FACULTY OF SCIENCE AND TECHNOLOGY

MASTER'S THESIS

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Author: Halmat Jabar	(Signature of author)
Faculty supervisor: Jan Aasen External supervisor: John Gjertsen and Erland Jørgensen	
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Master's degree in Petroleum Technology with specialization in Drilling and well technology at the University of Stavanger has been completed with this thesis. It has been five exciting, challenging, and educational years, of which I am very happy to have been a part of.

Abstract

The oil and gas industry continuously enters a phase with new challenges and new ways of thinking, the rise of a digitalization revolution can be the key answer to creating new opportunities to overcome the industry's challenges. The “new reality’’ of low oil prices, Covid-19 still threatening, and the increased focus on climate and environmental considerations globally, has led to a shift in the mindset of the industry; from an increased-production focus to a cost-efficiency focus while maximizing the productivity, minimizing operating costs and sustain operating flexibility. Accomplishing this new way of working may perhaps require a digital transformation.

There has generally been little technology development and digitization in the well intervention sector compared with the drilling sector. Real-time data, onshore support centers, and automation have long been used in the drilling sector. This master thesis introduces an innovative project that is being implemented by ALTUS Intervention. Digital Well Intervention (DWI) is a digital platform that digitizes large parts of today's way of working and how ALTUS Intervention is delivering well intervention services. This master's thesis studies how DWI will affect the work process in ALTUS Intervention. The thesis will provide concrete examples of how DWI improves work processes both internally and externally. The project is still in the planning phase, and thus, concrete proposals are given for the further development of DWI. Furthermore, it is studied how DWI can provide value creation. This is based on several case studies that have been shown to be.

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Digital Well Intervention

Value of digitizing well interventions and its impact on business and working processes

by

Halmat Jabar

Faculty of Science and Technology

University of Stavanger

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List of abbreviations

Acronym	Definition
DWI	Digital well intervention
DOF	Digital oil field
BHA	Bottom hole assembly
RF	Recovery factor
CT	Coiled tubing
IO	Integrated Operations
PLT	Production Logging Tool
HSE	Health, Safety, and Environmental
CSD	Completion String Design
HWO	Hydraulic Workover
NCS	Norwegian Continental Shelf
IOC	Geo Operation Centre
API	Application Programming Interface
DAQ	Data Acquisition
POB	Personnel On Board
KPI	Key Performance Indicators
GIH	Grease Injection Head
DHSV	Downhole safety valve
SV	Swab Valve

Chapter 1: Introduction

1.1 Background

The ‘’ new reality’’ has led to the industry being forced to implement new working methods and take a restructuring process. As a result, increases in efficiency, productivity, and savings have become crucial for oil and gas companies and survive in the market low-price market.

Over the last several years, the oil and gas industry has significantly benefited from advanced technology and new digital capabilities. The drilling sector has made enormous progress through digitalization and new technological solutions over the past 20 years. Advanced sensors, real-time data, drilling automation, and 24/7 onshore support centers are widely established and have been key elements to operational efficiency, productivity, and value creation in the drilling sector. However, compared to the drilling sector, real-time data, support centers, and automatisation are still limited in the well intervention sector, and much is still very old-fashioned today. Given the importance of well intervention, the industry seems to have had little focus on the well intervention sector

As a service company specialized in well intervention, ALTUS Intervention wants to take an innovative approach to well intervention by transferring the concept from the drilling sector into the well intervention sector through their innovation project *Digital Well Intervention* (DWI) platform. In addition, in most oil and gas companies today, the construction planning and execution are scattered across several disconnected systems, including old legacy software, manual paperwork, and spreadsheets. The planning process is generally a time-consuming and demanding process in most oil and gas companies. Communication and collaboration are still insufficient due to several disconnected, and outdated systems and software are being used. With the DWI, ALTUS Intervention wants to take a further step to streamline large parts of the work processes in every stage of the planning- and execution phases to increase efficiency and productivity and increase value creation.

1.2 Objectives and Limitations

The purpose of the thesis is to identify challenges in the oil and gas industry, especially the well intervention sector, and to study how Digital well intervention (DWI) will impact current work processes in ALTUS Intervention and how the DWI platform will contribute to value creation. The thesis aims to answer the following research questions:

- **RQ1:** How does the Digital Well Intervention (DWI) platform impact the work processes in ALTUS Intervention?

- **RQ2:** How will the DWI platform contribute to value creation?

1.3 Research approach

The primary data source for the thesis has been the interviews with the key personnel to get proper insight into how the current work prosses in ALTUS Intervention. These first research questions will be answered with the use of a qualitative method approach. Video interviews and discussion via Microsoft Teams were conducted with key-personnel involved in the planning and execution phases during a well intervention project in ALTUS Intervention to understand current work processes and challenges. In addition, ALTUS Intervention has been very open and given me access to their internal systems and databases to see how the current systems works and how the databases are systematized.

To best answer the second research question, I have reviewed several SPE papers and case studies that have proven to create value through a similar approach as the DWI contributes to.

1.4 Structure

The thesis consists of 8 Chapters. Following chapters with a brief description is provided below:

Chapter 1: Gives a brief introduction to the thesis objectives and the methods used.

Chapter 2: Provides Introduction to well intervention, the various methods, and the main components in a wireline system.

Chapter 3: Briefly describes lessons learned/experience transfer in the oil and gas industry

Chapter 4: Studies the concept of Digital Oil field and the challenges in the oil and gas industry, as well as in the well intervention sector.

Chapter 5: Introduces the innovation project and presents current work processes in ALTUS Intervention. This chapter aims to answer the research question one.

Chapters 6: Present how the innovation project will contribute to value creation. This chapter aims to answer the second research question where several SPE case studies are introduced-

Chapters 7: Discussion of the research questions will be provided in the chapter

Chapter 8: This chapter will present a conclusion based on the innovation study and discussion.

1.5 ALTUS Intervention

ALTUS Intervention is a market-leading supplier of wireline service, wireline tractor, coiled tubing, and pumping and logging services in Norway, Denmark, and the UK. The company was established in 1980 in Norway, which was then called Maritime Well Service. The company first started with core expertise in mechanical cable operations but quickly expanded its expertise in delivering well-logging services. In 1996, the company was acquired by Aker, and the company changed its name to Aker Well Service. The same year they started with the development of well tractor services. At the beginning of 2014, the company was sold by Aker Solutions and is now called ALTUS Intervention. Figure 1 shows the timeline of the company.

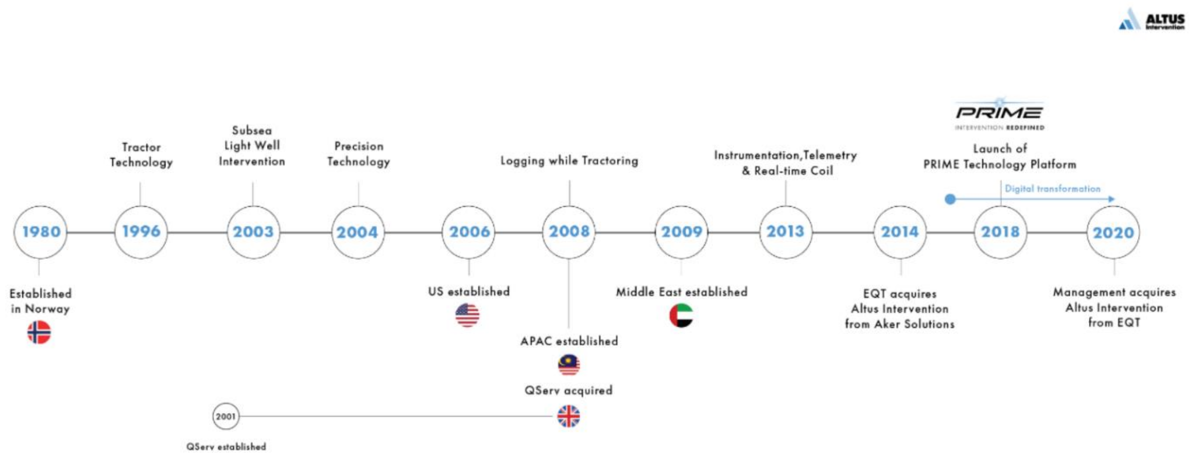


Figure 1: ALTUS Intervention Company Timeline [1]

ALTUS Intervention consists of 3 different departments: Wireline, logging, and tractor. Each department represents its own area of specialization.

- Wireline business area is based on cabling technology to lower equipment or measurement devices into the well with the intention of well access and recovery, well manipulation and well cleanout.
- Logging business area is based on electric line well intervention operations and consists of equipment used for formation and reservoir properties measurements.
- Tractor business area is based on electric line well intervention operations and consists of equipment used for deployment of toolstring for highly deviated or horizontal wells.

Chapter 2: Well Intervention and wireline equipment

This chapter presents the theory of well intervention, general wireline equipment, and wireline pressure-control system.

2.1 Well intervention

Well interventions are an activity in drilling, and well that is performed after a field has been developed. Over time, every field will need maintenance and optimization on a regular basis. The activity that takes care of this is called well intervention. Well intervention has a critical role in maximizing oil production from current fields, whether by generating extra production (increase IOR), safeguarding the well, or maintain optimal production.

2.1.1 Definition

The definition of well intervention can be described as any operation carried out on an oil or gas well that intends to increase production performance, extend production life, or change the well's condition and geometry [2]. Well intervention operation can be carried out either onshore or offshore, and it is usually divided into two categories:

- Light intervention
- Heavy intervention

Light Intervention refers to operations where equipment is lowered down into a live well while the surface pressure is maintained. During a light intervention, the equipment is generally carried out inside or through the Christmas Tree and completion tubing. Light intervention is carried out when change or adjustment of the downhole equipment such as valves or pumps is required or when the information about the well such as downhole pressure, temperature, and flow data is desirable [3]. Wireline and coiled tubing are typical light intervention operations [4].

