lifting costs and the concepts with the BTAs follows. To transport the platform parts to shore the HLV can do the transport, but the most time-efficient is to transport the objects on a cargo barge so that the HLV can proceed directly to next lift. Pieter Schelte will do the transport itself and have to take the topside to shore before commencing to the jacket lift. The transport speed is quite good, but if the distance to shore is long it will take some time to get back to the site. The jacket transport using the BTAs will be slow, but the BTAs are not needed on the site after the jacket transport because the platform has been removed. Therefore there is no rush to finish the transport. An exception however could be if the platform removal is part of a campaign of several removals. The cost of onshore work depends on how much there is to do. There is always a lot of onshore work required, but objects lifted in a single lift requires more onshore work than for objects that already have been cut and cleaned. Onshore work is however cheaper than the same work offshore. The scores of the above-mentioned factors are presented in Table 21.

Table 21: Concept comparison, the lowest number is the most efficient

Activity	**HLV only**	**HLV + BTA**	**Pieter Schelte**
Mobilisation	2	2	2
Preparatory work	3	3	1
Rigging	3	2	1
Other vessel assistance	2	3	2
Possible weather downtime	3	3	1
Manning	3	2	1
Lifting operation	3	2	1
Transport	1	2	3
Onshore work	1	2	3
Total	21	21	15

Overall in this comparison Pieter Schelte is the winner. The obvious reason is that lifting larger objects saves lifting time as well as there is less offshore work. It is also designed to carry out decommissioning from the beginning and is therefore well-suited to perform the tasks efficiently.

Now we have seen that for medium to large platforms removal a single lift system like the Pieter Schelte can be cost-effective. The main reason is already mentioned which is that less offshore lifts and work are required because of the large objects that are being lifted. Single lift systems can lift small objects as well, but their advantage is most obvious for large objects. The lifting operation requires about the same amount of time for both small and large objects. Hence, the heavier objects, the larger cost saving when using a single lift system like Pieter Schelte. The traditional HLVs can therefore compete with the single lift systems on less heavy lifts. Disadvantages for the traditional HLVs are the age of the fleet. The HLV will need more maintenance than the newer single lift solutions. The HLV only removal requires lots of personnel compared to the single lift systems as well as the total lifting time is longer as well. On the other hand, the single lift methods have to be proven in operations before trust is gained in the system and the investment cost of the system can be paid off.

Pieter Schelte will be a very good contribution to decommissioning once it is delivered. Personnel will be exposed to less risk when more work is done onshore because onshore dismantling is in general more inexpensive, faster, cleaner, and safer. This gives a better HSE profile as well as being more cost-efficient.

9 Conclusion

In this report decommissioning of offshore petroleum platforms have been investigated. Decommissioning is important to go through with because of the environment and the use of the area after the petroleum activities ceases. Other ocean users benefit from the decommissioning because the area can be utilized when it is opened for ordinary traffic. The environment will benefit from the cessation of production because of fewer spills to sea or risk of it and being restored to a state as close to possible to original. Sometimes it is found acceptable to leave facilities behind, partially or wholly, and the marine life in the area can actually benefit from this in some cases.

There has been an increased consciousness about the environment and resource use for several years and decommissioning regulations can become stricter than they are at the moment. As the petroleum industry developed, it moved into increasingly deeper waters. This required larger platforms and many are fixed to the seabed. These have to be decommissioned, but larger platforms are more expensive and difficult to remove.

A decommissioning project consists of the elements planning and approval, topside and jacket preparatory work, topside removal, jacket removal, transport, and onshore dismantling and recycling. There are two main concepts of removal, reverse installation and single lift. The elements of the project are the same whichever of the concepts are used. The vessels to be used need large lifting capacities in either concept, but presently there are a limited number of heavy lift vessels that can lift larger platform parts and new vessels will be a welcome contribution to the fleet. Especially designs that lift topsides and jacket in single lifts can improve the efficiency in the projects.

Several lifting vessels have been presented and a few concepts were reviewed regarding the future requirements. The concepts were platform removal using only a traditional HLV, topside removal using HLV and buoyancy tanks for jacket removal, and removal using the new lifting vessel design Pieter Schelte. It is found that all the concepts can remove fixed platforms, but Pieter Schelte was especially well suited. When Pieter Schelte is used, personnel will be exposed to less risk because more work is done onshore. Onshore work is in general more inexpensive, faster, cleaner, and safer. This gives a better HSE profile to the project as well as being more cost-efficient. On the downside, the vessel is not available before 2013. In the meantime the alternative with the HLV and buoyancy tanks can gain some more experience. This alternative scored the same as removal with reverse installation and is therefore not so successful in this comparison. There are however uncertainties involved and the solution with the buoyancy tanks are still interesting.

