Bachelor's project

NTNU
Norwegian University of Science and Technology
Faculty of Natural Sciences
Department of Materials Science and Engineering

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A comparative analysis of dual drilling methods as an aim to reduce the costs of drilling

Bachelor's project in FTHINGOG
Supervisor: Behzad Elahifar
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TOGT3001 - Bachelor Thesis Oil and Gas Technology

A comparative analysis of dual drilling methods as an aim to reduce the costs of drilling

Sammenliknende analyse av dual drilling metoder for å redusere borekostnader

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Aker BP ASA
Open thesis

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Preface

The work on this thesis was firstly made possible by Aker BP creating the subject for this project and secondly by the excellent assistance from both Aker BP as well as several distinct industry actors like Odfjell Drilling and Maersk Drilling who shared reports, documents, and relevant presentations for data collection and concept understanding. We would like to extend our deepest appreciation to all the people that helped us in collecting this information, and provided us with the necessary material to achieve a good understanding of the topic. A special thanks to our internal, NTNU, supervisor Behzad Elahifar for playing a supportive, kind, and understanding role during the work done on this thesis. His reassuring advice and concrete guidance have assisted us in an immeasurable way. To our external, Aker BP, supervisor Geir Håkon Steinsheim we would like to thank for both providing us with the contact information of people within the industry, and for all the time spent in helping us properly understand the topic. It was trough him that we got the opportunity to visit the Deepsea Stavanger, a visit which made this thesis truly enjoyable to work on. We would also like to extend our deepest appreciations to all the people from Odfjell Drilling who received us at Hanøytangen and showed us their impressive rig. A special thanks to Olaf Sissener from Aker BP who shared information with us that proved crucial for both the theory, conclusion, and discussion sections in our thesis.

Abstract

Dual drilling concepts for dual activity drilling, full dual drilling, top hole dual drilling, and dual riserless drilling were studied based on data collected from the industry. The aim was to investigate the potential of the various dual drilling concepts to reduce costs and NPT during drilling operations. Full dual drilling and dual riserless drilling is yet untested and hence our data is based on predictions. Yet the analysis of dual drilling seems to show that up to 30% of drilling costs can be reduced from implementing dual drilling concepts as a standard drilling method. There are several challenges ahead, the main ones being the required amount of capital investment and the successful development of necessary technologies.

Sammendrag

De ulike konseptene for dual drilling er dual activity drilling, full dual drilling, top hole dual drilling, og dual riserless drilling er blitt gjennomgått basert på data og informasjon samlet sammen fra ulike aktører fra industrien. Målet har vært å undersøke potensialet dual drilling konseptene har til å redusere kostnader og NPT for boreoperasjoner. Full dual drilling og dual riserless drilling er et uprøvd konsept, og data vi har brukt er basert på simuleringer. Vår analyse av disse dual drilling konseptene antyder at besparelsene kan utgjøre opp mot 30% av totale borekostnader sammenlignet med konvensjonell boring. Hovedutfordringene for dual drilling er kapitalinvesteringene, som er ganske betydelige, og dette er en utfordring git dagens markedet og lengden på borekontrakene.

Contents

1 Introduction

Across the oil and gas industry, cost and revenue are absolutely essential. If the market is stable, and the price is high enough, industry actors can accept a higher cost picture. If uncertainty is present in the market, and revenue is affected by lower oil prices, the industry must have a higher focus on its costs. Under current circumstances, drilling is the largest single contributor to total costs of field development and hydrocarbon production. Figure 1 illustrates a relevant cost distribution for the development of a generic hydrocarbon field. As figure 1 shows, drilling operations amount to just under 50% of the total costs, while the remaining costs are split between subsea design and construction, pipeline acquisition and installation, and procurement of a production unit. This thesis focuses on dual drilling as a way of reducing drilling related costs.

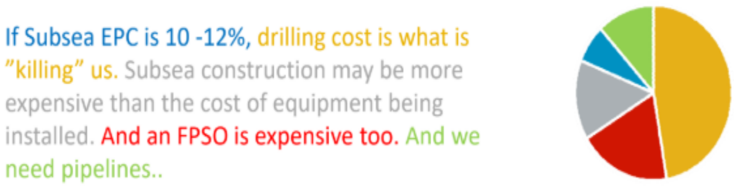


Figure 1: Generic field development cost distribution (Berge 2021)

Figure 2 shows an overview of the change in oil prices since the start of the Norwegian oil industry, correlated with the three main industry development periods. The yellow line marks the discovery and initial production of hydrocarbons on the Norwegian shelf. The green line represents the time period of establishing and expanding the national oil sector, while the red line marks the further maturation of the industry.

With regards to industry development as correlated to cost fluctuations, the green area is of interest as it represents a time of greater uncertainty and decline in oil prices, and shows the possibility of developing the industry in a cost friendly manner. This contrasts with the red period where the increase in oil prices and reduced uncertainty led to a cost explosion where the cost development increased along with the oil price.

As the drilling costs constitute the largest cost portion, this bachelor thesis aims to contribute to the discussion on how the Norwegian oil industry should be competitive in the future by analyzing the scope for dual drilling programs. This thesis aims to provide a thorough understanding of:

- Dual drilling capabilities of a selection of drilling vessels.
- Operational sequence management
- HSE and staffing requirements
- Dual drilling concepts and procedures
- Relevant technologies

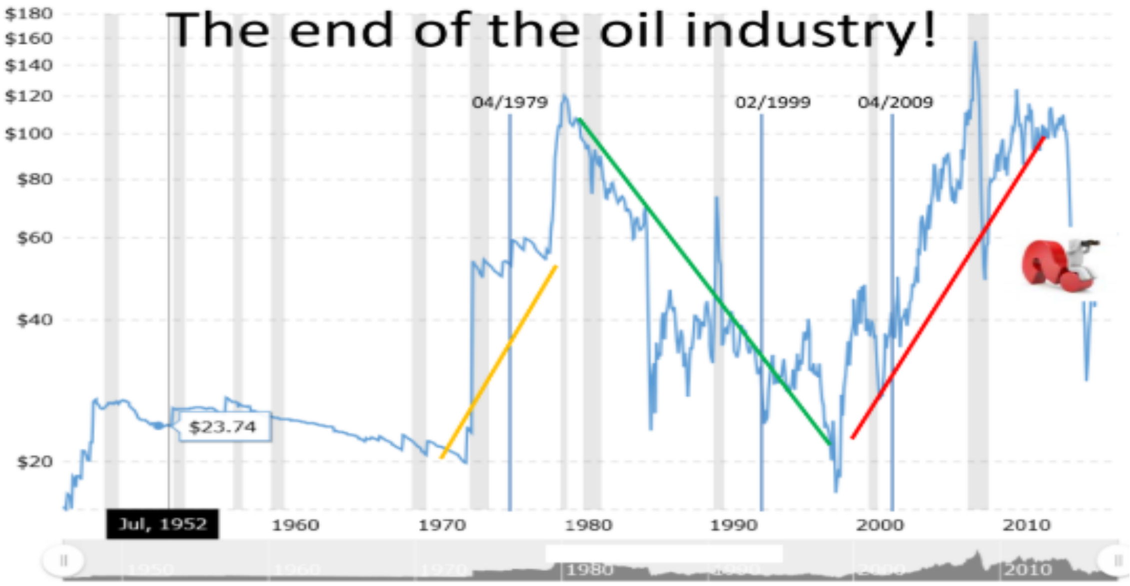


Figure 2: Correlation between oil price fluctuations and NCS development periods [?]. Y-axis indicate price pr. barrel of oil, and the X-axis indicates time. Yellow line marks the period of discovery, Green line marks the period of NCS development, and the red line marks a period of increasing costs alongside increased oil price (Berge 2021)

2 Abbreviations

Abbreviation	Description
AD	Assistant Driller
ADM	Assistant Derrick Man
Bbl	Barrel
BHA	Bottom Hole Assembly
BOP	Blow Out Preventor
D&C	Drilling and Completion
DF	Derrick Floor
DM	Derrick Man
DP	Dynamic Positioning
DDM	Derrick Drilling Machine
DFM	Drill floor Mechanic
DGD	Dual Gradient Drilling
DRD	Dual Riser-less Drilling
DSS	Deepsea Stavanger
EPC	Engineering, Procurement, and Construction
LMRP	Lower Marine Riser Package
MODU	Mobile Offshore Drilling Unit
ODU	Offshore Drilling Unit
NCS	Norwegian Continental Shelf
NPD	Norwegian Petroleum Directorate
NPT	Non Productive Time
PTP	Performance Tool-pusher
RKB	Rotary Kelly Board
SDD	Sequential dual drilling
SIMOPS	Simultaneous Operations
TP	Tool-pusher
UDD	Ultimate dual drilling

3 Theory

3.1 Introduction

This chapter will present the theoretical aspects of dual drilling. Necessary equipment, management tools, and staffing requirements for dual drilling are presented in their own subsections.

Dual drilling aims to meet the increased need for cost reduction and control. A key feature in evaluating the efficiency of dual drilling to cut costs, while maintaining HSE, is to analyse the non-productive time (NPT) during drilling operations. Dual drilling achieves cost reductions by enabling preparational tasks to be performed offline to the critical path. The concept of critical path, and the terms offline, online, and NPT are presented in their own subsections.

Both conventional drilling and the different variations of dual drilling are presented in their own sections to give the reader a good overview of the fundamental differences. This is necessary for enabling a good understanding of dual drilling. A key insight is to differentiate between dual activity drilling and full dual drilling.

Throughout this thesis dual drilling is defined as:

“Performing continual drilling activity from a drill floor with dual drilling capacity, with preparational tasks being performed simultaneous to the drilling activity”

As dual drilling falls under the category of simultaneous operations (SIMOPS), Schlumberger’s Oilfield Glossary definition of SIMOPS is included and is defined as:

"A term used mainly on offshore platforms, or installations with multiple wellheads, where more than one well bore is being accessed, such as where a drilling rig, slick-line unit or coiled tubing unit may be operating at the same time. Simultaneous operations generally have an impact on the installation safety procedures and contingency planning processes."

The final subsection will present some of the necessary technology for performing dual drilling. This will cover modifications on drilling vessels, yet unproven technological solutions currently in development, and modifications of existing subsea template designs.

3.2 Relevant drilling vessels

> *You need to think of (. . .) any drilling rig as a symphony. It must be well balanced. (...) right quarters, the right material handling equipment, the right deck space, correct motion characteristics, good stability, (. . .) a lot of equipment, and (. . .) right properties for flotation and safety. It is a vicious circle, and you have to get the proportions right*
>
> *D. Heagney*

In this theory section, relevant types of drilling vessels will be presented. Vessel types included are based on their relevancy with regards to their ability to perform dual drilling or to be upgraded to perform it. Types of drilling vessels presented are:

- The semi-submersible rig
- The jack-up rig
- The drillship

Throughout this thesis, the focus will be on the semi-submersible platforms due to the fact that most of the data collected, presented, and discussed during this thesis will be based on a semi-submersible rig, namely the Odfjell Drilling owned Deepsea Stavanger (DSS). The other types are included because they have characteristics worth mentioning when discussing dual drilling.

The semi-submersible rig

The semi-submersible drilling rig is a versatile mobile offshore drilling unit (MODU). The main advantages of using a rig of this type are in that it's offering improved operability and flexibility along with superior maneuverability. The Deepsea Stavanger rig type is equipped with both a dynamic positioning (DP) and a mooring system, and can therefore operate securely in both shallow and ultra-deep waters. The central advantage of using the semi-submersible rig type consists in its operability in ultra deep waters using a DP system. The DP systems allows the rig to spend less time, upon arrival at the drill site, securing the rig into position before drilling is initiated, compared to situations when mooring is used, as illustrated in figure 3 (Keener, Keji-Ajayi et al. 2003). The use of DP allows the rig to achieve higher maneuverability during operations, and when it comes to dual drilling it allows the rig to swiftly move between wells as operations are performed from the auxiliary and main well centers.

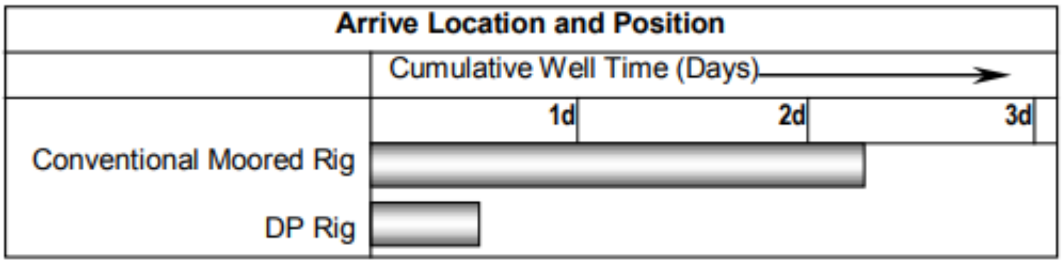


Figure 3: Relative positioning time prior to spudding the well
(Keener, Keji-Ajayi et al. 2003)

The gains from using DP stem from the use of dynamic thrusters instead of static anchor chains. The depth limitations for the use of DP is related to riser storage capacity, and this limitation is amplified in relation to the achieving of full dual drilling capability as the need for riser storage can be assumed to double.

Although DP requires minimal logistic support compared to traditional anchor handling operations, additional costs arise from the requirements of a separate engine system to power the thrusters (Offshore 1998). This complicates the on-board electrical systems design and adds to the required fuel storage. The Deepsea Stavanger is currently working on an assisting solution to this increased energy demand by installing a battery system on the top drives. The semi-submersible rigs have a comparatively larger deck area and can transport themselves between drilling locations using propulsion (Offshore 2012). As illustrated in figure 4 by Odfjell drillings Deepsea Stavanger, using an GVA 7500 sixth generation design, the rigs can be designed from the start for dual drilling capability (Offshore 2006).

Figure 4: Semi-submersible rig Deepsea Stavanger w/ GVA 7500 design
(Petroleumstilsynet 2017)

Deepsea Stavanger is equipped with two fully independent drilling centers. The enhanced version of the GVA 7500 design allows the two drill centers to operate autonomously. The centers can assist each other during well operations as well. In order for the system to fully function separately there is also an added capacity for equipment and tool handling as well as an increased pump and mud capacity. The rig is also equipped with a larger than regular moonpool size (appendix A and B) in order to accommodate simultaneous operations under safe conditions. The rig structure cannot support a dual BOP system, and the lack of dual subsea BOP limits the rig's ultimate potential for achieving dual drilling.

The rig can perform full dual drilling until the use of a BOP is required. From the point where the BOP is required the rig can perform dual activity drilling by using both drill centers to assist in the drilling of a well. The main well center can perform the drilling, while the auxiliary center can prepare equipment such as casing, bottom hole assemblies (BHA) and other equipment, and thus assist in reducing non-productive time (NPT).

The jack-up rig

The jack-up rig type is a drilling vessel operating from a fixed position on the seabed, typically using a design with three steel legs to support and elevate the structure above sea surface as illustrated by figure 5. The typical operational depth limit is up to 150m of seawater. Jack-up rigs are limited by the water depth, but within their operational limits they compete with semi-submersibles in their reliability and flexibility.

Figure 5: Typical jack-up rig design (Offshore 2020)

It is normal for this type of rigs to require towing vessels to move from location to location. When it comes to performing dual drilling operations, the jack-up can make use of an X-Y cantilever (fig. 6) that skids both transversely and longitudinally to move between drilling locations. The cantilever mobility reduces the need for a dual derrick design, used on semi-submersibles like DSS in order to allow for dual activity drilling operations.

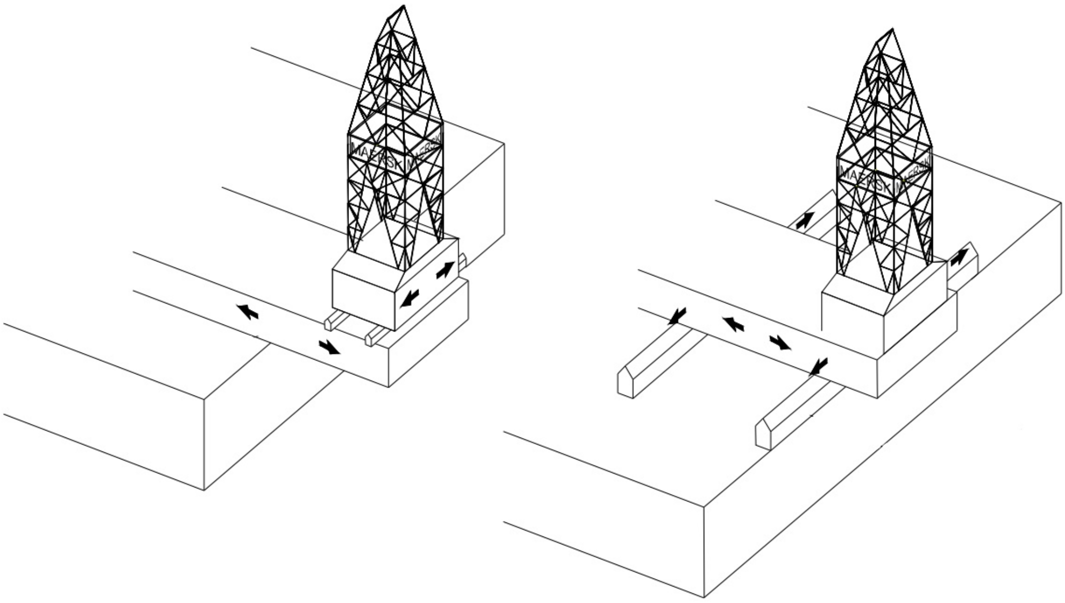


Figure 6: X-Y cantilever system (Smidth and Wulff 2005)

Today there are few jack-ups with the capability to perform dual drilling but an advantage of using the jack-up is the relatively lower cost for upgrading the rigs capacity. Upgrading the rig for dual drilling can be limited to building a new cantilever instead of building a new rig, which is the most likely scenario for semi-submersibles, and makes the potentiality for upgrades more accessible. The storage capacity on jack-ups is an advantage given the increased volume of equipment needed. If designing a new cantilever to perform dual drilling, different design options can be considered in order to enhance flexibility by increasing deck storage capacity, such as using multi-storied cantilevers. This increases the amount of equipment stored on the cantilever.

In the case of using multi-storied cantilevers, both BOP and XMT are stored on the cellar deck illustrated in figure 5. Some jack-up rigs are equipped with two moonpools of different size. The primary moonpool accommodates the BOP and drilling operations, while the secondary is used for a variation of well operations like, among others, coiled tubing (Smidth and Wulff 2005). If building a new cantilever is the best option for adapting an existing rig for dual drilling, the advantages are limited to the storage capacity on the cantilever, as the storage within the rigs hull remains unchanged.

Another advantage of the jack-up rig is that the BOP can be operated topside instead of subsea. Operating the BOP topside reduces the systems overall requirements and thus can reduce the size, weight, and power demand of the systems, and could enable the installation of a dual BOP system at a lower cost.