During the heavy intervention, the Christmas-tree and other pressure barriers from the well are generally removed to gain complete access to the wellbore. This type of intervention is preferred when the well needs major equipment changes. Typical heavy well intervention operations are Christmas-tree removal, replacement of production tubing, side-tracking, and acid treatment in the reservoir zone [4].

2.2 Types of Well Intervention Methods

2.2.1 Wireline

The term "wireline" refers to light intervention operations where cabling technology (single conductor, multi-conductor, or slickline cable) is utilized to lower and raise equipment into the borehole using an electro-hydraulic or diesel-powered winch. This type of well intervention method is conducted both from fixed platforms and floating units.

2.2.2 Pumping

Pumping is the simplest intervention process since it does not necessitate installing any equipment into the well. The method consists of pumping liquid/chemicals at a given rate into the well to maintain and optimize the well in various ways. One of the primary purposes of pumping intervention is to shield the well from scale or hydrates by injecting scale or hydrate inhibitors. Another application area is the bull heading method to control the well and pump acid to stimulate the reservoir.

2.2.3 Coiled tubing

Coiled tubing (CT) is a long tubing made of steel alloy that is rolled into a drum. The pipe is used as a working string for drilling and well maintenance. Using the coiled tubing, fluid can be circulated into the well through the tubing. CT is usually preferable in long horizontal wells or when liquid is to be circulated in the well. This approach is often used in well cleaning and other operations where a great amount of force is needed.

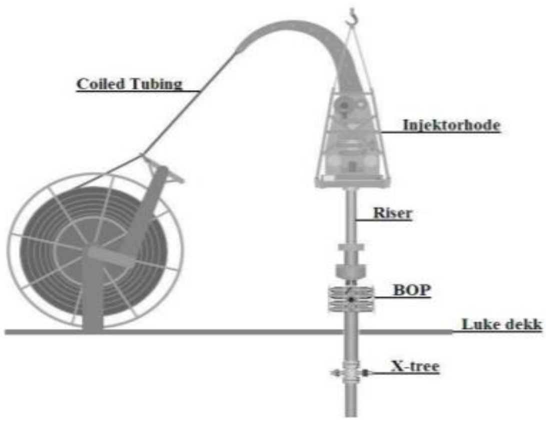


Figure 2.1: Coiled Tubing [5]

2.2.4 Hydraulic Workover (HWO)

The method of HWO consists of installing and removing tubular pipes in and out of the well by using a hydraulic jacking system. This method is performed in both live and dead wells without the need for a drilling derrick. In addition, the HWO method allows the pipe to be rotated, and vast amounts of fluids can be circulated through the pipe. This makes the method suitable for large circulation operations, heavy-duty fishing, milling, reservoir stimulation, and recompletions [6].

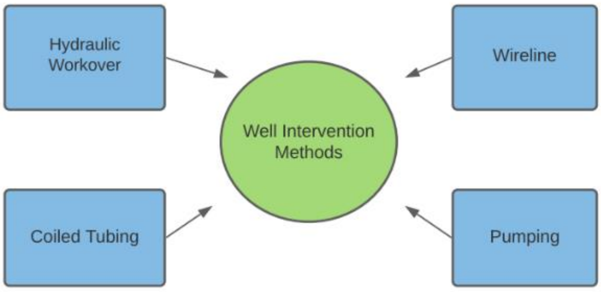


Figure 2.2: Well Intervention Methods

2.3 Wireline system

2.3.1 The wire and wireline services

Different cables are developed that provide different functions, each specific to a particular wireline operation. There are three main types of wire cables utilized for wireline interventions:

- **Slickline**
  - A thin cable used for light and simple operations with standard diameters of 27/250'' and 1/8'' 7/50'' and 4/25'' as well as coated slickline.

Applications

- Gauge cutter/centralisers runs.
- Placing/dragging gas lift valves, plugs, and chokes
- Remove sand and debris
- Temperature and pressure inspections
- Light fishing operations

- **Braided wire**
  - Used when higher tension or weight-carrying ability is desired and suitable for heavier operations, with a typical diameter of 3/16'', 7/32'', 5/16'' and 7/16''.

Applications

- Heavy fishing operations
- Swabbing operations
- Conduct transportation of heavy tool strings
- Operations at greater depth

- **Electric wire (E-line)**
    - It consists of electric cable encompassed by braided wire, utilized when communication through the wire to the surface is required under the operation. Typical diameter is 7/32'', 5/16'', and 7/16'' as well as special logging cables.

Applications

- Well logging activities (cased hole logging, open-hole logging, perforation, etc.)
- Well surveillance activities
- Zonal isolation
- Deviated wells, combined with tractors
- Well integrity tools

2.3.2 Bottom Hole Assembly – BHA

The term Bottom Hole Assembly (BHA) includes all equipment assembled and used in a work string in a well. It can be equipment for vertical drilling, directional drilling, logging, well testing, completion, and well service [7]. It consists of several different components, where each has its own specific purpose. In wireline intervention, the BHA refers to all the downhole components that are assembled and connected to the cable. Figure 2.3 shows an example of BHA.

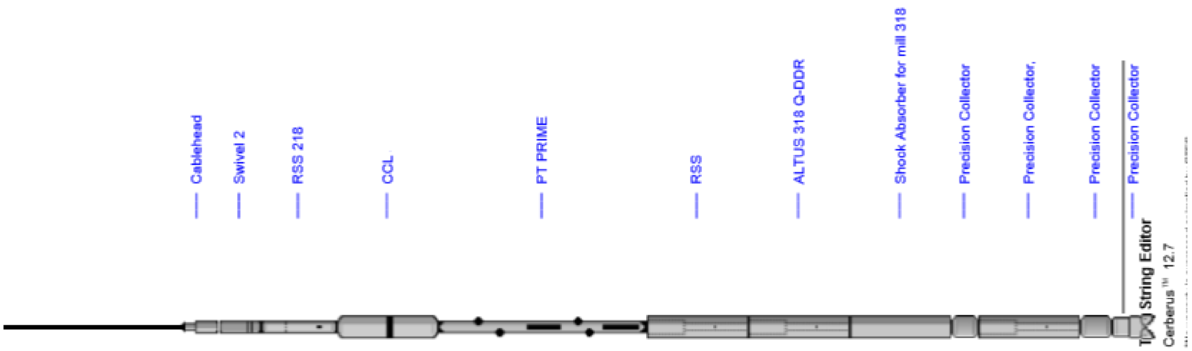


Figure 2.3: Example of an BHA [8]

2.3.3 Cable head

The purpose of the rope sockets is to attach the wire to the selected tool string securely. There are various types of rope sockets, and the selection of the rope socket relies on the type of wire/cable to be used. The lower part of the rope socket consists of a transition part where the tool string is connected to. Figure 2.4 shows different types of mechanical cable heads, and figure 2.5 shows ALTUS e-line cable head used for both logging and tractor operations.

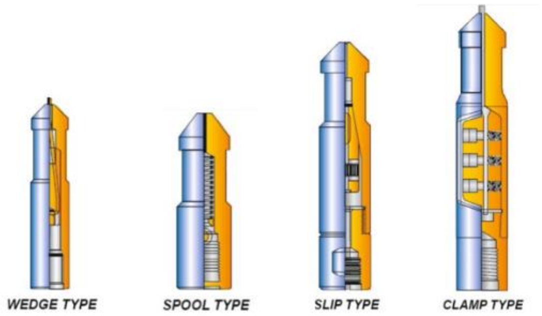
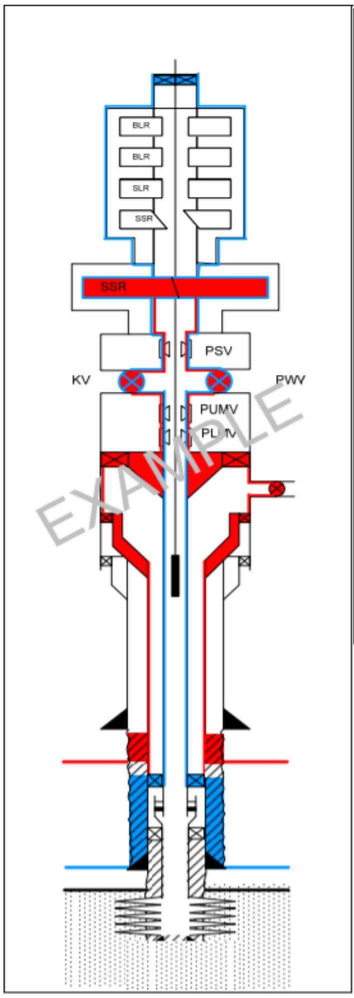


Figure 2.4: Different types of mechanical cable heads [9]

Figure 2.5: ALTUS e-line cable head [8]

2.4 Requirements and guidelines for wireline system in accordance with PSA and NORSOK standards

During a wireline intervention of a live well, the DHSV (Primary barrier), the swab valve (SV), and upper- and lower master valves (Secondary barrier) are open and not functional. To reinstate these barriers, it is established barriers in the wireline equipment to control the pressure. Under a wireline operation, the well pressure exists all the way up to the primary barrier at the top of the wireline rig (stuffing box/grease injection head). This poses a danger for the wireline crew and thus entails strict HSE routines [10]. The wireline operations and barriers must comply with the HSE practice and follow the regulations, guidelines, and standards advertised by the Petroleum's Safety Authority Norway (PSA) and Norwegian Shelf's competitive position (NORSOK). The requirements and guidelines for wireline operations are clearly described and illustrated in NORSOK D-010 and NORSOK D-002. It is also required to conduct a test of the barriers according to prescribed procedures and the wireline set-up before any operation starts and during the operation according to the requirement. Figure 2.6 (Section 10.7.2 in NORSOK D-010) presents the well barrier elements of wireline, respectively, run through a surface tree.