The challenges in decommissioning are to make it less expensive, less time-consuming, and safer than today as well as keeping the environmental issues satisfactory. This can probably be reached by making the process more standardised to some extent, making use of new technologies like new vessels, doing less work at the offshore site, carrying out less lifts offshore, and do a lot of the dismantling work onshore. Pieter Schelte can to a great extent be the solution to these challenges.

10 Further work

For further work on decommissioning more details should be found. There are too many uncertainties regarding this topic at the moment even if the broader picture is quite clear.

More details are needed about the decommissioning market such as number of facilities and sizes in different areas, types, and whether or not the single lift approach is feasible.

It is also lacking information about both available and possible future vessels when it comes to operation times, weather restrictions and economy among others. It could also be interesting to more information about involved equipment.

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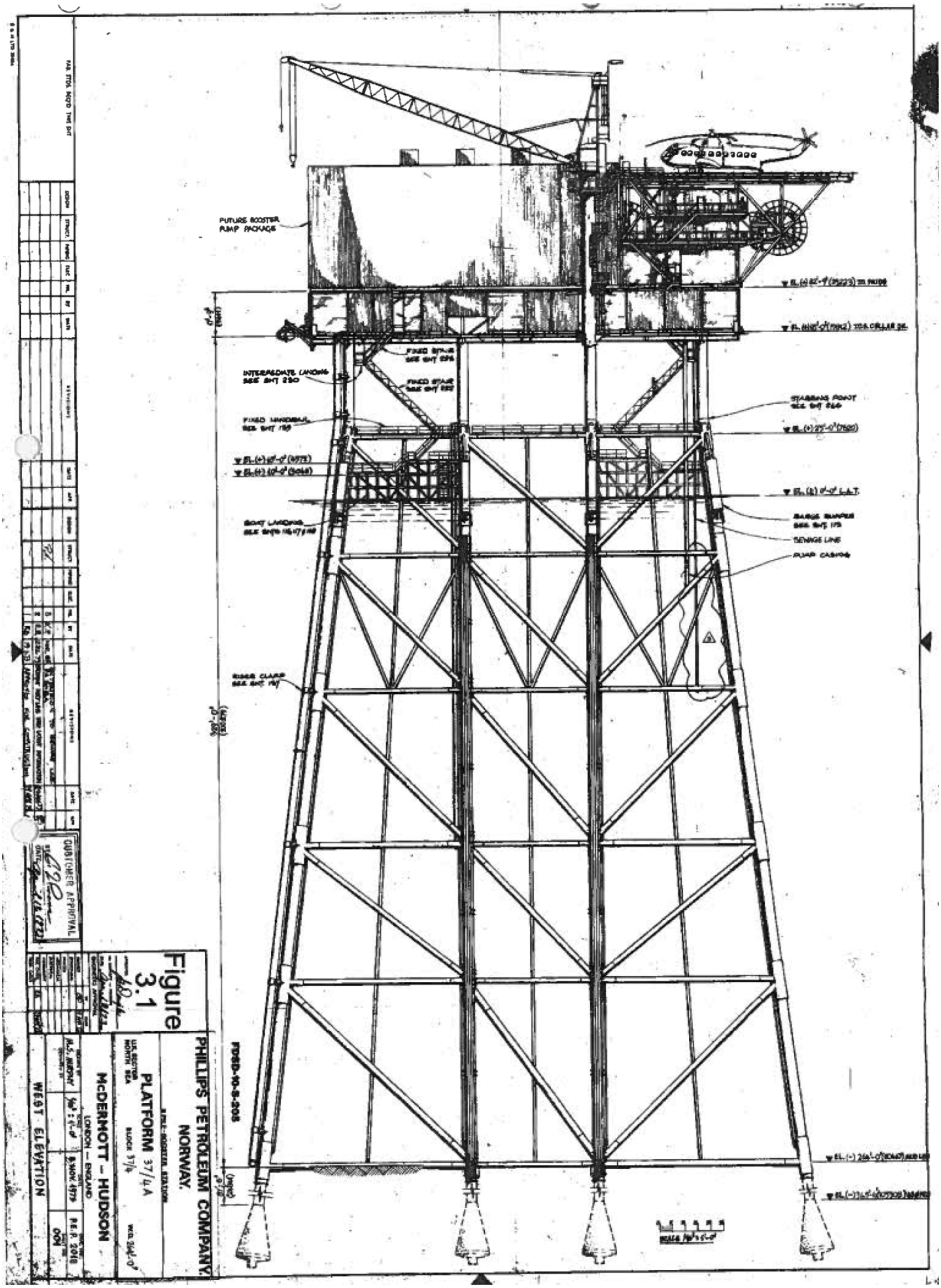
Appendix 1: Ekofisk booster platform 37/4 A – West elevation

Drawing from (ConocoPhillips 2009)



Appendix 2: Ekofisk booster platform 37/4 A – South elevation

Drawing from (ConocoPhillips 2009)