Previous analysis of rig performance suggests that the increased efficiency on a jack-up rig is highly related to crew performance. Existing literature suggests that the crew factor can account for up to 50% of the increased performance not including technical solutions. This increases the need for training in order to realise the full potential of dual drilling (Smidth and Wulff 2005).

Drillship

Drillships are a type of mobile offshore drilling unit that can also function as a ship. The type is operated with a full maritime and drilling crew. Drillships function as regular ships and can therefore move themselves between different drilling locations. It is usual that the different areas on-board are categorized according to their function. Different types of areas can include storage, drillfloor, marine control room and living quarters.

Both drillships and semi-submersibles have comparative advantages and disadvantages. Drill ships are less stable than semi-submersibles but offer higher deck loads. Their size is a critical factor regarding their safe operating ability. They need to be carefully sized to be able to tolerate high-capacity drilling equipment stresses and volumes, to achieve desirable motion characteristics and to meet the requirements for dynamic positioning. Drill ships are easier to dynamically position than semi-submersibles, and the more massive the ships are, the more they approach semi-submersible levels of stability and motion characteristics. Innovative design is also used to improve motion characteristics. As an example, some ships have a three moonpool design to increase stability by reducing the hull waterline area. Drill ships are the method of choice in tropical areas, in part because they can more effectively run from hurricanes (Offshore 1999).

To increase cost efficiency and maximize travelling and location time use, dual activity drill ships are employed and the traditional single rotary table sequential activities are shifted to coincident and dynamic dual rotary operations and methodical crew management (Offshore 1999). Dual activity drill ships have twin derricks and two drill areas with two well centers and some with even two complete drill strings. Dual activity capability also impacts drill ship size, as having the ability to assemble subsea trees without obstructing the other drilling operations comes with a considerable requirement of additional infrastructure support to accommodate a larger crew, more drill pipe risers and more materials like cement and mud with their required systems (Offshore 1997, 1999).

Dual activity allows for offline work to be performed on a second rotary table. This reduces well construction time and NPT by transcending the previous equipment limitations of conventional single-rotary, serial operations. Having dual capability entails the re-imagining of the entire drilling process, with special attention being paid to optimizing the use of the second station. While the first station is drilling, the second one can run the BOP, logging, or prepare the BHA, casings and cement. All this extra concomitant work to optimize the use of the second rotary means that logistical planning, deck load size, good teamwork and communication become very important. Operators are to be clearly aware of the big picture to be able to minimize downtime and interruptions by carrying out the necessary activities at the right moment, and the storage capacity is to be adequate to house the required quantities of well consumables. Various schedule management tools such as Gantt Charts are frequently used to optimize activity sequence management (Offshore 1997, 1999, 2001).

Drillship dual activity operations savings have been shown to be as high as 40%. Use of high-tech equipment allows for as little as 3% downtime (Offshore 2001).

Dual activity configurations imply having well centers that are not fully functionally equivalent, as certain operations will be restricted to one well center, as illustrated by figure 7. To achieve full dual drilling with well centers that have fully interchangeable functionality, innovative upgrades are needed. In full dual drilling mode, both well centers will need to be fully accessible at both the drill floor level and the moonpool. This can be achieved by changing the traditional longitudinal well center and moonpool arrangement to a transversely oriented one, as illustrated by figures 8 and 9. This will grant unrestricted, simultaneous well center access from both the forward and aft deck areas (Hendriks, Man et al. 2017).

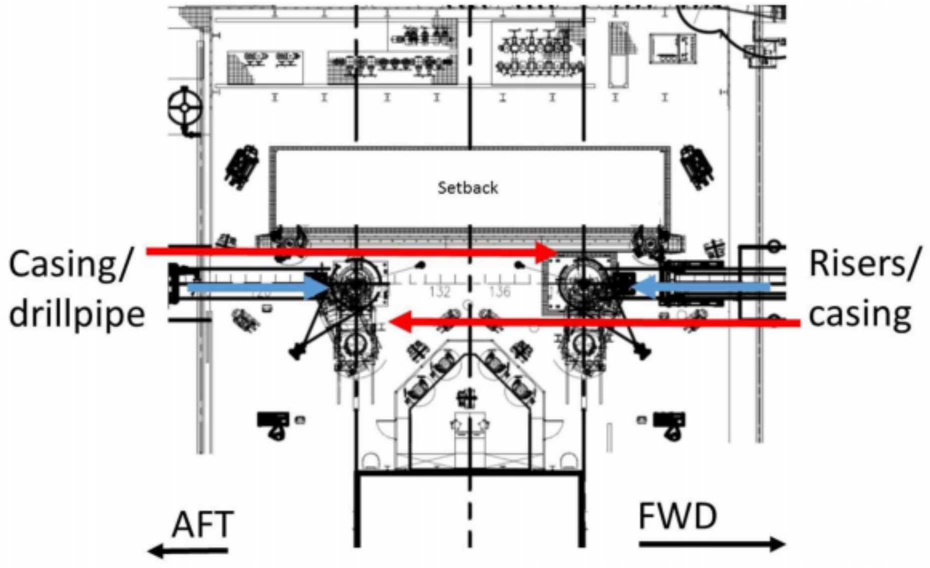


Figure 7: Longitudinally oriented dual activity drill floor (Hendriks, Man et al. 2017)

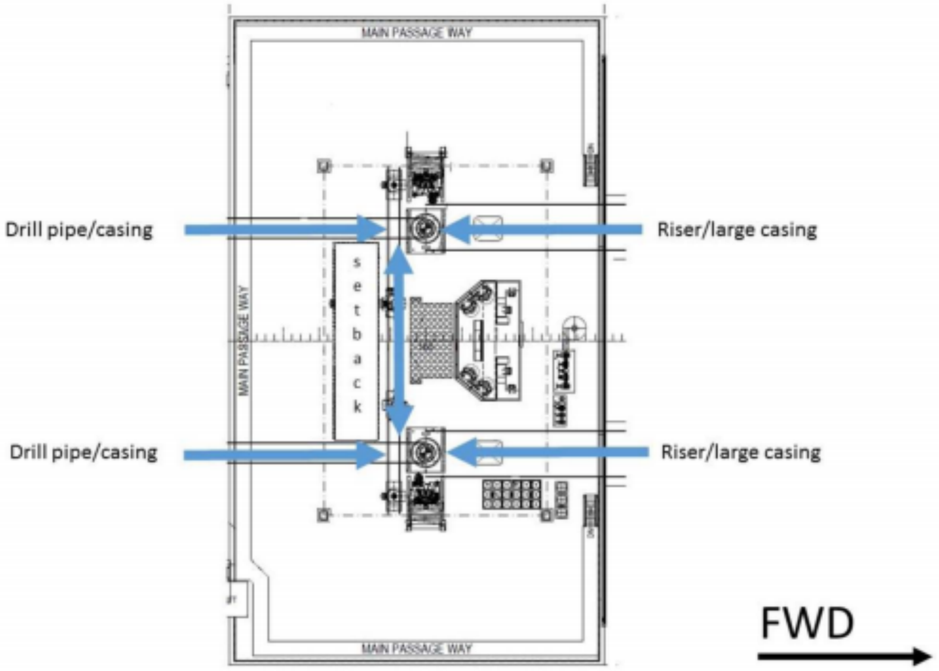


Figure 8: Transversely oriented drill floor optimized for full dual drilling (Hendriks, Man et al. 2017)

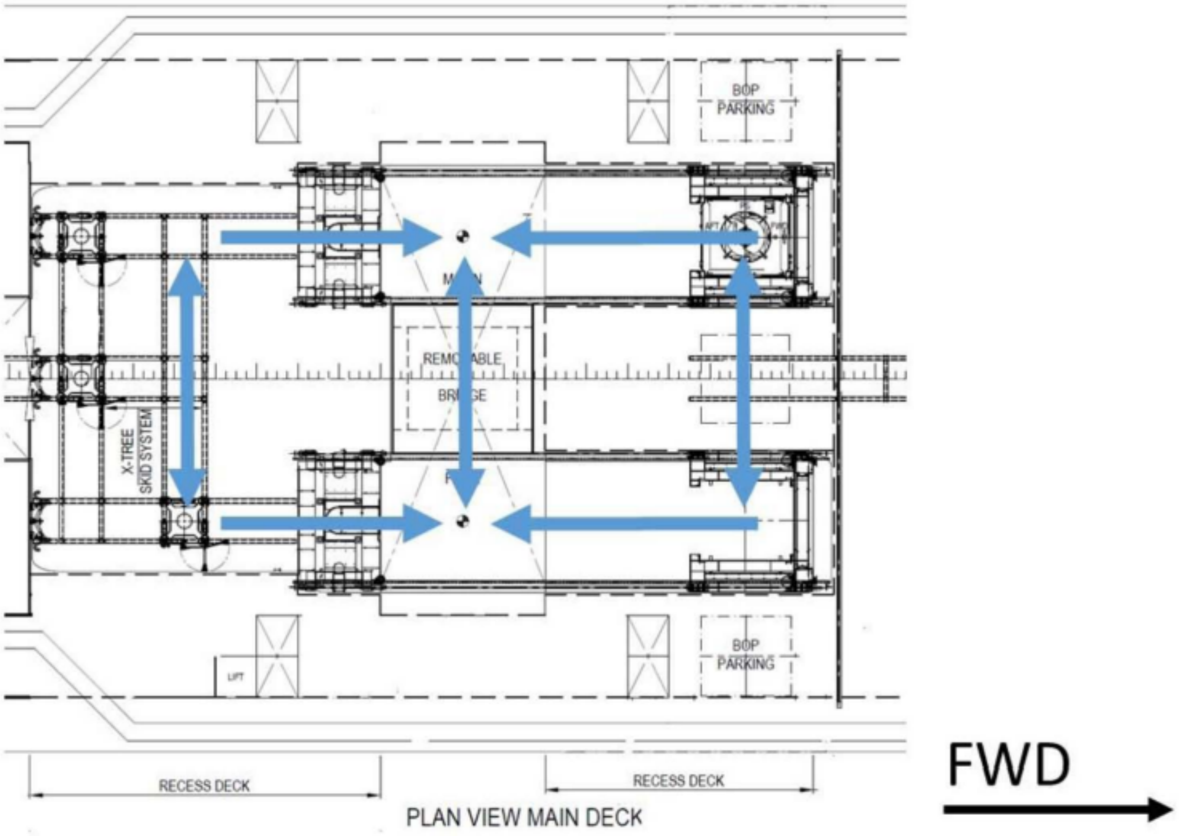


Figure 9: Transversely oriented moon pool main deck overview (Hendriks, Man et al. 2017)

Full dual drilling with two fully equivalent well centers will have all the benefits of dual activity while providing additional rig capability, flexibility and redundancy. Having more redundancy also increases safety (Hendriks, Man et al. 2017).

3.3 Operational management and HSE

3.3.1 Operation sequence management

Oil and gas projects usually have a complex and disparate range of associated operations starting with the more general ones like financing and regulations, continuing with forecasting and exploratory operations, which in turn lead to the actual drilling operations and on to the processing and transportation operations.

Managing the sequence and scheduling of operations of the diverse activities that oil and gas projects are comprised of is essential to their planning and execution especially given their high costs and long-term duration.

Activity planning, also called network planning, encompasses the determination of project-relevant activities and their order of precedence which are then modelled (fig.10) as a network diagram (Badiru and Osisanya 2013).

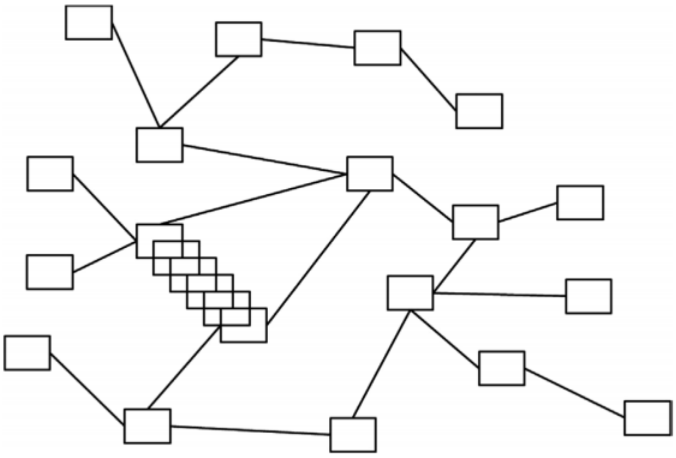


Figure 10: Network of project activities (Badiru and Osisanya 2013)

Project activity planning and subsequent schedule analysis offer clear-cut benefits related to communication, performance evaluation and team interaction (Badiru and Osisanya 2013). As a broad project documentation, it helps with the clarifying of the actual objectives while also serving as a visual communication tool and offering a way to an effective overall familiarization with the project (Badiru and Osisanya 2013).

Scheduling analysis and network management and visualization methods used, include the more traditional ones, like critical path method (CPM), Gantt charts, precedence diagramming method (PDM), program evaluation and review technique (PERT) and more novel ones like critical chain project management (CCPM) (Badiru and Osisanya 2013, Jo, Lee et al. 2018).

In what follows, these activity management and analysis methods will be briefly introduced.

Critical path method

(. . .) unless you are a particularly adept project manager, the ebbs and flows of criticality may burn you.

A.Hatfield
J.Noel

Critical path method (CPM) is a project-management technique used to plan project activities, their inter-dependencies and time estimates. It is a scheduling procedure for crucial tasks to be completed in their logical order of precedence with as low as possible downtime in-between. This technique allows for rearranging of various tasks in order to maximize logistical flow and minimize total time requirements (Dean 1998, Hatfield and Noel 1998, Filev 2010).

Once the relevant tasks or activities and their order of precedence have been established, they are then modelled on a network diagram. A common way of diagram construction uses graphic nodes connected by arrows (fig.11) to represent activities and their logic relationship of precedence order.

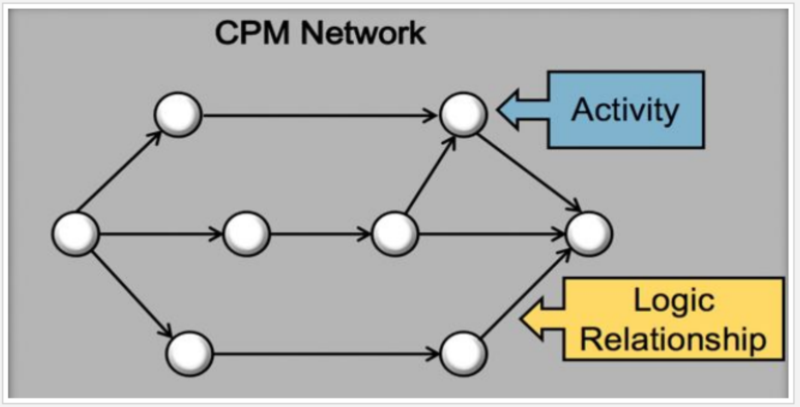


Figure 11: CPM activity network (Nagata)

Two principles of conceptual interpretation are currently predominating in the scheduling literature pertaining to critical path terminology: longest-path criterion and least-float criterion (Murray 2008). A path is a sequential linkage of the functionally interdependent tasks a project is comprised of. A project might have multiple paths. By the longest-path criterion, the longest of these paths, linking the project start and finish, is termed the critical path. Criticality is thus taken here to refer to the collective assembly of activities which directly affect completion time duration (Hatfield and Noel 1998, Murray 2008).

The term float denotes the spare time intervals between different tasks (Baldwin and Bordoli 2014). By the least-float criterion, the path with at most zero total float is the critical path. Criticality is thus comparatively referring here to the continuous path with no free time intermission (Murray 2008, Baldwin and Bordoli 2014).

In sum, contemporary scheduling literature tends to look at criticality as either an activity variable (longest assemblage of interrelated activities) or a path variable (path with zero slack time).

One area where CPM is applied in the drilling industry is the calculation of drilling time. Minimizing drilling time is of highest importance. Reorganization of time-consuming adjacent logistical activities, such as activities related to fuel, mud or tool availability in order to minimize completion time and streamline critical operations by following a critical path scheduling methodology allows for significant savings (Nash 2004).

Program Evaluation and Review Technique

CPM and PERT are the two most widely used network management techniques in oil and gas projects. The main difference between CPM and PERT is that the latter takes into account several different possible durations for each given activity, while CPM does not incorporate such possible variance in activity duration, being thus less flexible with respect to issues related to contingency and unforeseen circumstances (Badiru and Osisanya 2013).

Precedence Diagramming Method

Precedence diagramming method (PDM) is an expansion of the more traditional management techniques like CPM and PERT, that allows for parallel modeling of interdependent activities (Badiru and Osisanya 2013). The fixed starting and ending points of project activities that are serially and uniquely, that is with no schedule overlap, managed through CPM/PERT, can be loosened, and the activities themselves can be allowed to overlap (fig.12), granting significant improvements to schedule efficiency. It can also be successfully used in planning parallel projects.

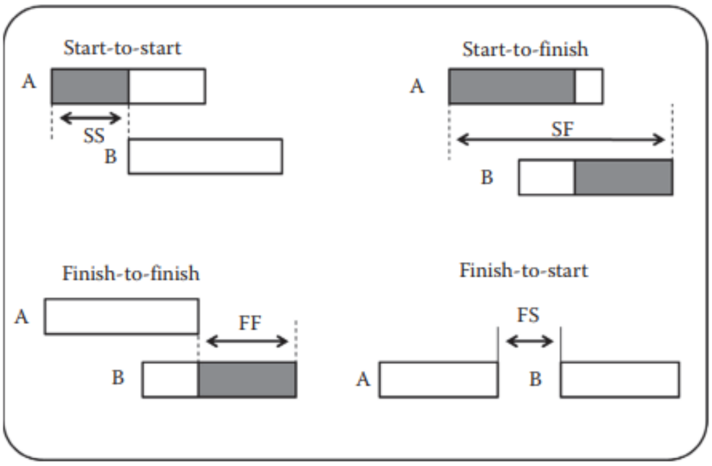


Figure 12: Precedence diagramming method (Badiru and Osisanya 2013)

At the core of PDM are the relationships between the overlapping points of start and finish of consequent activities schematized in the above figure. Given a prior activity A, the subsequent activity B is to start either after A has been ongoing for some time, but before it is finished (start-to start), or after A has been finished for some time FS (finish-to-start). Focusing on the finish point relationship between subsequent activities A and B, the two schematized cases are as follows: either activity B must finish after a certain amount of time since the start of A has passed (start-to-finish) or after a certain amount of time since activity A has been completed (finish-to-finish). This a more flexible modelling approach that can better accommodate real-life contingencies than traditional CPM where the focus is only on the finish-to start (modelled as FS=0, that is, no time passes between modelled activities) relation between activities A and B (Badiru and Osisanya 2013).