Well barrier elements	EAC table	Verification/monitoring
Primary well barrier		
In-situ formation	51	
Casing cement	22	
Casing	2	
Production Packer	7	
Completion string	25	
Tubing hanger	10	
Surface tree*	33	
Wireline shear/seal (safety head) - body	38	
Wireline lubricator	44	
Wireline BOP	37	
Wireline stuffing box / grease injection head	39	
Secondary well barrier		
Formation	51	
Casing cement	22	
Casing	2	
Wellhead	5	
Tubing Hanger	10	
Surface tree*	33	
Wireline shear/seal (safety head)	38	

*Common WBE.

Figure 2.6: Running wireline through surface tree

2.4.1 Wireline pressure control equipment

The pressure control equipment system varies according to which wireline operation is to be conducted. Due to differences in the wireline cable design, it has been necessary to introduce different types of equipment that are suitable for the selected wireline cable operation and meet the NORSOK requirements to complete the job safely and efficiently.

2.4.1.1 Stuffing box/grease head (Primary barrier):

Stuffing box (Slickline)

The primary barrier for a slickline intervention is a stuffing box. The device is located at the top of the lubricator equipped with rubber pack intended to seal around the slickline to prevent pressure leak. The sealing system can be achieved in both static and dynamic condition. According to NORSOK D-002, it is a requirement to implement a blow-out plug or ball check valve in the stuffing box in preparation of wire breakage. This primary barrier system can be operated either manually or hydraulically.

Grease injection head (Braided line)

For a braided line intervention, a grease injection head assembly is designed to replace the stuffing box to achieve a sealing system. The cable is led through sufficient number of flow tubes, and grease is pumped between the cable and flow tubes through minimum one grease injector collar to establish a seal. A pack off and line wiper is included in the grease injection head assembly to provide sealing function in static condition and clean the wire when pulled back to the surface. A blow out plug or ball check valve shall be included as part of the assembly.

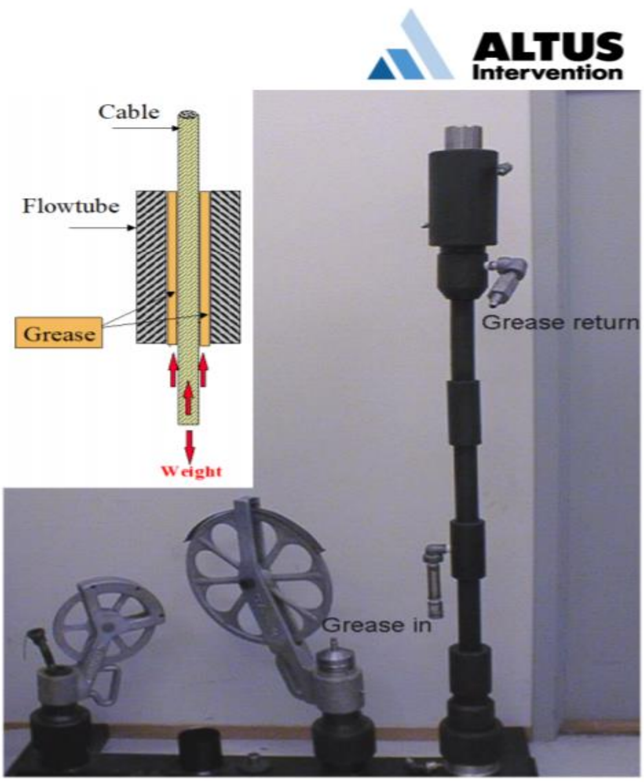


Figure 2.7: Stuffingbox (left) and GIH(right)   [8]

2.4.1.2 Lubricator

This element consists of sections of tubings connected by ''quick union connections''. It is located between the stuffing box and the BOP system and is implemented to allow tool string to be inserted and removed under the intervention. According to NORSOK D002, the length of the lubricator shall be long enough to allow both the tool string and the fishing tool to be run/pulled during the intervention. It is required to install a minimum one (1) bleed-off valve to the lubricator.

2.4.1.3 Wireline BOP (Secondary barrier)

The function of a BOP is to control the pressure during intervention operations in case the primary barrier fails (stuffing box/grease head). It comes in variable sizes and set-ups and must be constructed following NORSOK standards. The wireline BOP system shall be under an obligation to close the rams in under 30 seconds. The BOP system is established as a secondary barrier, and it is mainly located between the Christmas tree and the lower lubricator section. The BOP can either be hydraulically or manually operated.

For slickline operations:

Must consist of minimum one (1) blind ram to provide a sealing function around the slickline in aim to hold pressure from below. An equalizing device/valve shall be adapted to the BOP system to allow equalization of pressure across the rams. In addition to the simple BOP, there must be included an independently a shear/seal ram (safety head), that can cut the cable. It provides similar function as a blind frame by cutting the wireline cable as the rams closes and obtain a seal simultaneously in aim to fully shut the well bore and avoid a blowout situation. The safety head should be located near the Christmas tree as possible.

For braided cable and e-line:

Must be equipped of minimum two (2) blind ram valves, disposed opposite each other. The function of the inverted ram (bottom ram) is to hold pressure above. It is required to involve a pump-in port to allow grease pump between the two valves in the aim to obtain a seal between the wire strands to prevent gas migration between the voids space. The BOP system should also include a shear/seal ram (safety head) below the blind rams. In addition, it is required with a equalizing valve to be included.

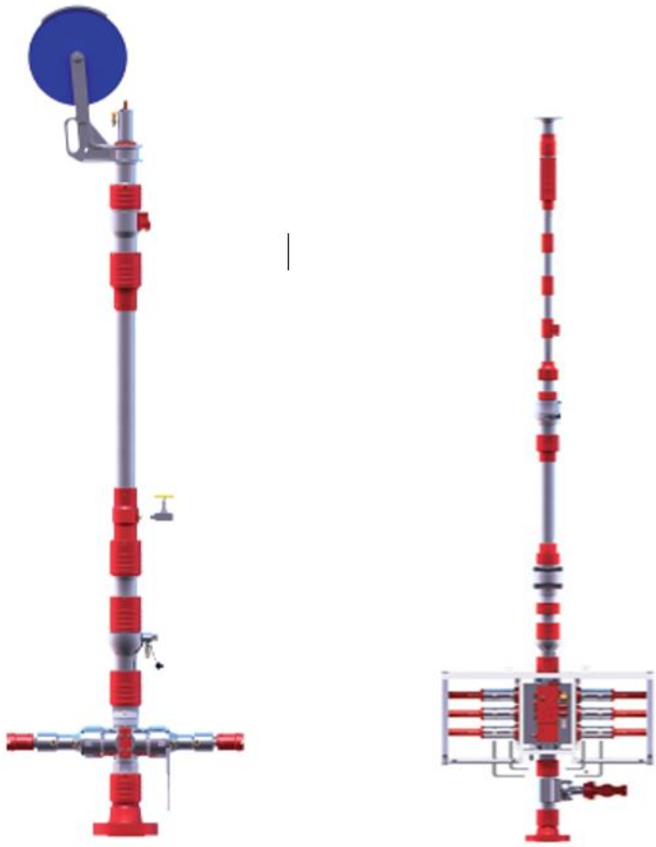


Figure 2.8: The system overview over slickline and braided/e-line [8]

2.5 Wireline Surface Equipment

Main wireline surface equipment consists of:

- Wireline Winch
- Wireline Control panel
- Tension & Depth indicator
- Power pack
- Smart skid (BOP control panel)
- Grease injection head and grease pump

2.5.1 Offshore Wireline Winch

The offshore wireline winch is either electric, hydraulic or diesel powered skid (not used in Norway) mounted system that controls the wire drum. The winch controls the speed of the cable and tool string entered or pulled out of the well. There are both electric and diesel-powered winches. The motors provide power to a hydraulic unit on the winch, which controls the drum itself with the cable on.

Figure 2.9: Offshore Wireline Winch [11]

2.5.2 Control Panel

The control panel is the place where the operator controls the wireline drum and manipulate several control systems such as: winch, pressure control equipment, power pack. It is often the case that the drum and winch can be placed in the steering and control cabin or in a separate container (add on).

Figure 2.10: Control Cabin [11]

2.5.3 Tension & Depth device

The tension and depth devices are important equipment. Weight tension under wireline operations is a crucial measurement, which is helpful information to avoid wire break. The operator in the control cabin set an alarm limit for maximum tension to avoid wire breakage. The tension device can either hydraulic, electric, or mechanical (electrical and hydraulic is most common).

Another crucial measurement is depth. The purpose of the depth indicator is to provide information about the depth of the tool string in the well. The measurement is conducted by a ''straight through'' depth measurement device, implemented with pressure wheels that measure the amount of wireline moving. When utilizing slickline, it is typically used a ''counting wheel'' to measure the depth. The rotations of the wheel record the number of meters used. Newer tension and depth units are combined. Figure 2.11 shows the combined depth/tension measurement device.

Figure 2.11: Combined depth/tension measurement device [12]

2.5.4 Electric-driven Hydraulic Power Pack

The power pack is a hydraulically drive unit that supplies all parts of the wireline equipment with the required motor power. It is located near the winch and is mainly electric powered.

2.5.5 Grease pump

During a braided cable operation, a high-pressure grease pump component is required to create a seal around the braided cable. The grease pump is usually powered by diesel or electric motors. The grease injection pump is an important part of a braided cable rig-up system.

2.7 Wireline Tractor Technology

ALTUS wireline tractor is named PowerTrac PRIME. The wireline tractor technology has a similar rigging system as the wireline rigging system. The main difference is that BHA consists of a tractor to reach the desired depth in the well, i.e., push the tool string into the hole using the tractor wheels. The tractor technology is usually used when the wellbore structure has an angle above 70° or when the well is difficult to access. The tractor is driven with an electrical signal transmitted to the tractor's electrical motor, which powers a hydraulic pump that activates the wheels in each section.

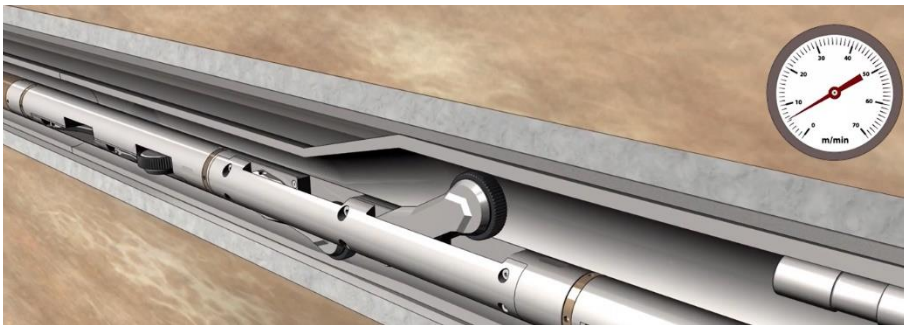


Figure 2.12: Tractor Technology [8]

2.8 Logging technology

Logging is a typical wireline operation that is a common term for several operations carried out to measure the properties of the formation and reservoir. There are several different logging tools where each tool has a specific purpose of collecting specific property data in the well. Typical properties may be the density and porosity of the formation and properties of the formation fluids and other well-related dimensions [13]. Typical logging tools are PLT (Production Logging Tool) which is used to measure the flow rate and reservoir properties. A caliper is a tool that measures the inside diameter of the well. The CCL (Casing collar locator) is a depth correlation tool that reacts to changes in the volume of tubing metal, and it can further be used to detect collars and indicate perforations or damage [14].

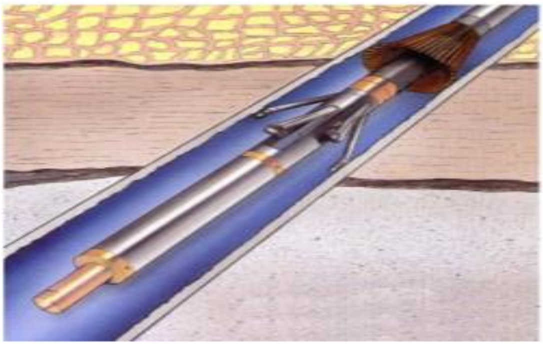


Figure 2.13: Logging Technology [5]

Chapter 3: Lessons learned in the oil and gas industry

This chapter presents the definitions of experience transfer, as well as experience transfer in the Oil & Gas industry.

3.1 Definitions

Experience sharing

The terms "experience sharing" and "experience transfer" are often interchanged. While the definition of experience is difficult to describe, it can be described as ‘’experience gained in work and leisure." The mechanism by which people make their experiences accessible to others is referred to as experience sharing. This assumes that the thoughts are commented on and coded into information shared with others either directly by communication or indirectly by, for example, a report.

Experience transfer

Onsøyen & Spjelkavik (2002) uses the term experience transfer in the context that a learning process has taken place through the sharing of experience [15]. The concept "experience transfer" refers to a learning process that occurs because of the experience sharing. Transfer of experience presupposes that you've been given information about other people's experiences, reflected on it, and adopted it as your competence. This suggests that you have either discarded/acquired old knowledge and gained new learning or that you have put your old knowledge into a new context.

3.2 Experience transfer/lessons learned in the oil and gas industry

Experience transfer is a well-known problem in the oil and gas industry today. The industry has frequently discussed the importance of experience transfer and that there is still great room for improvement in that field. 211 wells have been drilled on the NCS in 2020, and close to 6995 wells so far since 1966 [16]. In addition, there is also an unknown number of well interventions that have been carried out. This indicates an enormous experience base. Nevertheless, the industry has long been criticized for its lack of establishing a learning culture to learn from its mistakes [17].

Ptil, which is responsible for safety on the NCS, has criticized the industry for lack of learning and transfer of experience. According to the Petroleum Safety Authority Norway (PSA), if the oil industry had a greater focus on learning from its own and others' mistakes, more accidents could have been avoided [18]. There is a strong focus on experience transfer as an HSE tool. Transfer of experience is a topic with a central and high priority theme for the PSA, so that oil companies will be in a continuous improvement and improve HSE in the industry. They are concerned with experience transfer and learning, both internally in oil companies and externally between the oil companies. There is also a strong focus on using experience transfers to streamline the work processes, avoid repetitive tasks and increase the efficiency and profitability of O&G projects by learning from previous projects and mistakes. There will always be obtained experiences from previous projects that can be used to improve future projects to create a culture of continuous improvement.

3.3 Databases and arenas for experience sharing

An organization's or a key person's knowledge and experience are of little value if it cannot be shared with the organization's individuals and used in the daily project work. To learn from the experience of others or previous projects, information about these experiences must first and foremost be made available. An effective experience database is necessary to find experiences more easily from previous projects. Lack of an efficient database for experience transfer will often lead to the same errors being repeated.

How good the industry is at transferring experience varies from company to company. Experience transfer internally in the oil companies has been unsystematic and unstructured. There are still a lot of experiences that are based on individual memories. Experiences are still largely stored in different excel, word documents, and various systems with different formats internally in the companies. Most of the companies have databases for experience transfer. However, the experiences are often not systematized effectively. In addition, the databases are often not very user-friendly where it lacks a search function or that the search function is not very functional. Several experience databases, arenas, and information sources has been established for exchanging experience to address this challenge. Arenas such as lessonslearned.no and digitalnorway.com are created where experiences can be exchanged across companies.

Chapter 4: Digital Oil Field in the Norwegian Continental Shelf

This chapter will introduce the concept of the Digital Oil Field and present the progress of digitalization in some of the leading oil and gas companies. The challenges in the well intervention sector will also be highlighted.

4.1 Digital oil field

The concept of the digital oil field (DOF) has been around since the 1990s when Oil & Gas companies started to utilizing sensors for data gathering [19]. Most oil and gas operator and service companies have implemented DOF as a strategic tool to achieve safe, reliable, and efficient operations. Integrated Operations IO (Equinor), Smart Fields (Shell), and Onshore Drilling Centre (Conoco Phillips) are all terms for DOF that describe an approach in the E&P industry that is becoming increasingly necessary to improve efficiency and production due to the low oil prices, increased costs, and greater focus on productivity and climate and environment.

The concept of DOF breaks into technological challenges in the industry and issues involving the organization, its people, and its work processes. According to Larsen, (2012), DOF is the integration of people, work processes, and technology to make smarter decisions and better execution [20]. Equinor defines DOF as: *Cooperation between disciplines, companies, organizational and geographical boundaries made possible by the use of real-time data and new work processes to make safer and better decisions faster.* The concept of DOF is enabled by using real-time data, information, and communication technologies and multiple expertise across disciplines, organizations, and geographical locations [21]. The main goals of the digital oil field can be summarized as followed:

- Adopt new technology to achieve safer, better, and faster decisions
- Connect offshore and onshore together through technology and work processes
- Improve operational efficiency and safety
- Improve communication and collaboration between all parts of the organization
- Increase personnel involvement in the planning phase

The DOF is often misunderstood as a fancy technological hub with abstract concepts for visualization purposes and a small group of experts excessively comparing notes to deduce trends. However, a better description would be not to see the process as a physical presence but as a concept [22]. A concept that Petrowiki describes as:

''The purpose of the digital oilfield is to maximize oilfield recovery, eliminate non-productive time, and increase profitability through the design and deployment of integrated workflows. Digital oilfield workflows combine business process management with advanced information technology and engineering expertise to streamline and, in many cases, automate the execution of tasks performed by cross-functional teams.''

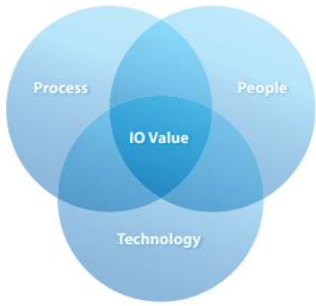


Figure 4.1: DOF/IO concept

Over time, there has been tremendous development in the offshore infrastructure in the North Sea. In the past 30 years, drilling technologies have improved significantly. The North Sea has seen a rise in onshore support centers and remote-controlled systems for offshore oil and gas installation. Baker Hughes Co., one of the largest oil-field service providers, has long been utilized onshore support centers to support the drilling operations in real-time operations. The company has successfully developed the BEACON center for the DOF located in Stavanger, Norway. The center has become deeply rooted in its vision and goals. The BEACON concept has been developed to utilize information communications technology to relocate people/work/positions from offshore to the BEACON onshore center [24]. Data preparation, quality control, data storage and other manually tasks that used to be carried out at the rig site are transferred to the BEACON center.

With a multi-skilled team offshore and the multi-discipline team made of experts, the company has established a 24/7 onshore support center service and onshore center. The offshore staff has been reduced by 25-50% [25]. Traditional offshore positions were transformed, multi-skilled positions were created, and new roles were brought into the BEACON center. Today, the Beacon center consists of several disciplines that work closely together. The center has enabled reducing POB and enhanced operational efficiency and productivity by establishing collaborative work processes and maximizing expert resources. The center has directly led to reduced operating costs, improved IOR and HS&E performance, reduced environmental footprint. Customers have expressed satisfaction with the quality of service provided through the BEACON center [25].

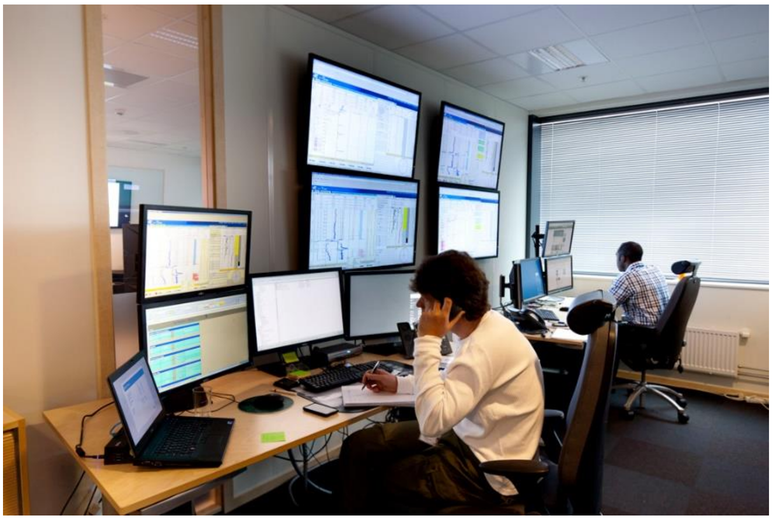


Figure 4.2: Baker Hughes' BEACON Center [26]

Equinor is also one of the leading companies that have invested heavily in the DOF. In recent years, Equinor has developed a 24/7 center called *Geo operation centre (GOC)*. Using real-time sensors, new technology, and increased data availability, they have managed to monitor and control the offshore drilling operations. Drilling equipment with advanced sensors and fiber-optic cables for data transmission are standard tools [27]. Experts continuously interpret data from the sensors to provide an efficient drilling operation, avoid drilling in unwanted formations, reduce the costs, and prevent undesirable scenarios. Equinor has an estimated annual saving of NOK 270 million through the GOC center [28].