Gantt charts

If a diagrammatic model of project activities, each with their own different duration, is arranged with respect to the time the project is to be completed in, the model becomes a timed schedule. A useful tool to make sense of the importance of visualizing time and sequential timing is the Gantt chart (fig.13) (Geraldi and Lechter 2012, Badiru and Osisanya 2013).

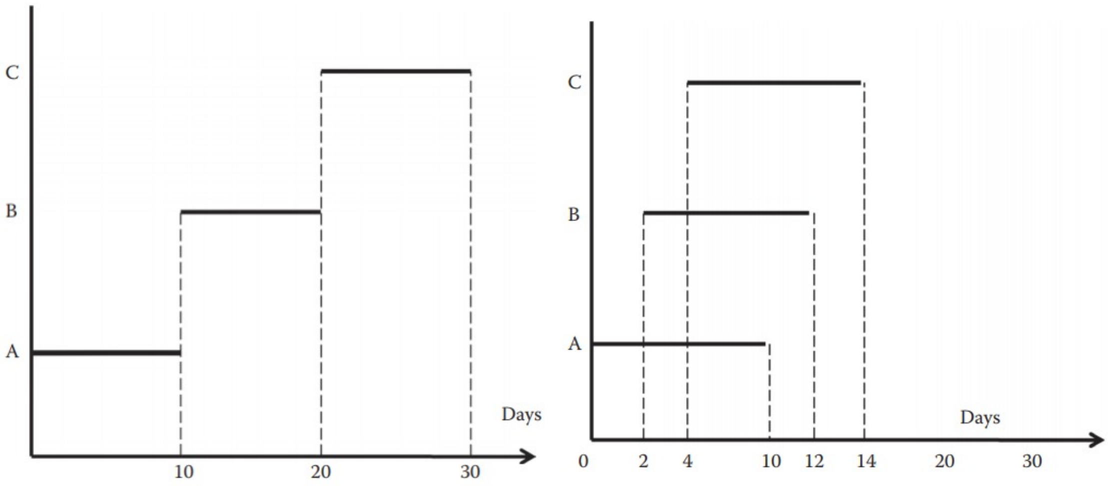


Figure 13: Gantt chart of serial and overlapping activities (Badiru and Osisanya 2013)

Critical Chain Project Management

Critical Chain Project Management is an effective activity planning and scheduling technique that incorporates logistical limitations and uncertainties in the material management process (Jo, Lee et al. 2018). It is considered to be the most important conceptual development in project administration since the introduction of the Critical Path Method (Luiz, Souza et al. 2019).

One significant way in which CCPM improves over the limitations of CPM and PERT management methods whose focus lies only on time and cost estimates alone, is by taking into the initial planning process the issue of resource availability and contention (Jo, Lee et al. 2018). This is particularly relevant for the oil and gas industry given the frequent need of managing a diverse flow of resources into the, often limited, transporting opportunities and storage spaces available.

As mentioned earlier, when applying CPM, work is split into offline and online. Non-productive time is time spent online not creating value. These three parameters are crucial when evaluating the efficiency of applying dual drilling.

Online

During an operation, online is defined as the performed operational work which is included in the cost and value creation. Online is thus defined as:

"Operational tasks performed on the critical path, creating value, and included in costs."

Offline

Contrary to online, offline includes operations performed during an operation not included in the cost picture. During the different versions of dual drilling, most of the work done offline is done parallel to online operations. Offline is thus defined as:

"Operational tasks performed off the critical path, usually in parallel to online operations."

Non-Productive Time

During operational activities, time spent on tasks not contributing to value creation is considered non-productive, and the total amount of this loss is summed up in the NPT category. NPT is defined in this thesis as:

"Time spent not contributing to value creation, yet paid for, on the critical path."

Fig. 14 shows the change in critical path during conventional drilling and a SIMOPS. As more activities are performed in parallel to main tasks, the path shortens and there is a reduction in NPT.

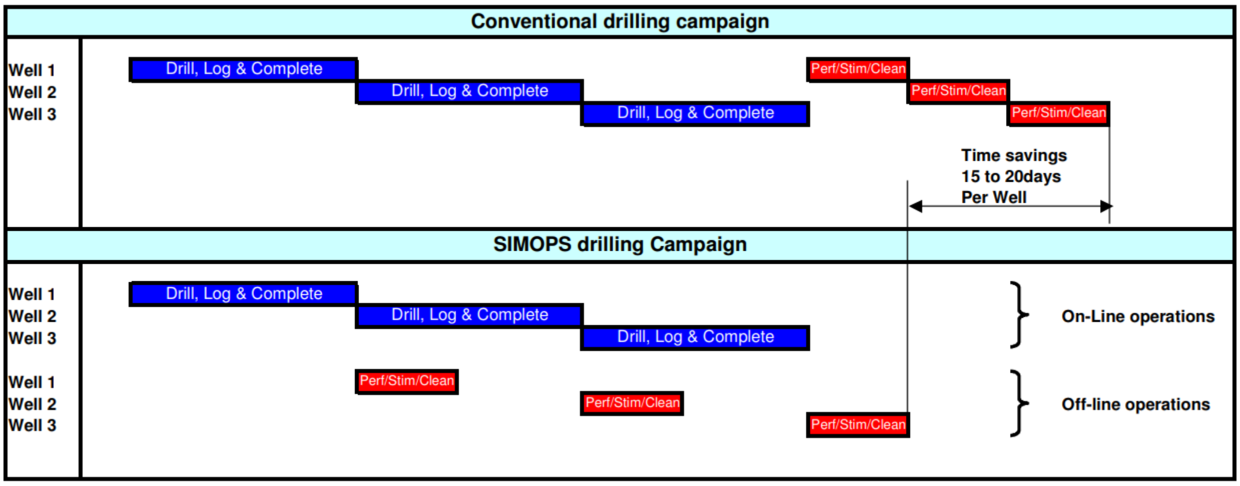


Figure 14: Changes in Critical Path due to parallel activities (Vos, Cross et al. 2008)

3.3.2 HSE

This section presents an overview of the relevant risk factors related to dual drilling operations, along with a short description of the increase in staffing required to perform the various dual drilling programs, using DSS as a standard staff reference. A short presentation of the relevant crew responsibility is included.

Operational risks

When performing any offshore drilling operation on the NCS there are certain risks related to equipment, personnel and environment that must be considered and assessed. The change in risk when performing dual drilling compared to conventional drilling is related to the increase in equipment handling, and decreased mobility when drilling using a semi-submersible. The increases in equipment handling and personnel require a higher focus on the preparational aspects of the drilling program and efficient coordination and communication between relevant crew. As usual on the NCS, most risks are assessed in a preliminary planning phase which aims to include all possible unwanted situations together with their related risks, and the required measurements of these risks and their consequences.

During dual drilling operations, an increase in simultaneously used equipment increases the risk of drops and collisions. This risk is more likely in possible interference regions between equipment like the drill string, riser, and various topside modules. Operations from a jack-up rig also include the added risk of the crane boom colliding with the equipment below the cantilever (Morales, Al Yamani et al. 2018; Zijderveld, Bonte et al. 2018).

Performing either dual activity drilling or full dual drilling operations reduces the maneuverability of a mobile offshore drilling unit (MODU) due to the simultaneous utilization of both available drill strings. The reduced maneuverability decreases the rigs ability to adapt to changing environmental conditions like winds and currents, and circumstances when the well control is lost. Another case of potential reduced mobility during dual drilling operations is related to the bending flexibility of the drill string. Using two drill string in parallel reduces the allowable inclination of both drill strings and could increase the likelihood of wellhead damage, fatigue, or unwanted well stream spillage during harsh environmental conditions or unforeseen events like power outages.

Dual drilling requires higher personnel activity and thus increases the likelihood of personnel injuries, yet, when performing dual activity drilling operations, the crew on board DSS experienced a reduction in heavy lifting operations which resulted in a lower overall risk picture. The increase in efficiency allowed by dual drilling could compromise health, safety, and environment (HSE) if the increased activity on the drill floor is not carefully planned to avoid having people in drop exposed areas during operations on opposite well centers (Sissener 2021).

Drilling top holes in parallel while hanging the BOP on the XT-trolley reduces HSE exposure of running and pulling the BOP for every top hole (Abuah, Okenyi et al. 2020). Dual drilling requires a higher level of positioning accuracy due to the fixed spacing between drill strings resulting in the additional risk factor of potentially lining up the rig wrongly (Sissener 2021).

Environmental risks are always present when drilling offshore. Using riserless technology demands ensuring no spillage when pulling out of hole (POOH) and to ensure that no contaminants are released into the surroundings, new technology for cleaning must be included for riserless drilling to meet environmental standards. Development of a pipe wiper will alleviate this risk. For the pipe wiper to be efficient it must ensure full cleaning of drill string when POOH. This puts an emphasis on quality measurement during cleaning.

Dual drilling operational crew

The higher level of activity when performing dual drilling increases the amount of staff required to be present during operations in order to maintain quality and safety. On board the DSS, which is to date equipped to perform dual activity drilling, some crew positions are doubled compared to a conventional drilling crew. On board Deepsea Stavanger the standard conventional drilling crew for a 24 hour cycle consists of:

- 1x Drilling Superintendent

- 1x Performance Tool pusher(PTP)
- 2x Tool pusher (TP)
- 2x Driller
- 4x Assistant Driller(AD)
- 2x Derrick Man(DM)
- 2x Assistant Derrick Man(ADM)
- 6x Roughnecks
- 2x Drill floor Mechanics(DFM)

When entering dual activity drilling mode, the staff is expanded in order to handle the increased activity, and staff the rigs two drill centers. On board DSS the increase in staffing consists of:

- 2x Drillers
- 6x Roughnecks

Full dual drilling has not been performed, but referencing the rigs AD Hanna Trondstad the staff is most likely to increase with some additional roughnecks and tool pushers.

Crew description

A short description of the work performed by the additional dual drilling staff positions follows:

Roughneck: On the drill floor the roughnecks are responsible for making and breaking connections during tripping in and out of the well bore. The roughneck works under the lead of the driller, and is also responsible for performing maintenance and repairs on equipment located within the derrick, and on the drill floor. Due to the increased amount of tool handling during a dual drilling operation it is necessary to increase the staff of roughnecks to maintain required operational quality and safety during drilling (Schlumberger).

Tool pusher: The role of a tool pusher is largely administrative, and is responsible for ensuring that the rig is sufficiently stocked with necessary materials, spare parts and that the drill floor is staffed with the required personnel to ensure safe working conditions during operations, and that the operations run according to the program in an efficient manner. The tool pusher is usually a senior member of the drilling crew. With a higher level of experience, it is the tool pushers job to also serve as an advisor to the rig personnel. Regarding the higher level of planning necessary to perform dual drilling operations, it is a sound practice to have enough tool pushers at hand to ensure operational quality during such higher activity operations (Schlumberger).

Driller: The driller is responsible for achieving efficiency during operations and maintaining crew safety. The driller is responsible for the work and control of the major systems at the drill site. Onsite, the driller operates pumps, the rotary table, draw works, and the hydraulic, pneumatic, and electronic instruments. An increase in driller staffing is required to operate both drill centers (Schlumberger).

3.4 Drilling

3.4.1 Introduction

During this thesis, the methods, procedures, and equipment used on board the Deepsea Stavanger will be defined as the standard method for dual activity drilling. This thesis will not discuss conventional drilling as it aims to present the current methods of performing dual drilling and how to move forward to perform full dual drilling. In the next section, how Deepsea Stavanger performs dual drilling will be presented. In subsequent sections, concepts for full dual drilling will be presented based on the interview with Olaf Sissener from Aker BP and his accompanied presentation. In this chapters last section the differences between how Deepsea Stavanger performs dual drilling (dual activity drilling) and full dual drilling will be presented and the technological advances necessary to achieve this from currently applied program will be presented.

3.4.2 Conventional drilling

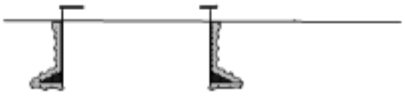
In this section, the process of drilling one offshore well from one well center is presented. In order to later discuss the advantages and disadvantages between conventional drilling and dual drilling it is necessary to present conventional drilling. The process described is based on the introductory part of chapter 2 in the “Introduction to drilling engineering compendium”. Drilling an offshore well is done by drilling in sections. A section is defined by its mud density and casing diameter. Drilling operations in each of the sections can be split into a three-step sequence, and are illustrated in figure 15:

1. Drilling new hole
2. Running casing
3. Cementing the casing in place

During single well drilling, all the operations, preparations, inspections, and testing are done online on the critical path. The details of critical path management are presented later in the thesis. Non-productive time (NPT) is a measurement on time spent not drilling, and includes pipe handling, bottom hole assembly (BHA) change outs, preparations, testing, and shut down due to risk factors like weather conditions. When presenting the different concepts of dual drilling the reduction in NPT is largely a result of the ability to perform more of the preparational tasks in parallel to drilling.

(a) Drilling

(b) Running casing.



(c) Cementing.

Figure 15: Illustration of the three-step drilling sequence (Hovda et al. 2019)

3.4.3 Dual activity drilling

In this section, dual activity drilling will be presented with a focus on operating from a semi-submersible. The Maersk-developed concept of dual drilling from a jack-up is also mentioned.

Dual activity drilling allows for an increase in drilling operation efficiency by having activities like open-water tripping, running casing, handling BOP, and running the Xmas tree, and other various surface activities, done in parallel and completely moved offline off the critical path. It also reduces contingent downtime related to investigating potential problems and testing of faulty tools (Abuah, Okenyi et al. 2020; Hall, Herrmann et al. 1999).

The considerable amount of offline activity in dual activity drilling requires greater storage and derrick spaces. It significantly reduces the overall time needed to perform operations by carefully planning the use of the main and the auxiliary well centers, and allows for significant savings when running batch drilling campaigns (Abuah, Okenyi et al. 2020).

The dual system is used for parallel making and breaking of BHAs, tool strings and pipe stands, for the parallel running of the BOP stack and riser, for the make up and running of casing while drilling the pilot hole or while performing top hole drilling, and for the preparation of well bore tools. There's further potential in also performing concurrent in-water operations. While the main well center is in BOP/riser drilling mode, the auxiliary well center can drill the pilot hole and run casing. Careful planning thus permits moving the BOP to the next well without having to return the BOP to the surface (Munch-Søegaard and Nergaard 2001). Additionally, the auxiliary well center can handle the removal of the wellhead or the running of abandonment gear while the BOP stack is concurrently pulled (Hall, Herrmann et al. 1999).

If the dual activity drilling operations qualification criteria are met, it has been proven that dual activity operations with two strings in the water at the same time can be safely performed by using a ROV to continually measure and observe the distance between the two submerged strings (Munch-Søegaard and Nergaard 2001). Managing the concurrent logistical and operational requirements of both main and auxiliary well centers has the potential for an overall increase in efficiency by adjusting the basic practices on the drill floor. This will help in further reducing NPT in the well construction process (Hall, Herrmann et al. 1999).

Dual activity drilling allows for the parallel drilling of a well by selecting between three different strategies, presented below.

Top Hole Drilling

Top hole drilling is the drilling of the first section in any hydrocarbon well. Standard practice within the industry is to drill and cement this section without using a marine riser or drilling fluid. Within the various concepts of dual drilling, top hole drilling can be performed by using different strategies (Enhanced-Drilling 2021):

1. Batch top hole drilling
2. True dual drilling
3. Offline top hole in parallel to well

For different concepts of dual drilling, top hole drilling is defined as two wells drilled at the same time.

Batch Top Hole Drilling

Batch drilling means drilling multiple top sections in one go. After finishing one top section, the rig moves to the next location and starts the top hole drilling process anew. From DSS, this operation is usually performed by drilling the hole from the rigs main well center, while building and running casings from the auxiliary well center. Organizing the drilling operation like this leaves no inefficient time on the well and hence reduces the NPT on that well operation (Odfjell Drilling 2020).

True dual top hole drilling

Using true dual top hole drilling means drilling two independent top hole sections using both well centers at the same time. Depending on the drilling rigs mud capacity, this drilling concept can be organized in different ways to alleviate the system. One option is to stage the drilling period so that the mud pump system is only used on one of the well centers at the time. It is also possible to drill both top holes in parallel if the mud systems use a large enough liner to supply the well operation. Using both well centers at the same time requires nearly ideal conditions with regards to template spacing and slots. If the template structure has an uneven number of well slots, i.e. 3, then only two well slots can be drilled in parallel and the last well can be drilled using dual activity drilling, using both main and auxiliary drill centers to drill and assist the last slot, much like the method of choice in batch drilling (Odfjell Drilling 2020).

Offline top hole in parallel to well

Drilling the top hole of a well in parallel to drilling another well is a variance of full dual drilling were the some wells are drilled in batch and the last well is drilled offline to these wells. A method could be to drill the last well while drilling the reservoir section on one of the other wells. This can be done on a rig that can perform dual activity drilling or riserless drilling (Odfjell Drilling 2020).

Jack-up Sequential Dual Drilling

The Maersk concept of dual activity drilling, named Sequential Dual Drilling, has as an operational principle the idea of alternating the drilling and casing operations between the two fully equipped wells (fig.16). During the first alternating sequence (Sequence 1), the first well center (WC1) starts drilling the top hole while the second well center (WC2) is standing by. In Sequence 2, the conductor and casing are run in WC1 as soon as the first top hole is drilled. While drilling the top hole, there is a huge requirement for power. The power requirement drops when conductor and casing are ran, so drilling the second top hole can commence immediately and is performed in the second well center while the first one runs the conductor and casing. After the second top hole is drilled - with drilling the top hole in the second well center taking a longer time than running the conductor and running casing in the first one - the two well centers are continuously alternating with respectively further drilling, casing and cementing the well. A relatively minor drawback is that the alternating sequences, especially when nearing completion, need to be very well planned in order to maximize savings (Norderud-Poulsen 2021).