Another company, ConocoPhillips, estimated that their drilling support center in Tananger had saved the company approx. NOK 60 million in less than a year. The savings have been achieved primarily due to more efficient decisions and relocation of some functions to land. In addition to cheaper wells, better well paths and fewer dry wells were achieve [29].

4.2 Challenges in the oil and gas industry

In a time of falling oil prices, increasing costs related to exploration and production, a stronger emphasis on climate and environment, as well as the Covid-19 pandemic, the oil and G companies have found themselves having to look for new operating models to optimize processes for management and execution of projects. Offshore O&G projects are mainly divided into a planning phase and an execution phase. Until now, the concept of DOF has mainly been associated with operative cooperation between the onshore and offshore teams through the establishment of an onshore support center to support the offshore team [25]. It has demonstrated the value to drive operations efficiency, optimize production, and maximize hydrocarbon recovery with better, faster decisions while reducing health, environmental, and safety risks. The industry has improved drastically and the technology development in the oil and gas industry has led to enormous hydrocarbon recovery from NCS.

However, the current situation in the industry leaves plenty of room for improvement. To further increase the hydrocarbon recovery from NCS, it is important to improve the processes at every phase of an O&G project, from planning to execution. However, the industry appears to have a limited focus in critical functions such as the well planning. Little effort has generally been made to transfer the DOF principle into the planning phase to improve the planning processes, efficiency, and productivity. In addition, data and information management seems to still be a major problem in most companies [30].

During the exploration, development, and production of oil and gas, the companies generate massive amounts of data. A vast amount of this information is currently stored in silos systems, spreadsheets, and papers [31]. A lack of clarity around data and information is still one of the most significant obstacles to effective well planning in the industry. The difficulty in well planning comes from finding relevant historical well data, which is often spread across different domains. Legacy systems are still widespread in most companies, making the collection, storage, and review of relevant data a time-consuming and frustrating process [32]. One of Europe's independent oil and gas operators, according to an SPE paper, has concluded that establishing a robust and effective planning process across several systems is a practical impossible [33].

A case study conducted by Rosendahl et al. (2013) in three international oil and gas companies revealed that the wide usage of different planning tools, systems, and databases across the organization made the planning process very difficult. Lack of harmonization between the various systems and software (simulation tools, databases, analysis tools, etc.) significantly reduced efficient information exchange between the project team and stakeholders. Manual transfer and data input are still required, and repetitive tasks are a big part of the planning process. The companies cited this as a problem that jeopardizes the integrity of information while also taking up unnecessary and expensive planning resources. The operational planning in all the three companies, as an organizational function, did appear to have a very low status in general.

Today, the industry is characterized in many areas by limited cooperation between different operators and service companies. In addition, there is still insufficient communication and collaboration internally across disciplines and departments in the companies [34]. This can be partly explained by the fact that the industry still uses traditional ''siloed'' systems, software, and databases that are not connected. Moreover, everyone is working on their own computers and systems, making communication and cooperation extremely difficult. In drilling, well planning is a complex and multidisciplinary activity where many engineering principles are involved. Therefore, high-level collaboration and communication are of utmost importance to establish proper planning to execute the operation successfully.

A need for new ways to communicate, collaborate, and improve data and information management in most oil and gas companies is necessary to overcome these challenges. Establishing a comprehensive and streamlined well-planning process where the multi-discipline team can work together and communicate towards a shared data set is demanded to streamline and optimize the planning process of an O&G project. The next breakthrough will be achieved when the oil and gas companies discover new areas of improvement by breaking operational silos between disciplines, improving data and information management, and communication and collaboration between the project team and stakeholders. However, with the new technology developed in recent years, this has become a possible mission. Several oil and gas companies have started to take advantage of the newest technologies to streamline every stage of an O&G project.

4.3 A new wave of the Digital Oil field

Implementing a successful Digital Oil Field is a key enabler for increased performance, enhanced safety, delivering remote operations, and unlocking an enormous amount of value. In the last two-three years, the focus on the DOF has drastically increased within several oil and gas companies. With the covid-19 pandemic, operator- and service companies are accelerating their embrace of onshore support centers and remote technology [35]. In recent years, the concept of the DOF has entered a new phase in the industry due to new and powerful information technology. However, further development of DOF has previously been an obstacle due to three technological gaps [36]:

1. Reliable high-speed data transmission capabilities

2. Cost-effective computing resources that handle large amounts of data

3. Powerful analytic methods that are capable of handling the speed and volume of the incoming data.

Due to technological innovation in recent years, the missing components have started to fall into place. Powerful advanced computing, data and analytics transformations, low-cost sensor technology, and advanced connectivity technology have already been developed [37]. 4G connectivity is already ubiquitous, vast offshore installations have fibre links, and the upcoming 5G network in the near future will further improve wireless communications [38]. A new game-changing technology that some companies have newly utilized is cloud-based software that offers limitless, low-cost computational capacity. The cloud solution makes data much more accessible and enables a new level of effective data and information management for the oil and gas companies.

Furthermore, data-driven techniques are becoming a standard tool in the industry. A strong new wave of artificial intelligence (AI) and machine learning (ML) technologies has arisen to extract information from vast amounts of datasets and sensors in the oil and gas industry [39]. Several companies have adopted ML and AI to streamline the planning processes and optimize the performance of drilling operations.

4.3.1 Digital Oil Field from planning to execution

In the last two to three years, several companies have opened their eyes to the challenges in the oil and gas industry. Initiatives have been taken to streamline and optimize the well construction planning processes to further improve the drilling operations. The companies have taken advantage of a digital cloud-based software system with high-power computing capabilities to introduce a digital well construction planning solution. Rather than working in different systems, the cloud-based system allows a multi-discipline team to work simultaneously, share design and data in real-time, communicate, and collaborate on a scale never seen previously in the industry. The various calculations, analysis software, and data sources are accumulated into a common platform to establish a more dynamic planning model. The cloud-based system has appeared to be a revolutionizing solution to further develop the concept of DOF.

The cloud-based system has been already developed and implemented by companies such as Schlumberger and Norwegian Oliasoft, and Pro Well Plan for well planning. Through *DrillPlan** software, Schlumberger has drastically improved the work processes and workflow in the well-planning process. The multi-disciplinary team communicates, plans, and receives real-time data from the offshore rig in a single shared system. With OMV utilizing Schlumberger's *DrillPlan** and AI application for the well planning, the company managed to plan eight wells in the time it would ordinarily take to prepare one well [40]. Another company that has successfully developed a digital well construction planning software is Pro Well Plan, which allows the multi-disciplinary team to work in one platform. Moreover, using ML capabilities, the company has allowed the software to find patterns in data and put vast volumes of data together [41]. The digital planning software has streamlined the planning process significantly by eliminating the traditional manual way of searching for data and offsets wells in multiple systems and unstructured databases.

Exebenus, which is located in Stavanger (Norway), is another company that has successfully developed a ML software that uses real-time data and historical data to recognize conditions that may result in stuck-pipe and other issues to increase the efficiency of drilling operations. [42]. eDrilling, located in Stavanger, is a world-leading supplier of data-driven techniques that have implemented proven solutions for the E&P that increase drilling operations performance and efficiency. According to a report from OG21, machine learning can help reduce costs, increase hydrocarbon production and reduce greenhouse gas emissions [43].

4.4 Digital Oil Field in the well intervention sector

Given the importance of well intervention, the industry appears to have lack focus and efforts to raise the visibility for the importance of well intervention. The total annual production associated with well intervention operations on existing wells is often greater than the annual production generated by recently drilled wells in the same year [44]. However, the concept of DOF has mainly covered the drilling sector. There is generally still a gap between the onshore and offshore in the well intervention sector, which results in reduced efficiency, productivity, and raised HSE risks. Real-time decision making, onshore support center, efficient collaboration is still limited in the well intervention sector. The reason for this can be partly explained by the fact that the drilling sector is much larger than the intervention sector, as well as more critical and complex. In addition, there are much more cost savings to be made in drilling operations compared to intervention operations. For instance, one hour saved during a drilling operation has much more effect compared to an intervention operation.

Furthermore, as the wells start to age over time, the uncertainty related to planning and execution of well intervention will also increase, and corrosion and well integrity (cement and casing) will critically impact a proper well intervention operation. As a result, old wells may require new intervention techniques and innovative intervention tools. In general, a higher requirement for service equipment and intervention work may be expected in the future, which in turn emphasizes the importance of a new and better approach to well intervention. Much of the timesaving's, measures, and operational efficiency that is made in the planning and execution phases in the drilling sector through the concept of DOF can also be transferred into the intervention sector by establishing and developing similar concept in the well intervention sector.

Chapter 5: Innovation Study – Digital Well Intervention

This chapter presents and analyses the innovation project: Digital Well Intervention (DWI), and aims to answer the following sub-research question: What impact will Digital Well Intervention (DWI) have on ALTUS Intervention's current work process?

5.1 Project idea

Digital Well Intervention (DWI) is a cloud-based platform developed by ALTUS. The core idea of developing the DWI platform is to establish and develop a new, more innovative, and efficient approach to well intervention that aims to reduce the cost and increase efficiency and quality of the well intervention operations, while also minimizing environmental impact. By recognizing the area of improvements and introducing a new level of digital tools, digitizing the rig's actions, enabling smarter collaboration between the offshore-onshore crew and all stakeholders involved, it will be a major step towards a more effective, successful and environmental friendly well intervention.

Moreover, with the DWI, ALTUS aims to achieve a new level of connection, collaboration, and communication between all involved parts during the life cycle of a well intervention project from planning to execution and reporting. Part of the project's innovation objective is to gather all the fragmented processes and systems into an open platform to improve efficiency and productivity across the value chain. It combines business process management with digital technologies to digitize the exchange between the planning and execution phases to streamline the work processes and workflows in ALTUS.

One of the key areas of improvement is utilizing real-time data to bring in experts to improve ongoing well intervention operations. A further aim is to streamline the planning process, select candidates for intervention more quickly and effortlessly, as well as identify and design the BHA without a heavy, cumbersome, and manual interaction with multiple vendors.

The innovation motive can be split into two main parts: a technical side and a business side. The technical side aims to introduce a new level of technology solutions that aims to improve the work processes and workflow in ALTUS. The other part of the innovation seeks to enhance value creation for the company. How the innovation project (DWI) contributes to value creation will later be discussed later in this thesis. Figure 5.1 shows the project's visualization.

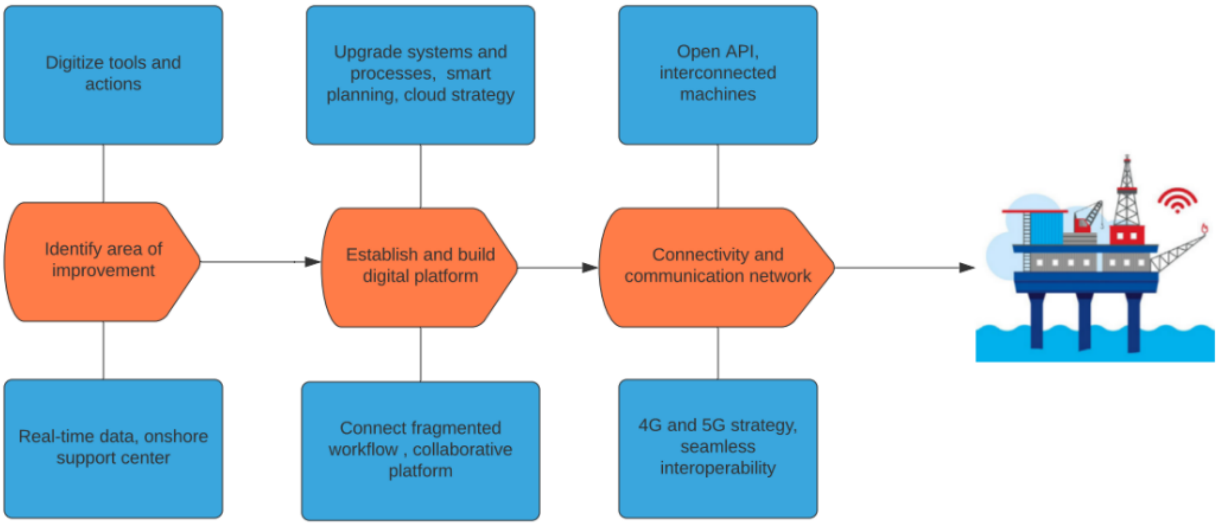


Figure 5.1: Project visualization

5.1.1 The background of the project – ALTUS Intervention

The goal of the project is to be able to introduce an innovative way of performing well intervention. ALTUS is the project owner, while Equinor and NORCE will participate as project partners. Workshops and frequent iterations between ALTUS, Equinor, and NORCE, will be performed to ensure that the system is built to serve its intended purpose. In addition, researchers from NORCE are participating to ensure high research quality work for this project. The project is planned for five-year period, starting in 2020 and ending in 2025. The project is divided into three phases and is currently in its infancy and is under development. It is not fully developed yet, and as part of this thesis, suggestions will be proposed for further development of the DWI.

5.2 Level of innovation

The project will introduce radical new functionalities for the DWI platform, enabling assisted planning and execution of well intervention operations. In order to achieve this, the following innovative capabilities are required:

- Smart planning
- Downhole technology integration
- Dynamic operations data model
- End to end intervention

Figure 5.2: Level of innovation [8]

5.2.1 Smart planning: Integrated and collaborative planning workflow:

The well intervention sector is presently characterized by sub-optimal work processes where integration of workflows (planning and simulations) and data sources from operators and third parties is needed. New processes and improved product deliverables to intervention operations will be established through the DWI smart collaborative planning. Smart planning will be developed to streamline the planning process and increase collaboration with the clients and other service partners. Integration of systems and standardization of data allows the engineers to dedicate more time to actual planning instead of exploring information and perform repetitive manual tasks. As a result, time and resources can be optimized to detect the best well intervention solutions.

Furthermore, the development of the communication infrastructure offshore will enable the use of 4G, and possibly 5G in the future. Superior network connections are needed to reduce all risks associated with operation delay or disruption. Currently, the connection of the offshore equipment is far from a "plug-and-play" activity. As a result, unnecessary time is spent in the operation.

5.2.2 Integrated Data Acquisition Systems:

A BHA includes several modules consists of multiple sensors with corresponding individual software systems. Additionally, the surface equipment also provides critical operational data. In order to enhance the decision-making process, minimize operation complexity, and establish an onshore support center, better data acquisition systems (DAQ) and are essential to establish seamless integration of systems.

Connecting the DAQ with the DWI platform allows operational data to be accessible to all stakeholders involved. Furthermore, aggregating all the data and systems would lay the foundation for remote operations technology and onshore support centers to support offshore operations. The establishment of the onshore support center will further pave the way for reduced POB. This will enable a more environmental approach to well intervention which is in compliance with the priorities of the Petromarks2 program plan and UN sustainable goals [45] [46].

5.2.3 Dynamic operational models:

As the historical data is gradually collected and real-time flowed in into the DWI platform, a dynamic state operational model of well intervention components and processes will be introduced to the market. New data-driven techniques, such as machine learning, can be used to recognize problems and determine their causes using the state estimation model. The ability to dynamically control operations based on real-time data will allow for more predictable results in the future and increase efficiency and provide support for the decision-making process during operation. Using data techniques such as AI, machine learning, and predictive analytics to improve the performance and efficiency of the operations has been implemented for years in drilling automation [47].

5.2.4 End-to-end intervention:

With the DWI, a semi-automated real-time reporting system will be developed, enabling operational progress reports. The operational status and progress report will be available for all parts involved in the operation, including the client. This will result in more transparent operation and makes all parts informed, contributing to better decision-making. In addition, manual reporting replaced with semi-automated reporting will provide a consistent and reliable data quality for future analytics. The semi-automated reporting system will help with end-to-end planning, execution, and reporting, creating a more harmonized well intervention project. In addition, the live reporting will serve as a foundation for software development that will aid in well intervention optimization by comparing operations over time.

5.3 Well Intervention Projects

Well intervention is a complicated project involving many parties, both internally and externally. Well intervention may consist of a small or larger and more complex project. Any mistakes done under an intervention operation from ALTUS as a service company, can in the worst-case scenario, force the operator to stop either the well construction process or production for longer than needed [48]. This will result in high financial costs and a bad reputation for the service company. Improving all aspects of a well intervention project requires effective communication and collaboration between all involved parts from planning to execution. For any well intervention projects, sufficient time must be allowed in advance to:

- Proper planning
- Detailed assessment of the risks involved
- Prepare crew and allocate responsibilities
- Set up contingencies in case of major failure mechanisms and deviations from the plan
- Allow operations personnel sufficient opportunity and time to familiarise themselves with equipment and work scopes

5.3.1 Service execution model (SEM)

Well intervention projects in ALTUS are executed in accordance with their own service execution model (SEM). The SEM is a generic breakdown of a project and a structured way of managing and executing the different phases. The SEM model outlines and describes the several steps that must be completed to deliver a well intervention project, from the beginning to the end. The SEM presents the way ALTUS works and delivers a project. The project management plan is divided into four phases:

1. Contractual
2. Plan & Prepare, (Study phase)
3. Perform Service (Study phase)
4. Close-out

The work processes are clearly defined in each phase in the SEM model. The objective of an SEM is to get consistency in every phase of the project by using a standard methodology that is familiar to everyone involved in the project and the company. Figure 5.3 shows an abbreviated version of the SEM. Since this thesis mainly focuses on work processes within planning, execution, and reporting, the thesis study will cover mainly the second and third phases; Plan & prepare and Perform service.

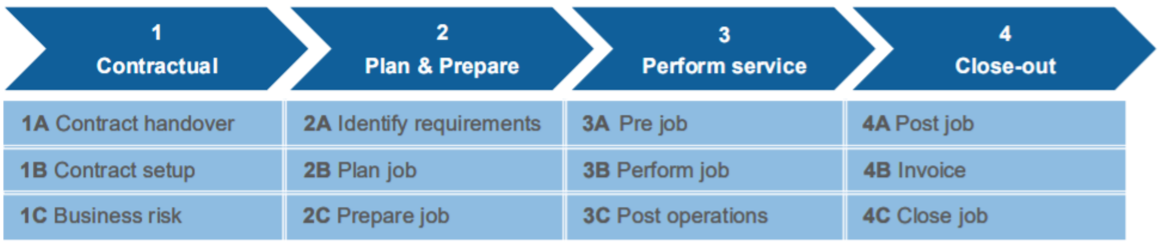


Figure 5.3: Service Execution Model (SEM) [8]

5.3.2 Well intervention project planning

The planning phase is the most crucial part of a well intervention project. A successful well intervention project depends on high-quality decisions and proper planning. If something goes wrong during the offshore operation at the well site, it can be traced back to planning phase onshore. The planning phase lays an important basis for the entire well intervention's efficiency, productivity, safety, quality, and costs. It is therefore of utmost importance that the decisions in this stage are made correctly. One of the most important purposes with the DWI is to be able to streamline and simplify the planning phase. Effective project planning and proper engineering solutions are crucial and directly related to the successful execution of an operation. Some well intervention operations can take few days to plan. However, more complex can take many weeks to complete planning. It depends on the intervention's complexity of the work scope and BHA, the number of runs, and whether slickline or e-line is used. In addition, a combination of tractor and logging tools in the BHA usually requires a longer planning time.