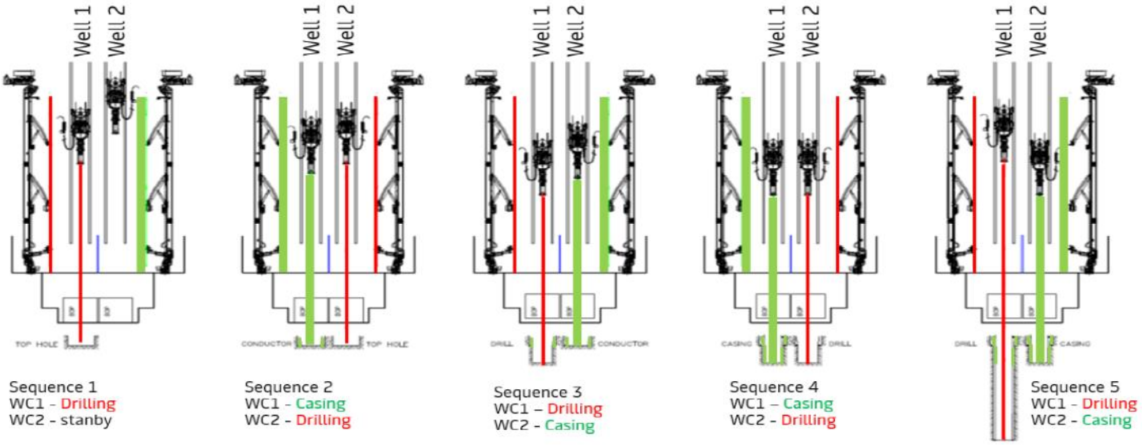


Figure 16: Illustration of sequential dual drilling for jack-up rigs (Sissener 2020)

3.4.4 Full dual drilling

Full dual drilling has definite benefits but also comes with a lot of costs. There are shared services between the well centers like cement pump, power generation and various utilities. But the mud and monitoring systems are completely independent as is all the equipment on the drill floor. There are two BOPs and there needs two be good physical separation between the well centers in case of drops and shutdown. If one of the wells gets shutdown, the required maintenance work at both the drill floor and the pipe rack, where the tubulars are handled, needs to be able to be done without interference with the operations performed on the other well. Logistic services and support might prove to be problematic due to the need of feeding two well centers with all the components, but this is something that can be worked at and overcome (Norderud-Poulsen 2021).

Dual BOP/Riserless drilling

Dual drilling using riserless technology and a dual BOP system is at the forefront of drilling technology. At current time, no drilling vessel is equipped with such a setup. Nevertheless, full dual riserless drilling concepts for achieving this are developed for both semi-submersible and jack-up rigs. Given the currently available pump capacity and power generation capabilities it is not feasible to drill full dual riserless from top hole to reservoir section. To accommodate these limitations, the large casing sections are drilled using batch dual drilling until sufficiently small casing diameters are reached. Once reached, full dual riserless drilling is initiated and both wells are drilled in parallel from each well center. At this point, drilling from each well center is performed similarly to conventional drilling. Riserless drilling allows maintaining of pressure control while drilling two wells in parallel (Sissener 2021).

3.5 Technology

In order to achieve full dual drilling different technologies are needed. This section will present some of the necessary technologies.

3.5.1 Subsea template

The distance between well centers on-board Deepsea Stavanger is 10m. In order to perform full dual drilling on a subsea template, it is necessary for the well spacing on the subsea template to match the distance between the two well centers on the rig. On the Norwegian Continental Shelf there exist today no subsea templates correlating this distance. Therefore, in order to accommodate full dual drilling on a subsea template it is necessary to design a new template enabling a rig like Deepsea Stavanger to position both of its drill centers over individual wells. Depending on the differences in template design, a combination of dual drilling procedures can be implemented by elongating a conventional 6-slots subsea template that traditionally, by NCS 2017 standard, has 6-meters spacing between wells. Because the dual derrick vessels have a 10-meters spacing between the two well centers, the template spacing must match that, in order for the drill string from the drill floor to the template to be vertical. Thus, the template gets elongated with 4 meters between each slot. On templates with an even number of well slots, full dual drilling of all wells is possible, while on templates with an odd number of well slots the last remaining well will be drilled using offline top hole in parallel (Sissener 2021). Figure 17 shows a design for an extended subsea template, optimized for the 10-meters spacing necessary for dual drilling drillstrings. As illustrated in the figure, components like trawl protection structure and mudmats will ensure the same level of operational safety as on conventional 6-meters templates.

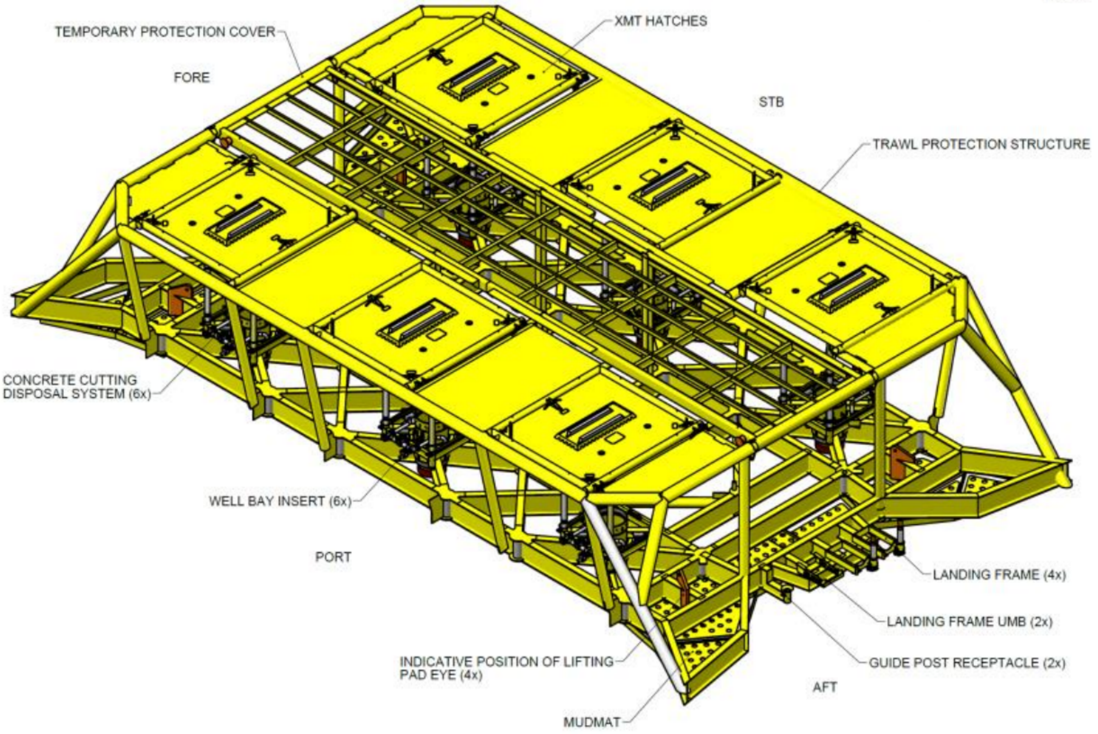


Figure 17: Extended subsea template design for dual drilling (Sissener 2020)

3.5.2 Riserless drilling

Riserless drilling, as illustrated by figure 18, sometimes called riserless mud recovery drilling, is a technological advancement within drilling to perform drilling in both shallow and deep water depths without the use of a marine riser. The technology aims to reduce the cost of deep-water drilling by eliminating the use of a marine riser and by reducing the required amount of drilling mud. A key feasibility requirement and precondition for achieving a substantial reduction in costs by implementing riserless drilling is for the riserless system to function on both newer and older rigs. The removal of the marine riser and reduction of mud volume and associated equipment will free up necessary deck space to perform dual drilling.

The standard drilling equipment for drilling a deep water well consists of:

1. Drill pipe
2. Subsea BOP
3. Subsea template
4. Subsea guide
5. Guide tensioners
6. Riser booster pumps

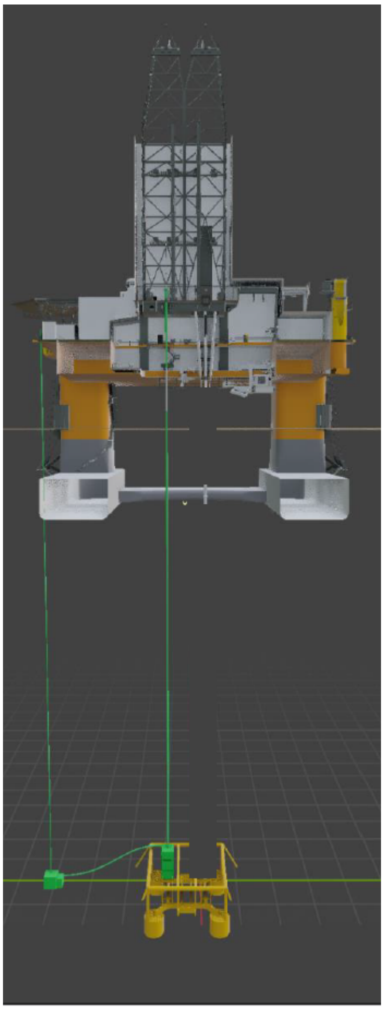


Figure 18: Single riserless drilling system (Sissener 2020)

In order to perform riserless drilling additional equipment must be applied. The primary tools necessary to perform riserless drilling is an "E-duct" tubing system with an associated E-duct return subsea module to return cuttings to surface. Modifications to the subsea BOP and subsea well housing systems allows it to assist the return of cuttings and drilling mud while performing riserless drilling. Along with the EdR a subsea rotating control device (RCD) is also added to the system. RCD technology ensures differential pressure control in open water. The system composed of the EdR and RCD works to motivate the return of drilling fluids and cuttings.

The system includes isolation valves to prevent spillage in case of disconnect or of a drive-off occurring. Along the return lines a choke and kill line is included within the system along hydraulic control line. The EdR uses an enhanced educator composed of a lobe star jetting component which supplies lifting force to the return fluids. Figure 19 shows the riserless system, showing the well head without the riser along with the mud return and safety lines.

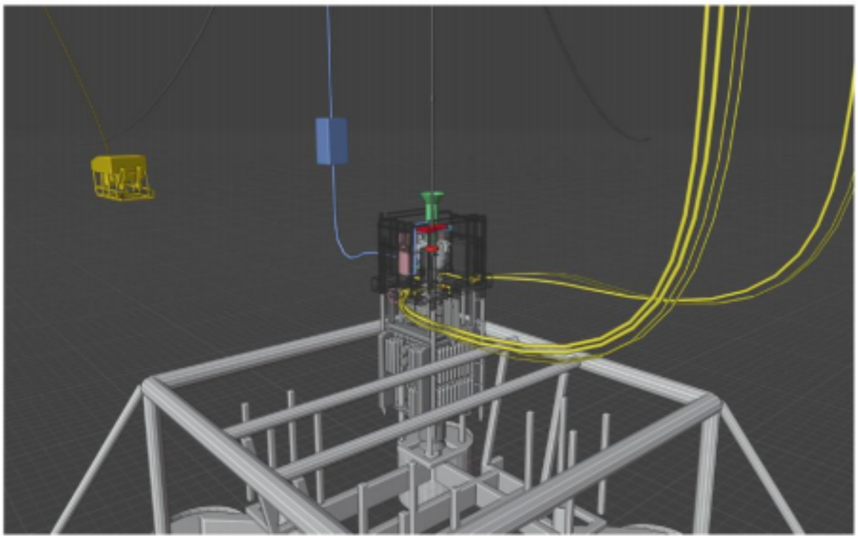


Figure 19: Riserless drilling concept (Sissener 2020)

Dual riserless drilling

Dual riserless drilling is currently an unproved drilling concept. The goal of developing this concept is to optimize drilling capability to decrease the time needed for drilling and well completion. In order for the concept to work, both technological advances, and rig upgrades have to happen. Among the modifications that are necessary to enable dual riserless drilling is the presence of an additional BOP in active service, accompanied by increased deck load and bearing capacity to store and handle the extra BOP. To operate a dual BOP installation, upgrades to the control and power systems are required. Pipe wiping and RCD technology needs to be further developed to ensure no spillage from the riserless system, and pressure control. Riser version RCD is commonly used but the riserless version needs further enhancement to account for the increased open-water drilling challenges such as corrosion resistance, rotation and erosion fatigue, and ease of maintenance. The pipe wiper needs to be very effective to ensure no oil based mud (OBM) spillage when pulling the drill string out of hole. Zero discharge is for now not yet achieved but work is being done at the supplier level to develop a good enough wiper (Sissener 2021).

In order to perform full dual drilling using the riserless drilling system, an extra riserless system is included in parallel to the single riserless system (Carter, Bland et al. 2005).

3.5.3 Dual drilling cantilever design

The cantilever houses the well centers, the top drive, the shaker room and various other equipment. When evaluating dual drilling from a jack-up rig, two cantilever designs were produced by Maersk (fig.20) to allow for the two dual drilling concepts, sequential dual drilling and ultimate dual drilling to be viably performed.

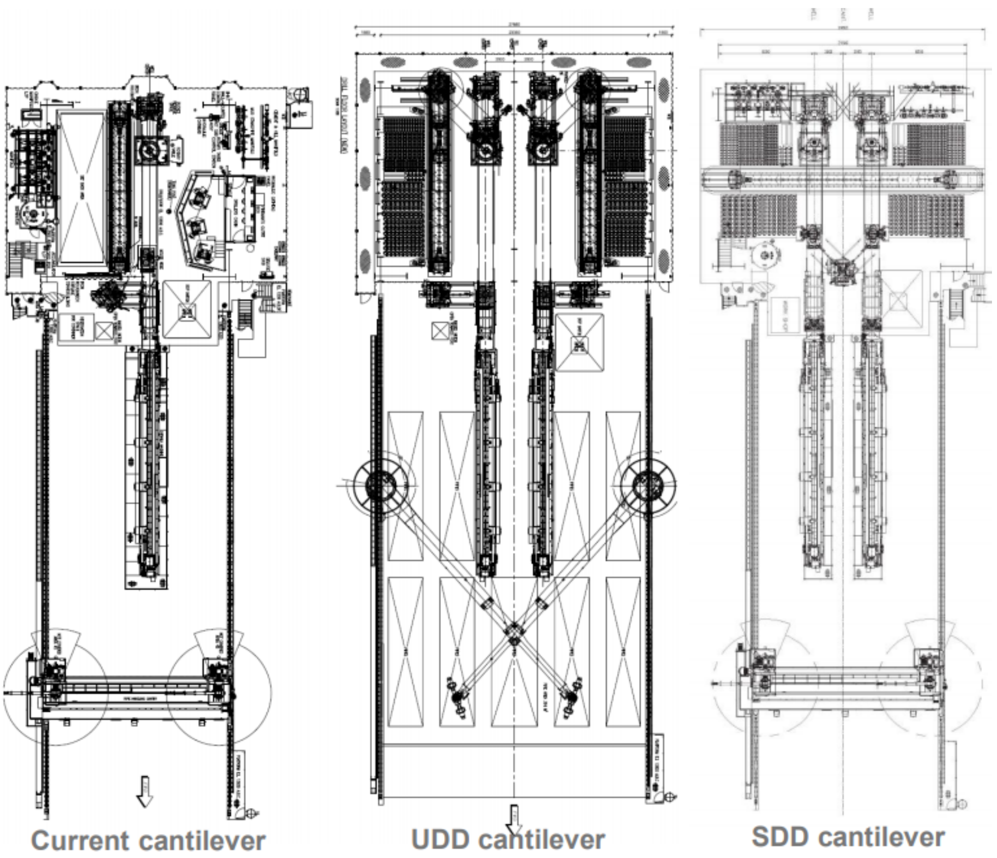


Figure 20: Different cantilever designs for dual drilling compared to conventional cantilever (Sissener 2020)

In producing the two cantilever designs, Maersk sought to transcend some of the existing submersible rig layout limitations and design constraints in order to present a commercially viable way of performing dual drilling operations from a jack-up.

The semi-submersible rig layout has two well centers, the main well center to the starboard and the auxiliary well center to the port side. All piping and tubulars can be only fed in via the port side and all the risers, through the starboard side. This means that, since the top and pilot holes are simultaneously drilled on the main and auxiliary well centers and pipes can be only fed in to the auxiliary well center, all the tubulars required to feed the main well center need to have been pre-planned, otherwise dual operations would frequently get interrupted.

It quickly became apparent that the logistic free flow is so important that fully independent well centers would need to be developed. This realization had Maersk looking at their jack-ups to develop two well centers that have completely independent material flow and logistic services so as not to be restricted on certain operations at a given time at each well center, and so as to not having to have the well center operations queue after one another in order to wait for material flow and for logistical services to be able to be delivered, due to rig layout limitations. From a process flow point of view, it is very important to get any tubulars in and out without operational interference between the two well centers (Norderud-Poulsen 2021).

On a jack-up rig, the well centers are fixed in position on the cantilever, and, to move them, would add a lot of complexity, so they cannot be easily moved. In addition, when performing dual operations from a fixed platform on a template with a fixed well slot pattern, the closer the well centers are to each other, the more flexibility one has. After looking into how the well slot pattern could be optimized for a jack-up working on the NCS, they concluded that a 5-meters spacing between the well centers would be optimal in order to accommodate both the top drive on the drill floor and the BOP below it. But this would still present some challenges in terms of equipment spacing and separation between the well centers, given the limited cantilever size (Norderud-Poulsen 2021).

Consequently, they looked into having a completely new cantilever (UDD Cantilever) that is 50% wider and around 40% taller to overcome the spacing challenges both on and below the drill floor where the BOP is stored. In order to drill two fully parallel wells from start to completion, the mud returns from the second well would also need to be able to be concurrently handled in their own extra shaker room. Since the existing, conventional drilling, shaker room size is already stretching the full width of the cantilever, and the whole current cantilever is full of equipment, with very limited free space left, being able to have a second shaker room would mean that much more space is needed. Thus, in order to achieve ultimate dual drilling capability, a completely new cantilever would need to be built anyway just to accommodate the mud systems. The current cantilever weighs around 4000 tons and a new one would most likely weigh around 6000 tons because all the drilling equipment would also need to be doubled. The design choice for the new UDD cantilever was thus between either having two completely new drilling packages on a new cantilever frame or retrofitting the old drilling package by stripping it down and reinstalling it along with a new drilling package. The second option would mean that one would end up with an old drilling package alongside a brand new one with totally different automation capabilities like new equipment and sensors and software. This was deemed unworkable, so the only option would remain to install two new systems and build the new UDD cantilever. But this UDD cantilever was going to be a quite substantial rebuild that would cost something between 200-300 million dollars, plus the cost it takes to have the rig out of service for the 6-9 months the upgrade takes (Norderud-Poulsen 2021).

The SDD cantilever is, by comparison, just a current cantilever retrofitted to accommodate and allow for the extra equipment and flexibility needed. This means that there's no need to build a new cantilever, which in turn means that the required investment, at around 100-175 million USD, is significantly smaller, while the circa 30% time savings, achieved by performing sequential dual drilling, are comparable to the actual 35-45% savings that ultimate dual drilling would achieve (Norderud-Poulsen 2021).

Ultimately, Maersk concluded that the SDD cantilever was a better concept in terms of cost to performance given that full dual drilling on a jack-up requires significantly more capital investment.

4 Method

This chapter will present the methodology used to gather information on dual drilling, with a focus on how the information was collected and processed. Due to the novelty of the topic of dual drilling, information was collected from expert interviews and additional articles and papers available.