5.4 Research sub-question: How does Digital well intervention impact the work processes in ALTUS *Intervention?*

A series of interviews and meetings were conducted through online Microsoft Teams with key personnel involved in the planning and execution phases to overview current work processes and challenges in ALTUS. The personnel who participated in the discussions and meetings had the positions *Operations Supervisor* (OS) and *Champion Service Leader* (CSL), and *Customer Service Manager* (CSM), where the CSL position also involved working in close with the client (operator).

Plan and prepare

5.5 2A: Identify Requirements

Once the PETEC (Petroleum technology) department in Equinor has identified the intervention to be performed and defined the well targets, and it has been established that ALTUS Intervention has a contract in place with the client, the terms and conditions have been agreed upon, and all operational parameters have been accepted, the job can start to be raised.

The CSL in ALTUS will receive the work scope of the intervention by the operator (hereafter referred to as "the client"). Data such as CSD (completion string design), wellhead pressure, downhole pressure, temperature gradient, well schematic, and well survey are important input information that needs to be collected, and quality checked to start the job. The data is forwarded to the OS to build the BHA for the well intervention. Based on the data and information about the well and the identified need for the intervention, what are to be rectified, modified, or changed in the well, the OS will provide a technical solution in the modeling phase.

Challenges:

Communication during the planning phase

During one of the interviews, questions were asked about how the communication is internal and between the client during the initial phase. One informant pointed out that there are still a lot of e-mails back and forth, both internally between the departments in ALTUS and external partners: Client, PETEC, and other service partners and third parties. The wireline and logging & tractor departments work relatively separately, and there is no direct structure on how the employee works and communicates at the different departments. As a result, the process can be delayed if there is a communication breakdown between any involved parties.

ALTUS operates in various systems both internally and with the client's systems. In most of today's practice, different systems with different APIs are used, making the systems impossible to interact with each other. Due to a lack of interoperability between the systems and lack of a common platform, endless reports, emails, presentations, and meetings are required to communicate work and obtain necessary feedback and verification to avoid misunderstanding. In addition, working on different platforms makes it difficult to make sure that everyone has the latest version of information between the workflows. One informant empathized with the need for a common platform to further improve the communication internally and externally.

Impact:

One communication platform

One of the main benefits of the implementation of DWI is to streamline the planning phase by introducing a new level of collaboration and communication infrastructure. Effective communication is a prerequisite for streamlining the work process within the company. With the DWI, all the communication channels will take place in one common platform. The DWI platform can be accessed from any browser on any operating system. This will be a common arena for ALTUS, the client, PETEC, and partners, enabling efficient communication and collaboration across the workflows. All the internal and external activities will be brought together.

The project owner in ALTUS will put together a team consisting of CSL, OS, field engineers, the client, PETEC, and other partners with defined roles and responsibilities, eliminating e-mails back and forth to assign the individual roles and responsibilities. With given roles and responsibilities, everyone will understand what needs to be done. Everyone will have access to all the necessary data and documents required during the planning phase. Working on the same platform allows faster data sharing, approval, and discussions between all stakeholders internally and externally. Any data input, communication, and discussions about the way forward are now taking place in a single place. Data and documents are entered once and seamlessly shared and available for all parts. The latest data will be displayed, securing all project stakeholders to keep up to date at every stage of the project, both onshore and offshore.

The platform also enables to work through auto-validation, where any changes that occur in the workflows, the effect of the other workflows are immediately available and visible for everyone. Another benefit is the dynamic link between ALTUS and the client, which ensures that all information and modifications are consistent and up to date. The common arena allows the team to be more effective and productive by eliminating the need for data and document entry into multiple silo systems, eliminating time spent searching in e-mails, and checking several systems to find the right data. It will allow the different departments in ALTUS Intervention to work and share their knowledge in the same system. It will eliminate departmental communication silos, enhance transparency, and improve collaboration across the three departments and all project stakeholders.

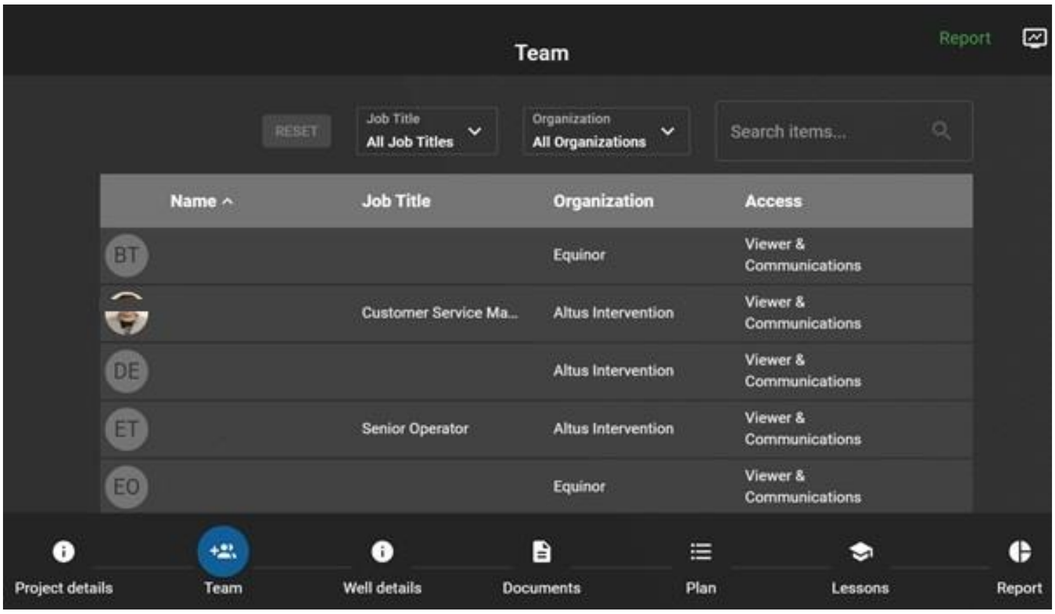


Figure 5.4: Snapshot of DWI platform during the team selection

5.6 2B: Plan job

5.6.1 Modeling/simulations

Designing the model and building the string components starts when ALTUS has all the necessary well details and information available from the client. ALTUS is currently using Cerberus as the software for modeling and simulation of the BHA. Simulations run will be performed to ensure that ALTUS can carry out the task required with the correct equipment. The lesson learned and experience transfer databases in the iOPS system will be reviewed, and best practices from previous projects discussed to ensure that all important information is captured. The iOPS is ALTUS data storage system. Most of the critical data and documents during for the planning and execution process will be stored in that system. All data and information from previous projects are usually stored in the iOPS system.

During the operation, the cable can only withstand a certain amount of tension before breaking. To ensure that one is within the requirements associated with the operation, the OS will select a realistic friction factor during the simulation to ensure that the cable can be able to pull the tool string out of the hole without reaching the cable's limits and leave a ''fish'' in the hole. It's therefore important to select the most realistic friction factor during the simulation. The chosen friction factor is based on previous well data or the most used friction factor for that specific well. Based on well data information, purpose of the intervention service, and the friction factor, OS will design and build the BHA. The selected friction factor will be verified during the operations offshore. Figure 5.5 illustrates the BHA modeled for one of the operations in the Johan Sverdrup field.

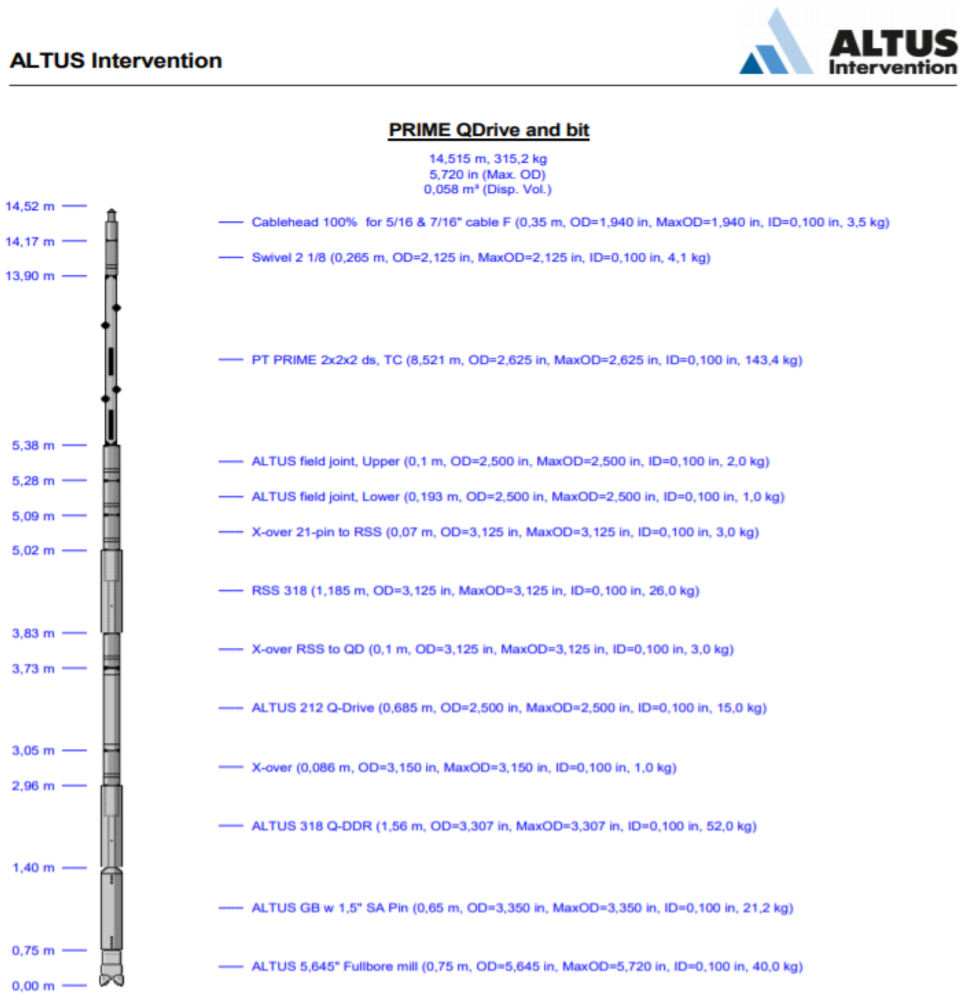


Figure 5.5: Bottom Hole Assembly design [8]

5.6.2 Program Steps

When the simulations are performed and the final design of the BHA confirmed, an detailed operational procedure (program steps) will be conducted. The lessons learned and experience transfer databases will again be reviewed to ensure all important information is captured. It is in the simulation and program step phases that everything is considered in detail. This is where most of the time, studies, and resources are spent in the actual planning. All the value that is created and generated in this stage is converted into a pdf file (program step) and transferred to the well site offshore. The program steps will be reviewed step by step on the platform together with the crew members and the client.