4.1 Expert interviews

Dual drilling is a relatively newer drilling program concept, with only a handful of companies having performed, or having plans to perform dual drilling operations. In order to collect relevant data it was imperative to conduct expert interviews with companies having either theoretical or practical experience with various dual drilling concepts, or both. With the assistance of this thesis supervisor from Aker BP, contacting the following relevant industry actors was decided upon:

- Aker BP
- Odfjell Drilling
- Neptune Energy
- Maersk Drilling

The expert interviews were conducted in multiple phases spread over several sessions with each company. The first phase largely focused on establishing contact with industry actors, and on gathering basic introductory information. The second interviewing phase focused on the different details necessary for both full dual drilling and dual activity drilling capabilities, like rig retrofitting, staffing, HSE, existing technological solutions and future technological challenges necessary to achieve full dual drilling capability.

After evaluating the information gathered during the interviews, information from Aker BP, Odfjell Drilling, and Maersk Drilling was deemed highly relevant. The amount of information gathered from Neptune Energy was deemed insufficient and too similar to the information gathered from the other actors and has thus not been included in this thesis.

The expert interviews were recorded in order to fully process the information within. The recordings were assessed multiple times to ensure factual integrity. Maintaining both practical and theoretical accuracy of the data presented in this thesis required having interview participants with backgrounds representing both theoretical engineering and managerial aspects, alongside practical operator know-how.

Interview participants shared documents and reports that included valuable information and data. The data collected from these documents and reports were instrumental in forming the results of the present thesis.

4.2 Literature and media survey

Several concepts of dual drilling have been available since the 1990s. Due to a reduced need for cutting costs on drilling operations, further development of these concepts have been until recently postponed. There is relatively little available information on performing the various concepts of dual drilling in the scientific literature. When supplementing the information gathered from expert interviews by using existing scientific and industry literature, specific key words were identified as necessary to classify relevant data when searching within different online archives.

Key words used for online research

Following is the list of keywords used to search for literature and other resources.

- Dual Drilling
- Dual Activity Drilling
- Riserless Drilling
- Dual Riserless Drilling
- Drilling
- SIMOPS
- Drillship
- Semi submersible
- Jack-up
- HSE
- Safety
- Risk

After collecting all relevant articles from our sources based on paper and article titles, each paper was independently searched for above mentioned keywords. For papers that included more than five hits, the abstract was read. If the paper or article contained enough (i.e. >5) hits, and the abstract seemed relevant they were selected and read trough. The number of hits in each paper was selected to simplify the selection process. It was concluded that if the paper title was vague and had low hits on the relevant search words it would most likely not include information efficiently contributing to the thesis and was thus discarded.

YouTube

YouTube is a large source of visually presented information. performing a search using the keywords mentioned above, resulted in multiple relevant videos presenting the concept of dual drilling. The videos assisted in achieving familiarity with the concept of dual drilling but contained no relevant data. Given the informal nature of these sources, they have been excluded from this thesis.

Offshore-mag.com

Offshore Magazine is an industry news source from whose archives a collection of relevant articles were collected using above mentioned search words. From these search results, articles related to various dual drilling concepts were selected and read trough. These articles contained less valuable data than the papers collected from Onepetro.com (next section). Nevertheless, the generality and simplified information in these articles were valuable for orienting the data extraction from relevant scientific papers.

Onepetro.com

Onepetro.com is an online industry database featuring petroleum related scientific papers and articles. Searching this database using the listed keywords, resulted in the collection of a myriad of interesting and relevant pieces of information. Using the same practice as mentioned in an earlier paragraph, each paper and article was analysed for relevancy. The remaining papers, after the selection process was completed, contributed the theoretical backbone of the present thesis.

Google

When reading the final selection of papers, Google was used to help understand minor aspects within the different papers. These aspects relate to definitions, word translation, concepts. The "Schlumberger Oilfield Glossary" was used for referencing definitions.

4.3 Field Trip

The authors were able to visit Odfjell Drilling' semi-submersible rig Deepsea Stavanger. With the assistance of the supervisor from Aker BP, contact with relevant personnel on-board the rig was made and a trip was organized. The visit was held on Hanøytangen in Hordaland. The crew on-board DSS gave a physical tour of the rig, presenting areas like

- Drill floor
- Helipad
- Riser storage
- Moonpool
- Pump room
- Platform bridge
- Loading area

On the rig, its crew showed and shared information on a variety of tools and operations related to dual drilling, tool handling, and rig maneuvering. A brief discussion on the rigs limits regarding dual drilling assisted in orienting literature searches.

The field trip is photographically documented with some personal pictures included into Appendix B.

5 Results

5.1 Introduction

In this chapter of the thesis the results of performing dual drilling using various methods will be presented. The results presented will show the savings in costs and time compared to conventional serial drilling. In the following chapters these results will be discussed based on the theory presented in earlier sections of the present thesis.

5.1.1 Top hole drilling

Top hole drilling is presented in the relevant theory section. In this section, the projected savings in time and costs, as determined by Odfjell Drilling, are presented.

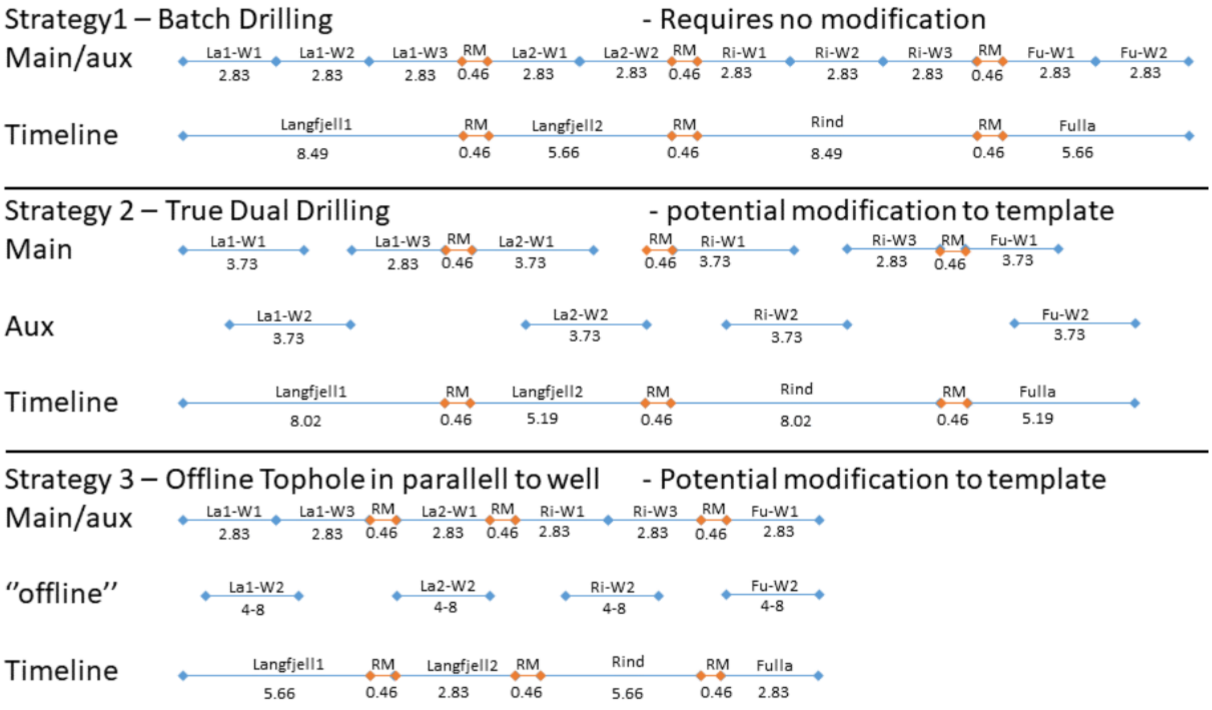


Figure 21: Time saving between a) Batch drilling, b) True dual drilling, c) Offline top-hole in parallel to well (Odfjell Drilling 2020)

Figure 21 shows the saving potential from each of the three different dual drilling concepts for a 10 top holes campaign. Where strategy 1, batch drilling, takes 29.7 days to complete 10 top holes, strategy 2, true dual drilling, takes 23.8 days, given no pump restrictions. Strategy 3, offline top-hole drilling, takes 18.4 days. The difference between strategy 1 and strategy 3 is 11.3 days. Given the day rate of DSS at 9500000 NOK, the potential savings on rig time is 107350000 NOK.

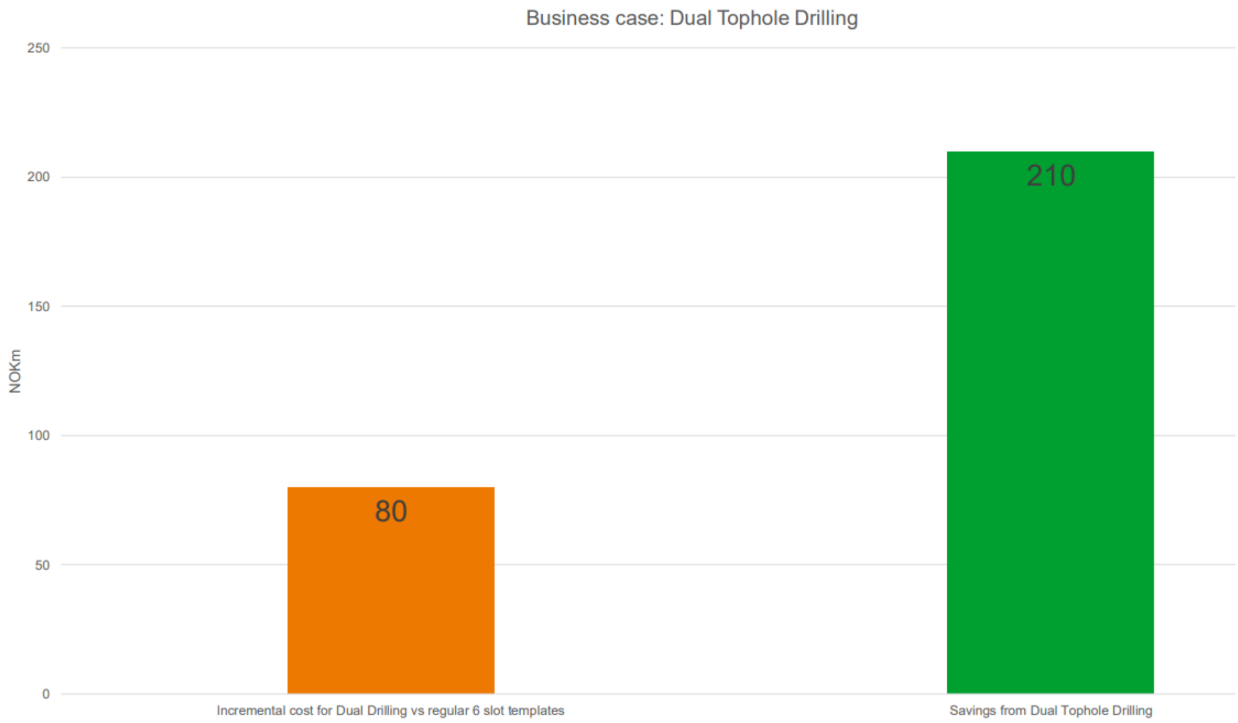


Figure 22: Cost of top hole dual drilling vs. savings on top hole dual drilling, with the Y-axis showing cost in million NOK (Sissener 2020)

Dual top hole drilling has a positive business case. Figure 22 shows the difference between added costs for top hole dual drilling and savings. The incremental cost accounts for the increase in the distance between well slots. The difference amounts to approximately 130 million NOK due to the reduction in rig time.

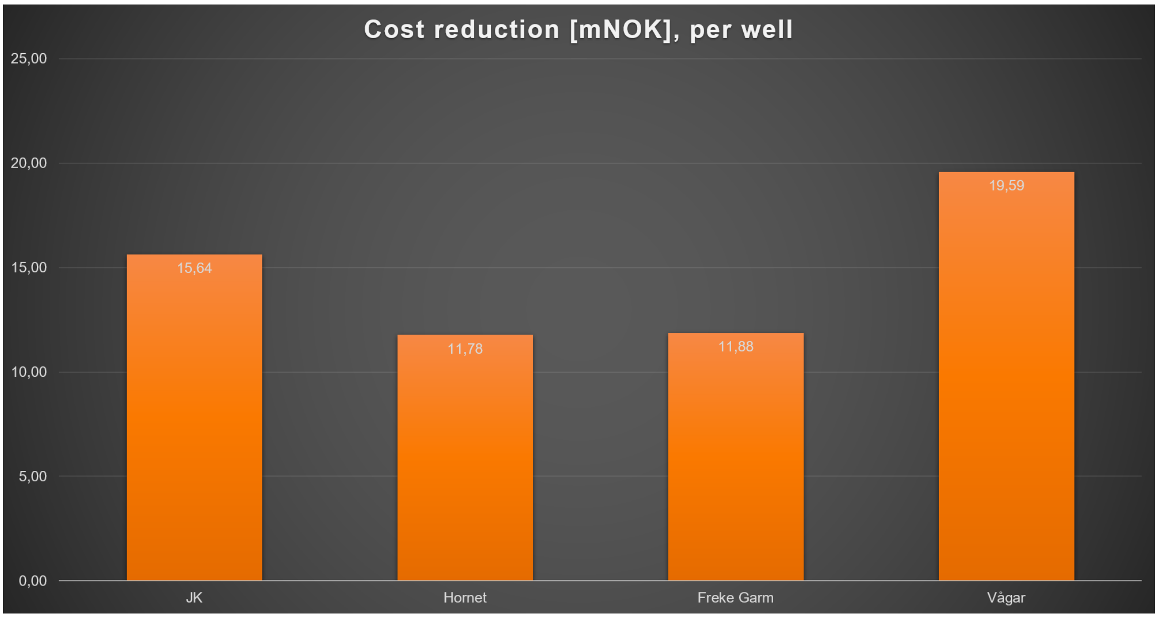


Figure 23: Savings from top hole dual drilling campaign, Y-axis i mNOK (AkerBP 2019)

Figure 23 shows the savings achieved by drilling several wells using dual activity top hole drilling. The drilling was performed by Deepsea Stavanger.

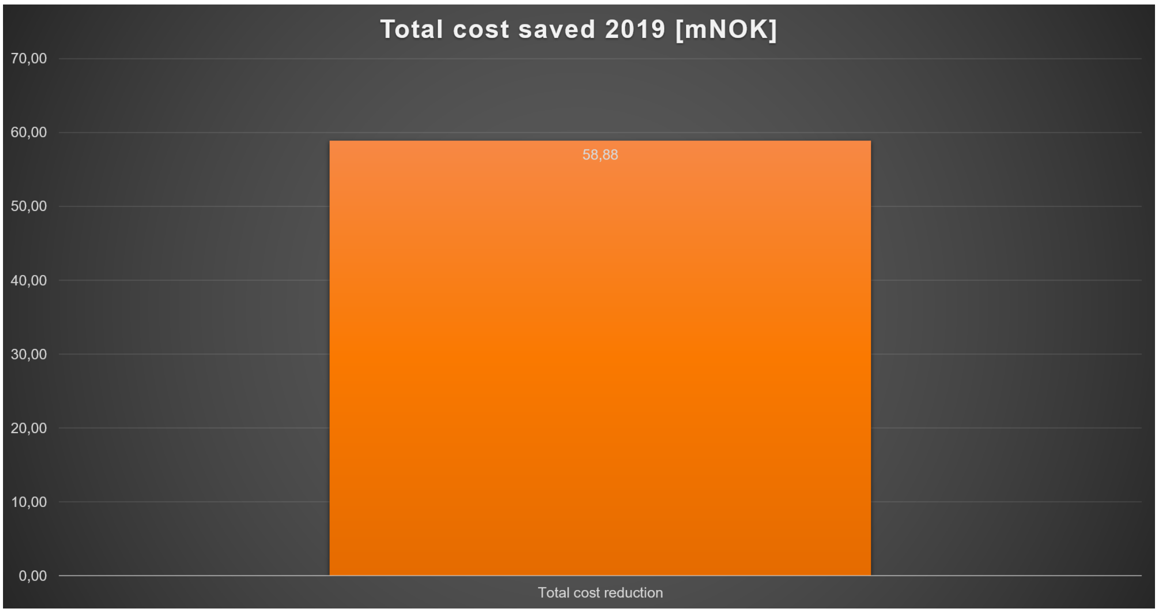


Figure 24: Savings from top hole dual drilling campaign, Y-axis i mNOK (AkerBP 2019)

Figure 24 shows the total savings from the dual top hole drilling campaign i mNOK.

5.1.2 Riser-less drilling

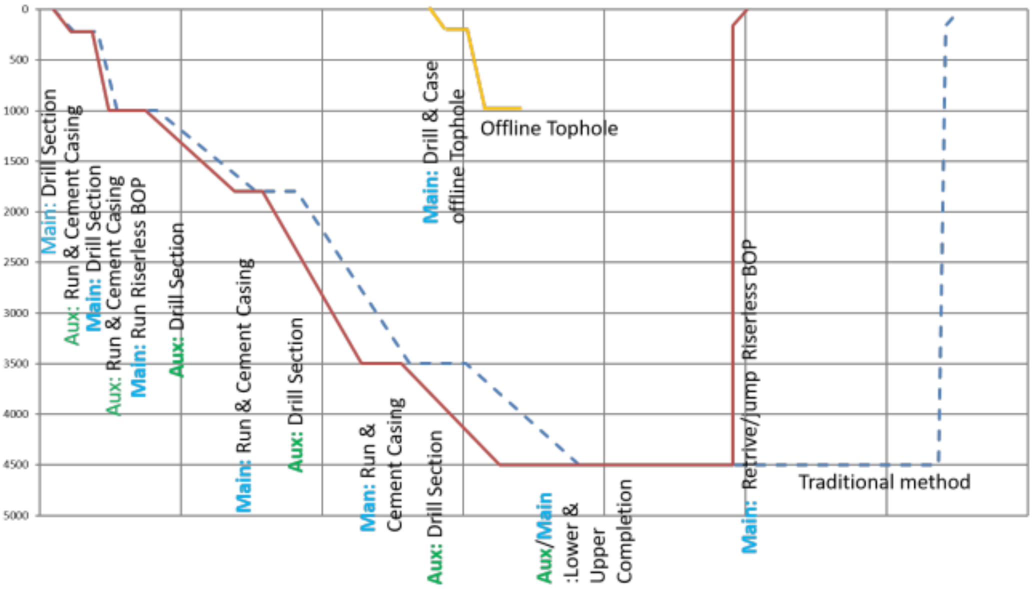


Figure 25: Depth-time curve showing differences between conventional drilling and riser-less drilling with offline top hole (Odfjell Drilling 2020)

Figure 25 shows the difference between drilling conventionally and drilling riserless dual activity with offline top hole. Top hole is drilled off the critical path, and is hence "free", the solid red color line shows the time-depth curve of drilling using riser-less dual activity drilling, and blue dotted line shows time-depth correlation using conventional drilling method. The graph does not include the additional savings coming from applying riserless drilling, such as "waiting on weather" which should provide additional savings on both sides of the event.

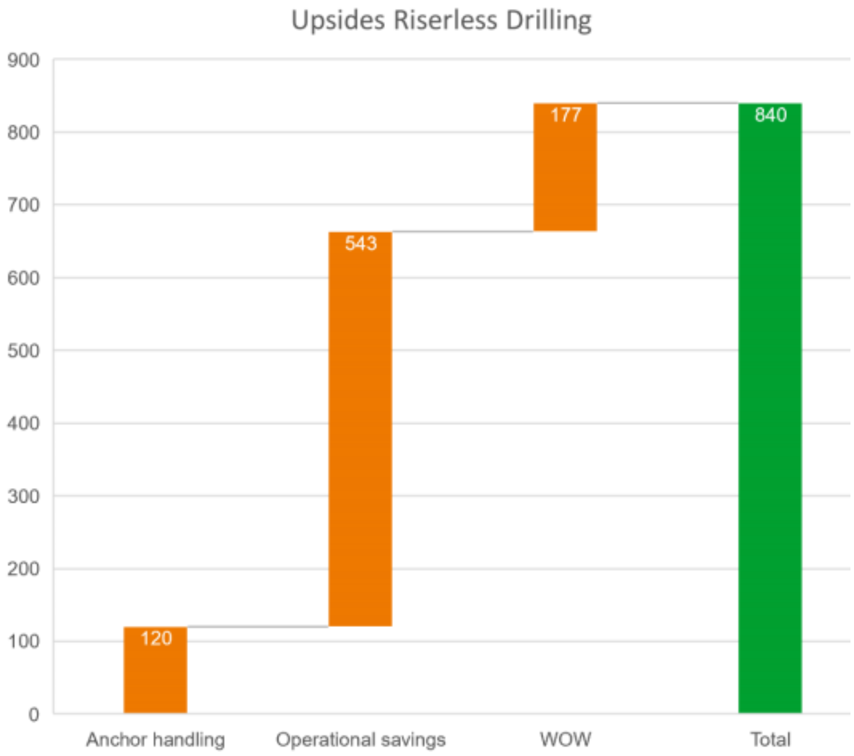


Figure 26: Potential savings using riserless drilling, with the Y-axis showing cost in million NOK (Sissener 2020)

Figure 26 shows the potential savings from applying riserless drilling technology compared to drilling with riser. There are three main categories where significant savings are projected: anchoring operations, operational savings and reduced time spent on waiting for weather (WOW). The savings in anchor handling occur from the reduced need of anchoring due to the added flexibility allowed by the riserless technology design. Savings on operations are due to the less time spent handling the traditional riser systems, less overall flat time, faster turnaround on drill floor and faster running of BOP. The final addition to potential savings comes from the projected savings in WOW time due to the increase in flexibility when drilling riser-less on DP with no riser connected to the wellhead.

5.1.3 Jack up dual activity drilling

Figure 27: Drilling two wells conventionally compared to sequential dual drilling of the two wells (Sissener 2020)

Figure 27 horizontally juxtaposes the Gantt charts depicting the expected drilling times of two wells in sequential dual drilling and in conventional, "as-is", drilling modes. The lower part shows that conventional drilling mode, where the second well is drilled in the same well center immediately after the first one is finished, takes circa 59 days. The upper part shows that sequential dual drilling mode, where the two wells are drilled in parallel mode, with the second well being drilled in the second well center while the first well center is running the conductor and installing casing, takes around 41 days. The 18 days difference represents a 30% time saving.

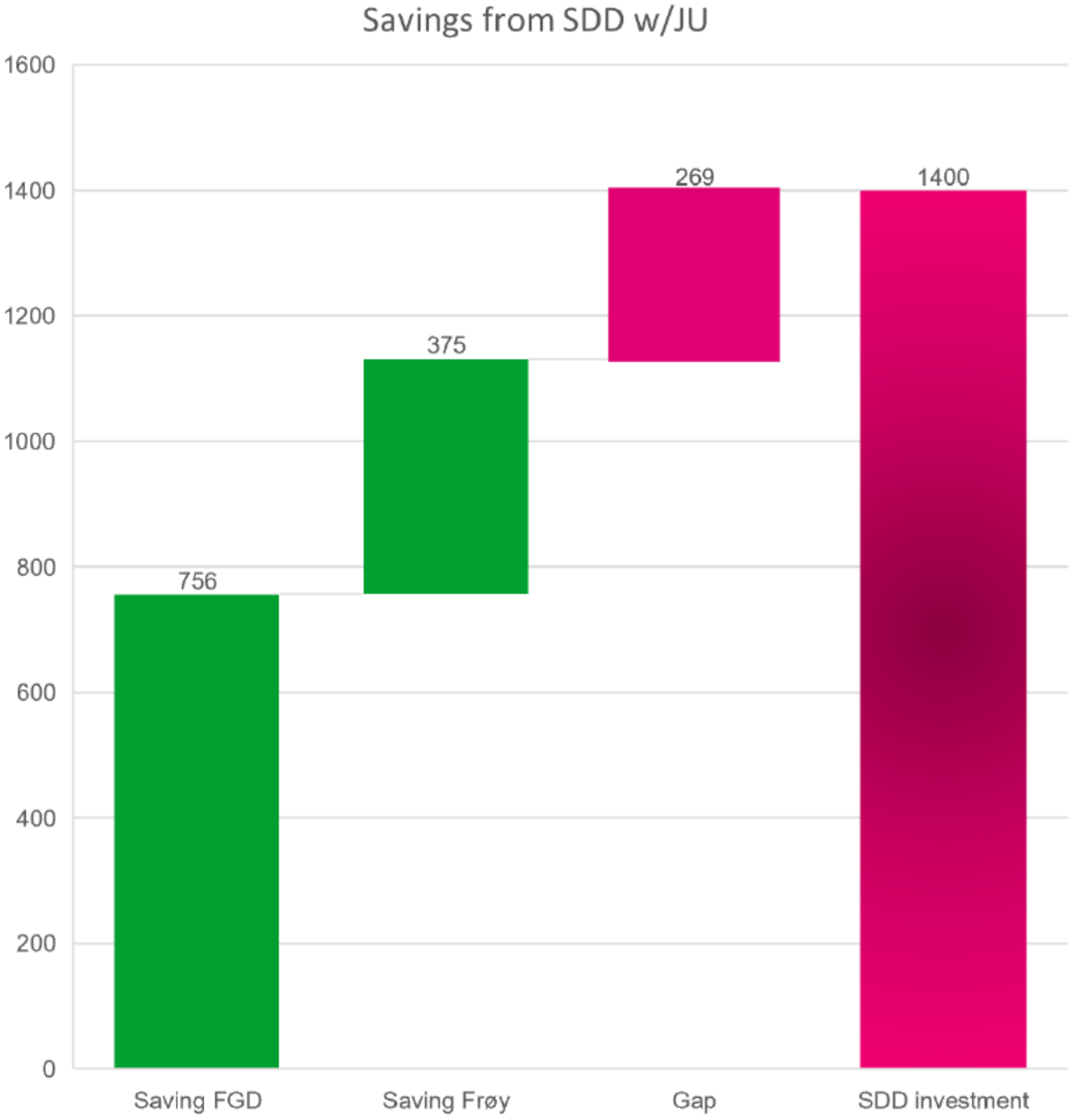


Figure 28: SDD saving and costs. Y-axis in mNOK (Sissener 2020)

Figure 28 shows the financial model of the potential savings from applying dual drilling on the jack-up platforms FGD and Frøy in the NOAKA field development plotted against the investment needed. The green bars show potential savings obtained by performing dual operations with a sequential dual drilling jack-up rig. Total savings come 270 mNOK short of the total investment needed to upgrade the rig's cantilever modules for dual drilling capability. The 270 mNOK gap renders the sequential dual drilling investment not lucrative by considerably raising the ultimate break-even dollar per barrel costs.

6 Discussion

6.1 Drilling vessels

This thesis had looked into three different types of drilling vessels. Each type has the potential to either perform dual activity drilling, or to be upgraded or retrofitted to enable both dual activity drilling and full dual drilling.

Semi-submersible rigs seem to be a viable alternative for a company aiming to perform dual activity drilling or to achieve full dual drilling at the current date. The advantages of selecting a semi-submersible are, in no small part, due to its operational range, given that the rig can operate in both shallow and deep waters by selecting the most efficient positioning method, i.e. anchor mooring or DP. Using the DP system allows for time savings when arriving at the drilling location. If operating using the DP system, the rig is not dependent on additional support vessels to fix it in position. This independence reduces preparational costs. Due to the reduced amount of time needed to prepare the rig for drilling operations when arriving at location, and the nearly eliminated need for additional support vessels, costs could be reduced by as much as 120 mNOK, as shown in fig. 26. The positive effects of a cost reduction of 120 mNOK might not inform the reader as much without a related comparison. In 2019 Aker BP contracted Odfjell Drilling to drill five top hole wells using DSS dual activity drilling capability. From figure 23 and figure 24, and given DSS daily rig rate at 9.5 mNOK, savings from applying the rigs dual activity drilling capacity resulted in a cost reduction of 58.88 mNOK. This comparison should present the net value of performing drilling operations using DP system compared to anchor mooring. The downside of using DP is that the rig is more vulnerable to the consequences of unwanted events like a power outage. DSS is currently working on a project to reduce the risk of such unwanted events as a power outage. The new project aims to install a power saving battery system mounted on the rigs top drives. The system will allow the rig to store energy from raising and lowering the top drive system during drilling operations. The project shows enough promise to store sufficient amounts of energy to power the rigs thruster system for a sufficient length of time, enabling the re-positioning of the rig if its power systems fail, or climate conditions require more power directed to its positioning system, or in case of a loss of position control. Given that a semi-submersible rig is equipped with thrusters, it has the ability to optimally position itself depending on the surrounding weather and water conditions. The rigs maneuverability also enables these types of rigs to change their position in case of lost well control, and also to optimally position themselves when performing dual drilling. We see that the semi-submersibles ability to strategically move and position itself according to the operational and environmental requirements are a positive characteristic of using this type of rig. As mentioned in section 3.3.2 regarding management and HSE, the full risk picture is highly influenced by factors like crew experience, planing, and intersecting communication. With regards to planing, it can be inferred that the ability of the drilling company to plan a dual drilling campaign thoroughly by including activities such as when to move, and where the rig is supposed to be positioned during the different operational phases, and the communication between crew to inform relevant personnel and thus adapt the plan to current events should help reduce both risks and costs entrenched with the higher activity level during dual drilling operations. The ability to plan and execute the sequence of activities of a dual drilling operation with its associated increase in tool handling, active staff, and active equipment, also relates to the ability to properly plan the overall dual drilling campaign. In order to perform dual drilling, there is a need to increase the on-deck staff. Since both dual activity drilling and full dual drilling are characterized by operating two drill centers, the increase in crew must be sufficient to staff both centers and other critical areas related to the drilling operations. Given that dual drilling experience is currently fairly rare, and that there are few cases to build a strong case on, a drilling company should think to include additional staffing in case of unforeseen events. No company planning or envisioning itself performing dual drilling should avoid the addition in crew size, as the costs of having sufficient manpower available are small compared to the cost of equipment, rig rates, and, in the worst case, the cost of an unforeseen event.

Though the case for selecting semi-submersible rigs to perform dual drilling is strong, there is still a question of upgrading the rig to enable full dual drilling. As no offshore drilling vessel to date is capable of performing full dual drilling given structural, systematic, and financial limitations, it is clear that the capital investment necessary to achieve full dual drilling is significant. In order to enable DSS to perform full dual drilling, upgrades are needed. Firstly, the semi-submersible's structural strength must be upgraded to handle the weight increase due to additional equipment like a dual BOP system, increases in system capacity to handle the dual BOP system, and increases in on-rig available equipment like supplementary casings and risers needed for a dual well operation. Given today's market, such an investment is risky given the short length on contracts. In cases looked at during the work on this thesis, mainly the cooperation between Aker BP and Odfjell drilling, it is clear that the necessary capital investments needed must be divided between the different actors in order to ensure a sound cooperation. From Odfjells position, the case is the cost of the rig upgrade and loss of revenue given DSS downtime due to the work needed to perform upgrades. From Aker BP, there is a net positive gain to have a full dual drilling rig available for future projects, but it is not favourable for the company to singlehandedly cover all necessary costs since Aker BP is not the owner of the rig, and thus risks paying the cost for its competitors. This discussion is well outside the scope of the thesis, but it is necessary to include it as it gives insights into challenges surrounding dual drilling projects.

The jack-up rig is a fixed drilling platform. The operational water depth is lower for a jack up than for a semi-submersible. The industry standard is approximately 150-180m of water depth. This limits the use of such rigs to shallower waters. Within this depth window, jack ups compare to semi-submersibles. The rig is dependent on support vessels to transport between drilling locations. The dependence on support vessels increases the cost of using jack-ups. A major advantage when evaluating jack-ups for dual drilling ability is how these rigs can be upgraded. As presented in theory chapter on the cantilever, designing a new cantilever for various dual drilling concepts shows promise in both price and feasibility. Figure 27 shows that performing sequential dual drilling on a jack-up with an SDD cantilever design can save as much as 30 % compared to conventional drilling on a standard cantilever. Dual drilling from jack-up rigs are dependent on either designing a new cantilever to either perform sequential dual drilling (dual activity drilling) or ultimate dual drilling (full dual drilling). In interviews with Aker BP we were told that selecting a UDD cantilever shows approximately the same saving as selecting a SDD but required a higher capital investment (Sissener 2021). Given the higher capital investment, it is more feasible to select the SDD cantilever design for the jack-up. Still, from figure 28 we can see that the drillex investment for Aker BPs NOAKA development have a savings gap of 268 mNOK between investment and savings. The gap shows that the price of investing in a new cantilever is high and that upgrading semi-submersibles is comparatively more favourable.

Drillships are not an alternative that has been investigated by the companies contacted during the work on the present thesis. Nevertheless, when reading the scientific literature we looked into the feasibility to upgrade drillships for dual drilling capacity. From our investigation, the benefits of selecting a drillship is in large part due to the "ship" qualities. Drillships have a higher deck load capacity and can easier maneuver themselves according to weather conditions and drill location. Drillships are nevertheless less stable than semi-submersibles, but, if the drillship increases in mass, it will approach the level of stability experienced from semi-submersible rigs. The higher deck load capacity is an advantage with regards to the increased amount of equipment and tools needed for performing dual drilling operations. Drillships are, compared to semi-submersibles and jack-ups, better predisposed for upgrades like a dual BOP system. A main feature for ensuring efficient dual drilling operations on offshore drilling units (ODU) is the vessels ability for sustained equipment flow. If the assumption is that cement, casing, riser, and drill string activities are doubled, then it is vital for the drill floor to allow for seamless flow of such equipment in order to avoid bottlenecks, lost time and increased waiting time, all of which will contribute to increases in NPT, instead to a reduction. In figure 7, in the relevant theory section, we present an illustration of a longitudinally oriented drill floor, which to date is the standard design layout. From the figure, it is clear that performing dual activity or full dual drilling on the standard design could result in experiencing logistical bottlenecks, given that each well center blocks equipment flow to the other well center due to the standard design allowing for the flow of well consumables and tools to the aft well center to only be fully accessible from the aft area, and that the forward well center to only be fully accessible from forward area of the drillship. As described in the drillship theory section, it is also a challenge that both well centers on drillships with dual derricks are not fully equivalent. Each well center is optimized for certain tasks. From figure 7 we can again see that drill pipes and casings are handled in the aft section, and that the forward center handles risers and casings. However, when reading the "OTC-27694-MS Euryale moonpool" paper, which discussed designing newer drillships with a transversely oriented setup, a solution seemed promising. Figure 8 shows a transversely oriented design where access to both well centers is unrestricted, making them able to perform all drilling operations independently. In effect, a transversal setup increases the redundancy for drilling operations. Between the two well centers, on the main deck, as illustrated by figure 9, a removable bridge, or temporary work station, is installed. This area increases the available work space during drilling operations. To reduce NPT, a method for transporting a submerged riser between drill centers has been developed. The solution is called a trip saver system. To utilize this system, the temporary work station must be removed for the system to transport the submerged riser to the parallel well center. Using this system reduced NPT with the time that would have otherwise been needed to retract and make and break the riser.

6.2 Dual Drilling

Dual drilling can be performed in several different methods. This thesis has looked into dual activity drilling, full dual drilling, sequential dual drilling, top hole dual drilling, and dual riserless drilling. How these drilling concepts function is presented in the theory section on drilling. At the current date no offshore vessels can perform full dual drilling, nor dual riserless drilling. Dual activity drilling is possible given available technical solutions and has been done by Odfjell Drilling on an Aker BP contract. The semi-submersible rig Deepsea Stavanger drilled four top hole sections using its dual activity drilling capacity. The aim of dual drilling is to reduce the cost of drilling offshore hydrocarbon wells, mainly be reducing NPT. The capability to drill either two separate wells simultaneously or to use two full drill centers to drill one well, is achieved by moving several tasks off the critical path. The ability to perform tasks off the critical path enables drilling to run continuously and thus increases the effectiveness of the drilling operation.

As presented in the theoretical section, the conceptual wingspan of a dual drilling approach ranges from drilling one well using two drill centers to simultaneously drilling two fully independent wells. These different conceptual variants bring with them distinct advantages and challenges.

DSS is currently equipped to perform dual activity drilling, and has performed top hole drilling using this method. Dual activity drilling can be considered the cheapest alternative to perform dual drilling as, since existing drilling vessels are already capable to perform it. From interviews with the staff on-board the rig, it is clear that one of the major contributing factors to a successful operation was a skilled crew, good communication, and a thorough planning process. Performing top hole dual activity drilling reduced NPT by performing several activities off the critical path. Operations like simultaneous making and braking of BHA and drill strings made the reduction in NPT possible.

Top hole dual drilling is a method were both drill centers are actively drilling. The main well center drills a full top hole section of a well, while the auxiliary well center drills a pilot hole to check for shallow gas, and assists the main center with tool handling. If the pilot hole does not come into contact with shallow gas, then the auxiliary center can drill the full top hole section in that well when the main well center has finished drilling the first top hole. This reduces time as there is little to no risk of gas contact while drilling with a larger diameter bit. A variation of top hole drilling is batch drilling. Batch drilling fully utilizes dual activity drilling. The goal of batch drilling is to complete top hole sections as fast as possible. Both well centers focus on a single well. This reduces time because all of the tool handling is performed off the critical path, and in effect the rig performing batch drilling is continuously drilling. This is a contributor to a reduction of NPT because less time is spent waiting for pull out activities, and other activies like preparing casing, strings, BHA, and BOP are performed in parallel to drilling activities. Batch drilling and the other top hole drilling methods are shown in figure 21 and the difference in time to drill the 10 top holes varies with 11.3 days, from 29.7 days to 18.4 days. The savings in time are due to the reduction of NPT from utilizing two well centers to perform drilling related activities. From figure 22 it is clear that top hole drilling can save as much as 130 mNOK due to the reduction in NPT which reduced the amount of days when a drilling unit is needed.

Full dual drilling has to date not been performed, but plans to upgrade semi-submersible rigs like the DSS are in the works. The main issue with going from dual activity to full dual drilling capacity involves capital investments that will need to be shared between the rig company and the operator, to ensure a fair distribution of capital gains and costs. Furthermore, the major obstacle to performing full dual drilling is the increase in tool handling and increased staffing working in parallel. This entails that the rigs capacity will be fully utilized during full dual drilling and will prompt the necessity to plan operations carefully. The main advantage of dual activity drilling compared to full dual drilling is the available time for crew to prepare equipment and perform HSE tasks, which is lost during full dual drilling due to the increased activity on the drill floor.

Dual drilling using riserless technology and a dual BOP system is at the forefront of drilling technology. At the time, no drilling vessel is equipped with such a setup. Nevertheless, full dual riserless drilling concepts for achieving this capability are developed for both semi-submersible and jack-up rigs. Given the currently available pump capacity and power generation capabilities, it is not feasible to drill full dual riserless from top hole to the reservoir section. To accommodate these limitations, the larger casing sections could be drilled using batch dual drilling until sufficiently small casing diameters are reached. Once reached, full dual riserless drilling is initiated and both wells are drilled in parallel from each well center. At this point, drilling from each well center is performed similarly to conventional drilling. Riserless drilling allows maintaining of pressure control while drilling two wells in parallel (Sissener 2021).

Dual riserless drilling is, as of yet, an unproved drilling concept. The goal of developing this concept is to optimize drilling capability in order to decrease the time needed for drilling and well completion. In order for the concept to work, both technological advances, and rig upgrades have to happen. Using Deepsea Stavanger as a standard case, some of the necessary modifications to enable dual riserless drilling are having an additional BOP in active service, accompanied by increased deck load and bearing capacity to store and handle the extra BOP. To operate a dual BOP installation, upgrades to the control and power systems are required. Pipe wiping needs to be further developed to prevent spillage from the riserless system. The pipe wiper needs to be very effective to ensure no oil based mud (OBM) spillage when pulling the drill string out of hole. Zero discharge is for now not yet achieved but work is being done at the supplier level to develop a good enough wiper (Sissener 2021). Figure 25 shows the difference in drilling time between conventional drilling (dotted blue line) and riser-less drilling (red line). Combined with figure 26 which shows savings from anchor handling, operation, and waiting of weather. The application of riserless dual drilling reduced the risk factors of weather disturbances. Due to the lack of a riser there is less risk of the rig moving too far away from the well center which reduced the shut down time of operations. Operational savings are largely achieved by not having the need to run and pull riser casings. Yet in order for dual riser less drilling to become feasible additional advances in technology is needed, like the development of a pipe wiper and riserless RCD.

When drilling with riserless technology new challenges are present. The lack of a marine riser that protects the environment from pollution requires the rig owner to apply alternative solutions to prevent the spillage of well stream fluids into the open sea. When POOH the drill string, a higher emphasis on cleansing is important to prevent discharge of unwanted material into the ocean. A solution is to develop a system that cleans the drill string as it is POOH. The challenge with such pipe wiping systems is to ensure that the drill string is properly and thoroughly cleaned before it exits the wellhead. Ensuring necessary cleaning might also demand a system that reliably measures the effectiveness of the cleaning. This cleaning effectiveness is of such importance that the whole riserless project depends on it getting effective enough. If the pipe wiper is not effective enough, the drilling operation will be restricted to the use of solely WBM and forego all the advantages of OBM. Abandoning the use of OBM is not feasible at this time. This renders the pipe wiper a crucially important part for the riserless drilling operation.(Sissener 2021)

For dual drilling to become feasible there is also need to modify subsea templates to fit with the spacing between drill string.

In order to perform dual drilling for a MODU like Deepsea Stavanger with a well center spacing of 10 m in-between, the well slot spacing on a template must be extended from today's 6 m standard to 10 m. The requirement of modified spacing between well slots creates a problem with operations on preexisting offshore petroleum fields not designed for dual drilling. The template redesign also requires future fields to be planned as dual drilling fields, and a change in business standards for template design. If a field is not designed for dual drilling, then the dual drilling activity will be limited by template design to only be performed as dual activity drilling, which still is an improvement on efficiency compared to both conventional drilling and the drilling of wells without template structures.

6.3 Management and HSE

Management planning in both the drilling and completion phases is paramount to successfully performing dual drilling operations. Drilling management teams ensure successful drilling campaigns by establishing management structures and administration systems for, among others, mitigating collision risks and general footprint and equipment management, safety, incident and hazard management, fluids, waste and general well operations and well work management, and costs management for the two well phases.

Managing the shuffle of simultaneous operations a dual drilling program entails is especially relevant for the program's success. The real-time management of total power requirements due to the limited power generation availability during the more power-hungry drilling phases, and the increase in staffing requirements during dual drilling operations are challenges that require both relatively complex shift and crew management strategies and proactive HSE management, commitment and support. Aker BPs management strategy of having no crew in the area around the well center except during certain manual operations, succeeds in achieving the desired levels of operational crew safety while managing the inherent challenges of optimizing operations at the one well center while simultaneously responding to the manual crew operations requirements around the second one.

As seen, Critical Path Method (CPM) and Gantt charts are widely used in the industry to make sense of, plan and optimize both the bigger projects as a whole and the related activities within a given project, down to the minutiae of drill floor logistical flow. However, the scheduling literature has produced advances, with more refined theoretical and practical methods being developed in the last decades. These newer methods, like Precedence Diagramming Method (PDM) and the Critical Chain Project Management method (CCPM), do not seem to be widely used despite their prima faciae helpfulness in the further optimization of the extensive day-to-day practicalities around the general planning of logistical flow. Use of these methods might present significant room for efficiency and versatility improvement especially given the challenging logistical environment dual drilling operations adduce.

Experience with dual drilling is limited. When Odfjell drilling started to perform dual activity drilling, on behalf of Aker BP, they included additional time to prevent mistakes and unwanted events. Since dual drilling requires a bigger staff, and a higher flow of equipment, the surprising observation was that the predicted learning curve for dual drilling operations was shorter than expected. In expert interviews we were told that the additional time added for learning was almost unnecessary due to existing crew experience and competency during the planning and execution process.

7 Conclusion

During this thesis the possibility for dual drilling to reduce NPT has been investigated. Trough the information gathered from previously mentioned industry actors, our conclusion is that dual drilling in both of its concepts can be both feasible and economical in the adequate market conditions. There is a potential to save upwards of 30% of the drilling costs compared to conventional drilling. The reduction in NPT does not seem to impair the existing high quality standards of routine HSE principles during operations. The roadblock for dual drilling is the capital investment for upgrading drilling units, and the necessary technologies that must be in place to ensure high environmental standards.

By having two entirely independent well construction centers, both top hole and down hole operations can be simultaneously executed with zero HSE issues. A dual drilling set up can speed field development in both single well applications as well as an multi-well subsea template situations. Dual drilling packages have proven themselves to be an overall positive experience by ensuring operational redundancy by delivering additional rig flexibility combined with proper well accessibility, while minimizing the amount of needed equipment.

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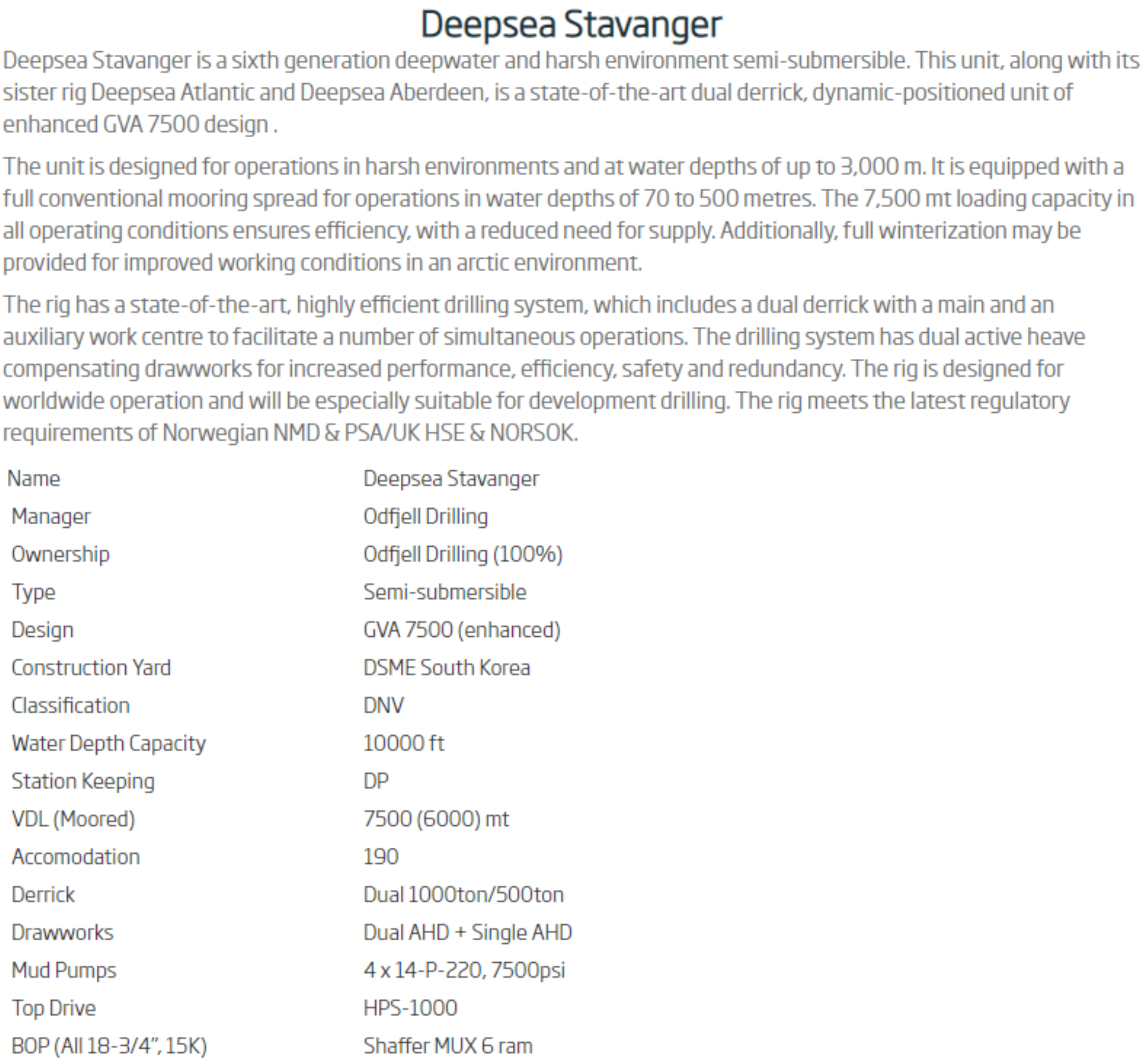
Appendix

A Deepsea Stavanger rig brochure



Deepsea Stavanger

Deepsea Stavanger is a sixth generation deepwater and harsh environment semi-submersible. This unit, along with its sister rig Deepsea Atlantic and Deepsea Aberdeen, is a state-of-the-art dual derrick, dynamic-positioned unit of enhanced GVA 7500 design .

The unit is designed for operations in harsh environments and at water depths of up to 3,000 m. It is equipped with a full conventional mooring spread for operations in water depths of 70 to 500 metres. The 7,500 mt loading capacity in all operating conditions ensures efficiency, with a reduced need for supply. Additionally, full winterization may be provided for improved working conditions in an arctic environment.

The rig has a state-of-the-art, highly efficient drilling system, which includes a dual derrick with a main and an auxiliary work centre to facilitate a number of simultaneous operations. The drilling system has dual active heave compensating drawworks for increased performance, efficiency, safety and redundancy. The rig is designed for worldwide operation and will be especially suitable for development drilling. The rig meets the latest regulatory requirements of Norwegian NMD & PSA/UK HSE & NORSOK.

Name	Deepsea Stavanger
Manager	Odfjell Drilling
Ownership	Odfjell Drilling (100%)
Type	Semi-submersible
Design	GVA 7500 (enhanced)
Construction Yard	DSME South Korea
Classification	DNV
Water Depth Capacity	10000 ft
Station Keeping	DP
VDL (Moored)	7500 (6000) mt
Accomodation	190
Derrick	Dual 1000ton/500ton
Drawworks	Dual AHD + Single AHD
Mud Pumps	4 x 14-P-220, 7500psi
Top Drive	HPS-1000
BOP (All 18-3/4", 15K)	Shaffer MUX 6 ram

B Deepsea Stavanger Field Trip

Figure 29: Deep Sea Stavanger Moonpool

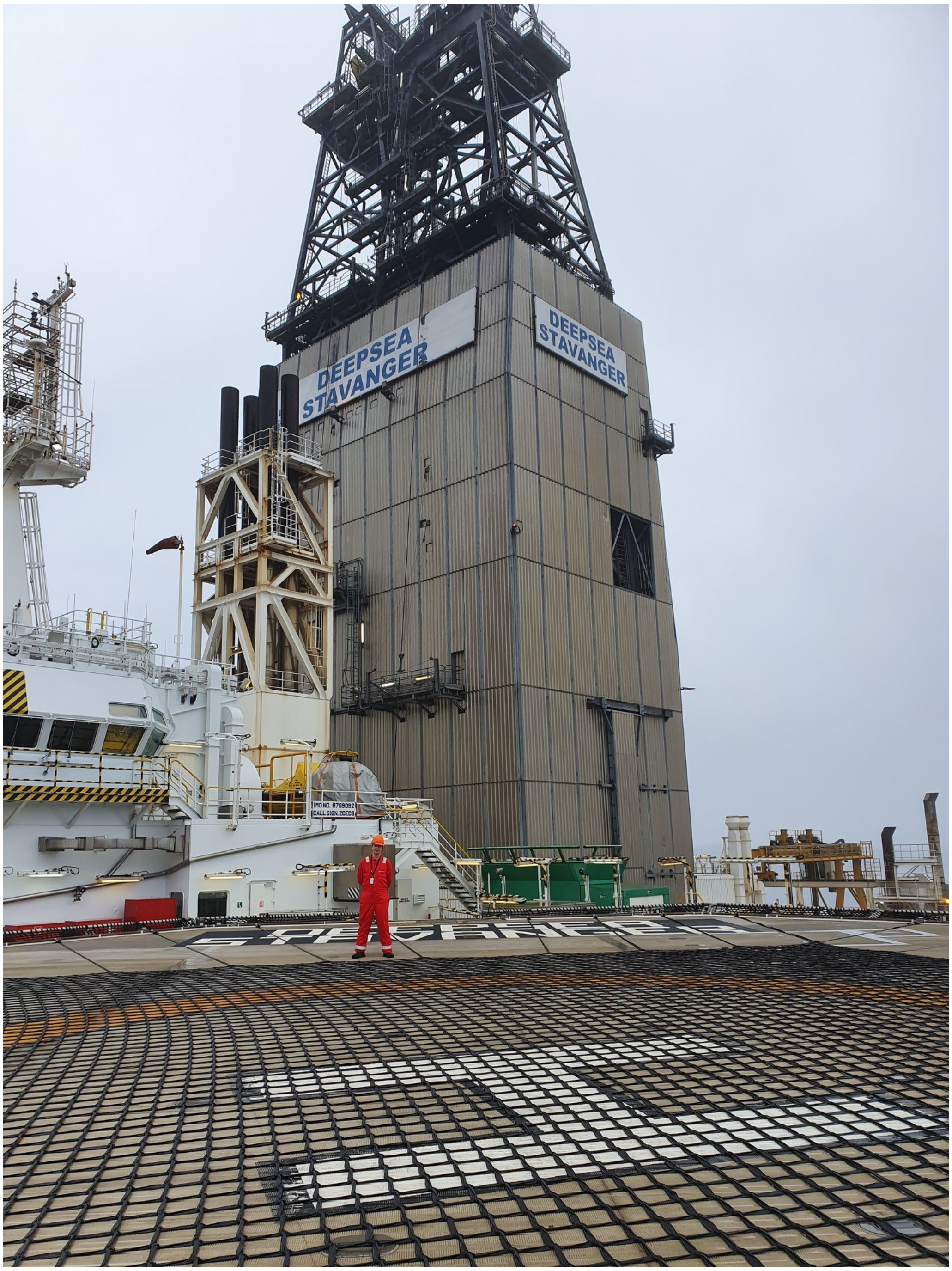
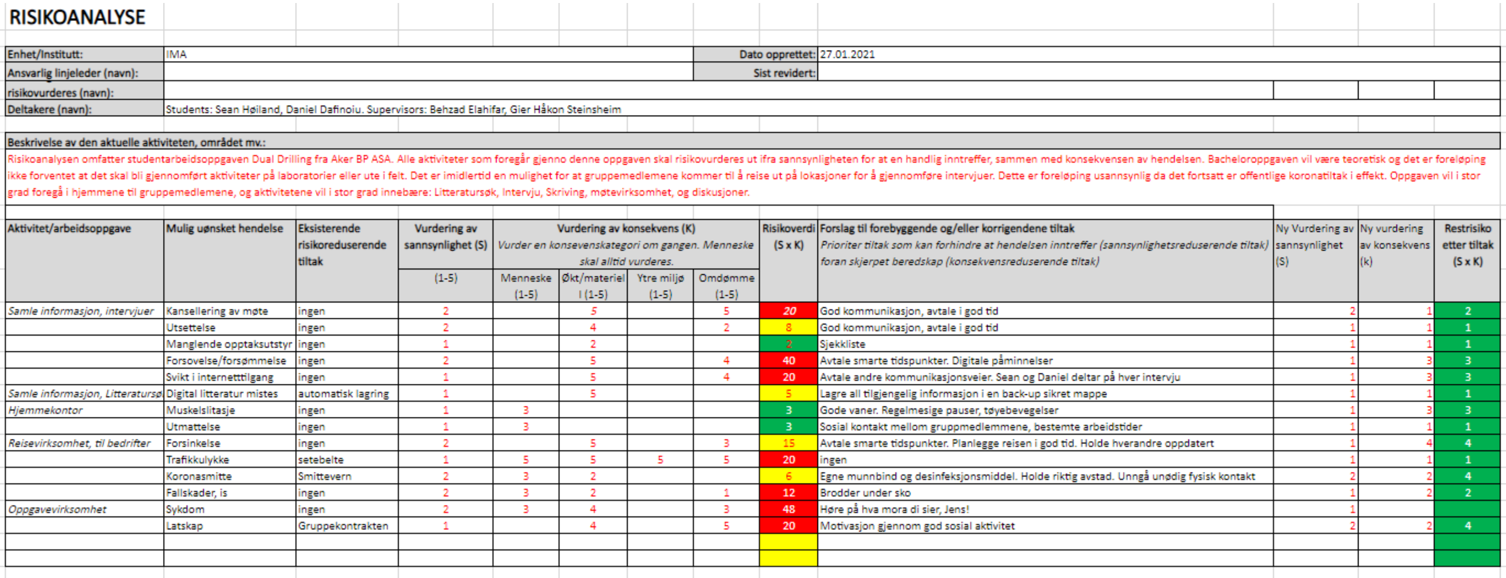


Figure 30: DSS Heliport and Dual Derrick

Figure 31: Man and machine. Esteemed Authors group photo

Figure 32: DSS overview picture

C Risk assesment



RISIKOANALYSE

Enhet/Institutt:	IMA	**Dato opprettet:**	27.01.2021
Ansvarlig linjeleder (navn):		**Sist revidert:**	
risikovurderes (navn):			
Deltakere (navn):	Students: Sean Høiland, Daniel Dafinoiu. Supervisors: Behzad Elahifar, Gier Håkon Steinsheim		

Beskrivelse av den aktuelle aktiviteten, området mv.:

Risikoanalysen omfatter studentarbeidsoppgaven Dual Drilling fra Aker BP ASA. Alle aktiviteter som foregår gjenno denne oppgaven skal risikovurderes ut ifra sannsynligheten for at en handlig inntreffer, sammen med konsekvensen av hendelsen. Bacheloroppgaven vil være teoretisk og det er foreløping ikke forventet at det skal bli gjennomført aktiviteter på laboratorier eller ute i felt. Det er imidlertid en mulighet for at gruppemedlemene kommer til å reise ut på lokasjoner for å gjennomføre intervjuer. Dette er foreløping usannsynlig da det fortsatt er offentlige koronatiltak i effekt. Oppgaven vil i stor grad foregå i hjemmene til gruppemedlemene, og aktivitetene vil i stor grad innebære: Litteratursøk, Intervju, Skriving, møtevirksomhet, og diskusjoner.

Aktivitet/arbeidsoppgave	**Mulig uønsket hendelse**	**Eksisterende risikoreduserende tiltak**	**Vurdering av sannsynlighet (S)**	**Vurdering av konsekvens (K)** *Vurder en konsevenskategori om gangen. Menneske skal alltid vurderes.*				**Risikoverdi (S x K)**	**Forslag til forebyggende og/eller korrigendene tiltak** *Prioriter tiltak som kan forhindre at hendelsen inntreffer (sannsynlighetsreduserende tiltak) foran skjerpet beredskap (konsekvensreduserende tiltak)*	Ny Vurdering av sannsynlighet (S)	Ny vurdering av konsekvens (k)	**Restrisiko etter tiltak (S x K)**
			(1-5)	Menneske (1-5)	Økt/materiel l (1-5)	Ytre miljø (1-5)	Omdømme (1-5)					
Samle informasjon, intervjuer	Kansellering av møte	ingen	2		*5*		5	*20*	God kommunikasjon, avtale i god tid	2	1	2
	Utsettelse	ingen	2		4		2	8	God kommunikasjon, avtale i god tid	1	1	1
	Manglende opptaksutstyr	ingen	1		2			2	Sjekkliste	1	1	1
	Forsovelse/forsømmelse	ingen	2		5		4	40	Avtale smarte tidspunkter. Digitale påminnelser	1	3	3
	Svikt i internetttilgang	ingen	1		5		4	20	Avtale andre kommunikasjonsveier. Sean og Daniel deltar på hver intervju	1	3	3
Samle informasjon, Litteratursø	Digital litteratur mistes	automatisk lagring	1		5			5	Lagre all tilgjengelig informasjon i en back-up sikret mappe	1	1	1
Hjemmekontor	Muskelslitasje	ingen	1	3				3	Gode vaner. Regelmesige pauser, tøyebevegelser	1	3	3
	Utmattelse	ingen	1	3				3	Sosial kontakt mellom gruppmedlemmene, bestemte arbeidstider	1	1	1
Reisevirksomhet, til bedrifter	Forsinkelse	ingen	2		5		3	15	Avtale smarte tidspunkter. Planlegge reisen i god tid. Holde hverandre oppdatert	1	4	4
	Trafikkulykke	setebelte	1	5	5	5	5	20	ingen	1	1	1
	Koronasmitte	Smittevern	2	3	2			6	Egne munnbind og desinfeksjonsmiddel. Holde riktig avstad. Unngå unødig fysisk kontakt	2	2	4
	Fallskader, is	ingen	2	3	2		1	12	Brodder under sko	1	2	2
Oppgavevirksomhet	Sykdom	ingen	2	3	4		3	48	Høre på hva mora di sier, Jens!	1		
	Latskap	Gruppekontrakten	1		4		5	20	Motivasjon gjennom god sosial aktivitet	2	2	4

D Scientific article

Dual drilling – a cheap way to drill

By Sean Høiland and Daniel Dafinoiu

Dual drilling is a drilling concept which utilizes an offshore drilling vessels ability to simultaneously drill two wells from one platform.

If a mobile offshore drilling unit is equipped with two derricks and well centers then the rig can drill two wells at the same time. The goal of implementing this is to reduce the time needed to complete the drilling campaign. There are two main strategies for dual drilling:

- Dual activity drilling
- Full dual drilling

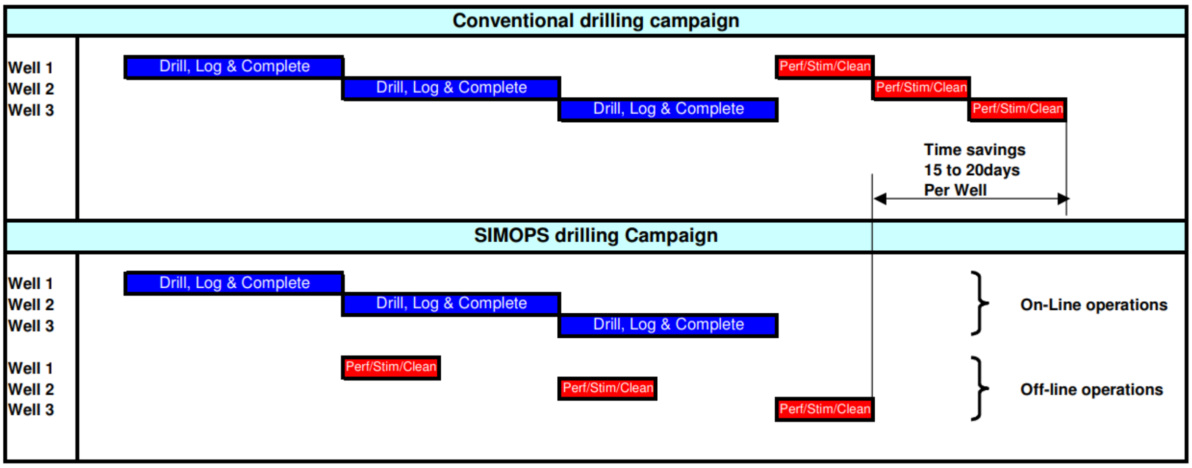


Figure 1: Savings in time applying SIMOPS like dual driling compared to conventional drilling.

Dual activity drilling uses the rigs two well centers to drill one well. When performing dual activity drilling, time is saved by moving tasks like pulling out of hole, running casings and cement in parallel to drilling. Dual activity drilling is a drilling concept available in todays market.

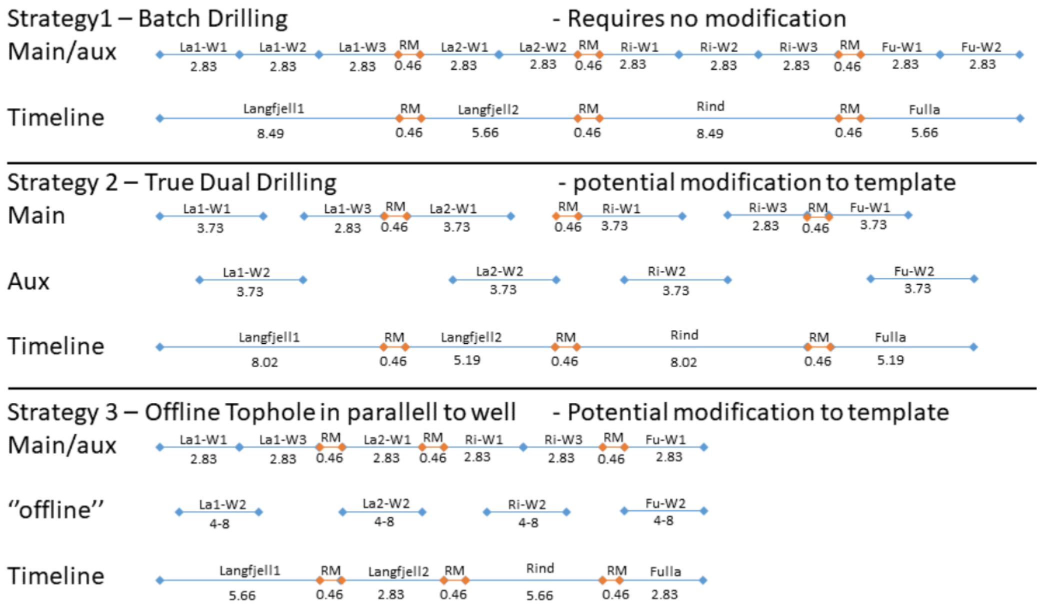


Figure 2: Time saving between different strategies of dual activity drilling.

Full dual drilling uses rigs with two complete and independent well centers to drill two separate wells. When performing full dual drilling the time saved comes from the ability to drill two complete wells at the same, or close to the same, time it takes to drill one well using conventional drilling. Full dual drilling is not a drilling concept which is finalized. For full dual drilling to work, a drilling unit needs specific upgrades like an increased deck load capacity as the rig needs a dual BOP system.

Dual drilling concepts entail a higher flow of equipment. In dual drilling, the goal is to continuously drill, while performing additional task in parallel. Thus, there arises a higher need for careful planning and tool handling. The planning needs to be throughout to ensure a high quality on HSE.

With the increased flow of consumable tools like casings, drilling mud, cement there is an additional need for either better deck storage of consumables or a higher deck storage area. During the investigation into dual drilling a further new drilling concepts to alleviate this need for storage shows interest. Riser-less dual drilling.

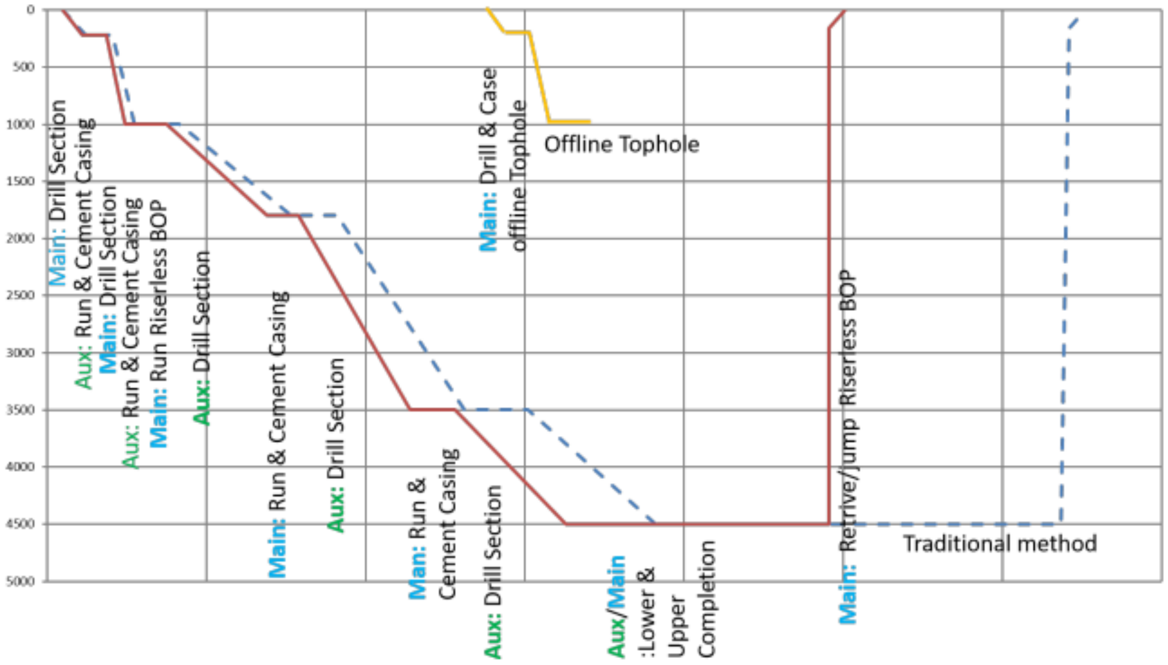


Figure 3: Operational time differences between riserless dual drilling and conventional drilling.

Riser-less dual drilling aims to use technology to drill wells without the use of a marine riser. Given that the semi-submersible rig Deepsea Stavanger is equipped with 3000 m of riser, the ability to drill without a marine riser will free up deck space for more consumables. The use of riser-less technology will also help with the reduction in non-productive time spent on each well, as the waiting time to build and break the riser is removed.

When applying two drilling strings at the same time, floating rigs like semi submersibles are less flexible during drilling. When drilling with conventional methods, a rig is expected to move around and the drill string can tolerate up to 10 degrees of inclination, when using two drill strings at the same time, this inclination in reduced. A limiting factor is the marine riser. When using riser-less drilling this limiting factor is counteracted and the rig will regain its flexibility. Riser-less drilling could also reduce the drilling time lost in preparations to severe weather conditions. With conventional drilling method there is a need to shut down operations in good time before the weather conditions hit. The reduced need to stop operations, and the time lost reinitiating the drilling operations is thus removed and more time is saved.

If a drilling unit operates with two full drill centers there is an addition to the needed staff to perform the drilling operations. On board Deepsea Stavanger, operating using dual activity drilling, the additional crew includes a minimum of two drillers and six additional roughnecks. Full dual drilling will require and additional increase in crew with extra roughnecks and tool pushers. The addition in crew is required to operate both well centers, additional tool handling, and pump room.

Rigs utilizing full dual drilling must consider the spacing between well centers. The distance between drill string (and well centers) on Deepsea Stavanger is 10 m. If drilling is performed on a subsea template, then there is also a need to design a new standard for subsea templates. With conventional drilling the standard distance between well centers (and template slots) is 6 m, this distance must be extended to the required minimum for the rigs doing the drilling. Drilling from

Deepsea Stavanger the slot distance must be increased to 10 meters. Drilling from a jack up rig will require a 5 m distance. At the current date there are no subsea templates with these dimensions. Because no subsea templates are designed for dual drilling dual drilling has a backwards compatibility issue and thus limits dual drilling to drilling without a template, or to drilling on newer templates on newer fields.

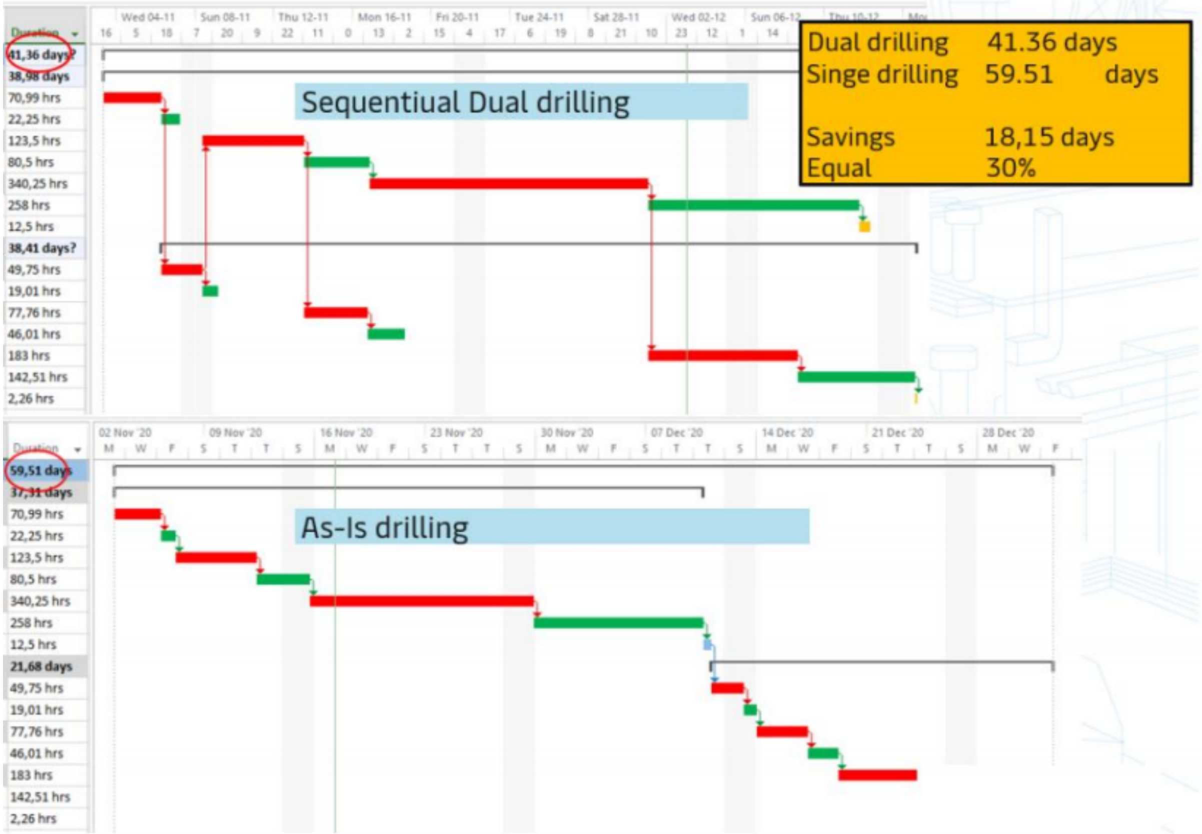


Figure 4: Time savings between dual drilling and conventional drilling from Jack ups.

Due to this limit, if dual drilling is to be a preferable strategy for well operations in existing field, dual drilling is currently limited to dual activity drilling.

When investigating dual drilling on jack-up- and semi-submersible rigs the predicted time savings are between 20% and 40%, with 30% being the accepted time savings predicted. Currently no data indicated the possibility to reduce costs with 50% due to several factors.

The hindering of achieving a 50% time and cost reduction is due to what is called fixed costs. In the designing of a drilling campaign there are costs which do not vary with time. These costs are related to the needed tools and consumables. Drilling two wells with a total well length of 4000 m each requires the same amounts of casings, cement, and drilling mud. Cost related to this does not vary with time, and will thus not be affected by the increased drilling speed.

Each well drilled is different. The variations in subsurface rock formations results in variations in drilling time for each well section, thus when planning each well the drilling schedule should be planned so that the time between alternating drilling and running cement and casings are aligned in order to reduce the non-productive time for each well as much as possible, or to plan preparational tasks, inspections, and maintenance operations into time slots with a waiting period between tasks.

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