Challenges:

Fragmented system and poor data management

Today, intervention planning is a time-consuming process. Most steps in the planning process are performed in separate systems. The various calculations, modeling, and data analysis are performed in various systems and software that are not connected. Important data is stored in different files with different formats. Multiple unstructured spreadsheets, word documents, and databases are stored in different computers and systems. One informant pointed out that lots of time is spent on manually gathering relevant data and asking other employees for information and where it is stored. In this case, reusing or reviewing relevant data is incredibly time-consuming. It makes it very difficult to achieve an efficient planning process and get good quality and robustness in the final plan. Easy access to relevant information makes it time-consuming and challenging to improve the planning process. This takes valuable time away from highly paid administrative employees to work efficiently and focus on the actual problem or engineering analysis.

Lesson learned

During the interview, it was pointed out that one significant time-consuming task for the OS and CSL is searching for lessons learned from previous projects. Much time is spent on looking for comments and noted lessons learned in the databases. Both the lessons learned and experience transfer databases are stored in different systems. The databases have no searchable function, and if one wants to find information from previous projects, one must click on each individual project and find the information the user seeks.

Some of today's lesson learned is based on individual experience and memories. Private excel spreadsheets are also used to collect notes and gather lessons learned from previous projects. Lessons learned are not easily accessible, and the lessons learned that are included in the planning are frequently based on the personal experiences of those directly involved. As a result, the intervention planning process may often be planned from experience based on the individual person. One informant pointed out that one weakness of today's setup is that the systems are still person-dependent. Further, the interviewee emphasized the need for a common system that gathers all the information in location to make the planning phase less person-dependent.

Experience transfer database

The database for experience transfer is in a SharePoint database, where the link to this is in the iOPS system. ALTUS has many years of experience stored electronically and reporting of experience is a high prioritized in the company. In this experience transfer database, the user will find general experiences related to equipment, incidents at the rig, and damage to personnel and equipment. The experience transfers are documented with photos and contain detailed descriptions. The company has an experience database in place. However, utilizing this database seems to be the obstacle. The challenge lies in exploiting this to its full potential. The reason for this is mainly due to limited user-friendly database and that poor systematization of the database. For instance, the database is not systematized in a way where one can easily find experiences from a desired rig.

Impact:

System integration

With the DWI, there will be a single platform that aims to make it easy and lucidly to find any relevant information during the planning process. The ideal goal is to establish a comprehensive and streamlined well intervention planning process by working towards a shared dataset and that the various calculation and analysis programs are integrated into the DWI. This will allow the DWI to function as ''one system'' that will drastically improve data accessibility, shareability, and information flows in the ALTUS. This removes the bottleneck that is often in the planning phase in the form of searching for data and processing data to compare from different offset or previous projects. Rather than wasting time going through multiple systems and spreadsheets, the team can have access different data with just a few clicks. In addition, gathering all the systems allows the employees to see what other employees work on. As a result, it will significantly enhance the transparency and communication between the employees and departments in ALTUS, as well as between client and other partners.

Web-based simulation tool

As pointed out earlier, one of the main goals of the DWI is to streamline the planning process by connecting gathering the different system and databases into a single platform. An important part of this will be integrating the software into the platform by developing a web-based software or using a web-based version of Cerberus developed by NOV. Using a web-based software can be used with any PC or laptop with an internet connection anywhere. It will also allow for seamless integration of any service partners and third-party tools into the web-based simulation tool.

With the DWI, the client will be integrated and included in the planning phase. They will immediately have access to the BHA and see how the engineers in ALTUS thinks. The ALTUS engineers can go through the solution along with the client. It will allow the client to share their knowledge and experience to improve the solution or propose a better solution. The DWI platform will enable seamless collaboration between ALTUS and the client, integrating them as one team. Combining the DWI platform with video conversations is a great combination to seamlessly work together towards finding the best intervention solution. The platform immediately forms a common arena for discussion, knowledge, and best practices transfer among all parts involved, creating a ʺone team approachʺ. This will boost the collaboration with the client in a scale never seen before.

Lessons learned

With the DWI, the lesson learned process will be significantly improved. Lessons learned stored in various computers, spreadsheets, and databases are now collected in a separate section in the DWI platform. In addition, each lesson learned is categorized under ʺtitleʺ with a description or recommendation handling. Compared to today's setup, the lessons learned will be much more systematized, and the availability of lessons learned will be significantly improved. It eliminates lessons learned that are based on an individual's experiences or stored in private excels spreadsheets. The DWI platform will to a much greater extent, ensure that all lessons learned will be reviewed and captured for future well intervention planning. This will contribute to improved continuous culture in ALTUS. Figure 5.6 shows the lessons learned section in the DWI platform.

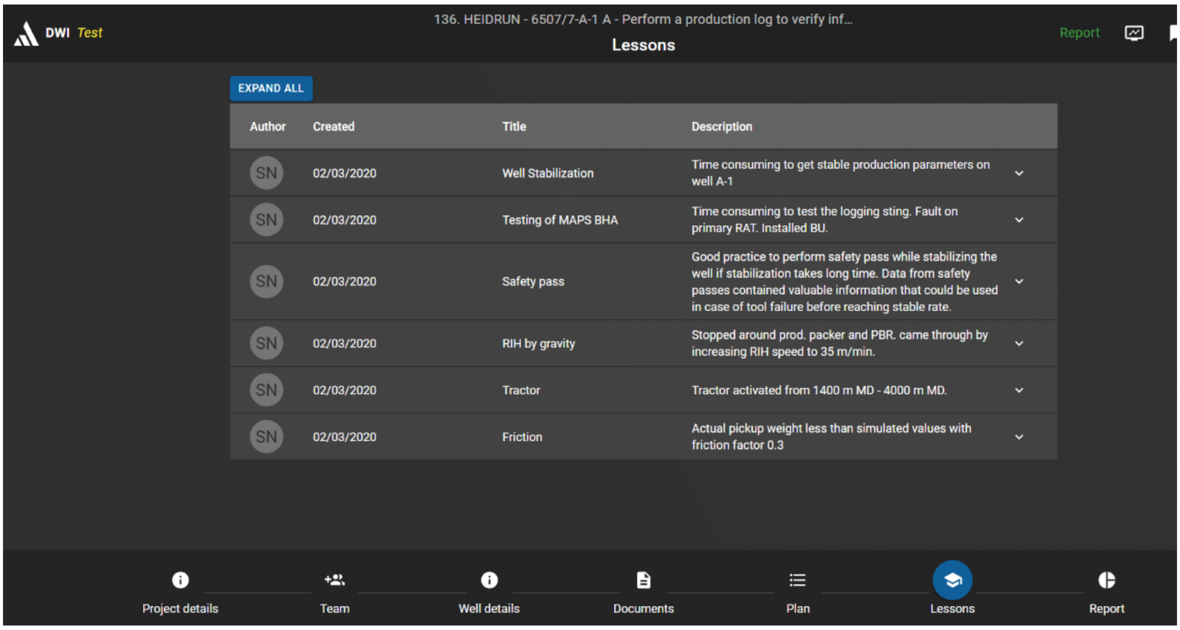


Figure 5.6: Snapshot of the lesson learned section in the DWI platform [8]

Re-cycling previous projects

In the early phase, a tremendous amount of time is used to plan a well intervention project. This includes data-gathering, simulation, BHA, cost/time estimation, etc. (building blocks). All the values, experiences, and building blocks created in this stage are put into a PDF file (program step). However, after the operation is executed, all the valuable experiences and building blocks that are created to present the PDF file are stocked in different systems, excel spreadsheets, report files and forgotten or faded away. This makes it extremely difficult to capture and re-use valuable experiences and building blocks from previous projects and use this as experience analysis for future projects. As a result, the engineers most often start on a ''blank sheet'' when planning a new project in the future. This is a common problem in most oil and gas companies today.

One of ALTUS's goals to achieve with the DWI platform is to automatically extract all the knowledge/experience and building blocks from previous projects to improve and simplify the future planning process. With the development of DWI, all the datasets from every project will be stored in a single platform, allowing the DWI platform to function as one database. This will pave the way for integrating AI and ML techniques into the DWI platform to find similarities between the datasets and projects. For instance, based on similarity data such as well schematic, well survey, and CSD, BHA, or work scope of the intervention, the DWI platform can automatically extract all the previous projects similar to the new input data from the new project. With this in place, all the previous projects and their experiences and building blocks will automatically be transferred into the new project.

Instead of starting on a ''blank sheet'', the engineers will have access to all the similar projects at a click of a button. With a simple modification of the BHA for the new project, the planning process will be drastically speeded up and streamlined. In addition, the engineers can quickly analyze the final report, time- and cost estimations of the previous projects to predict and improve the accuracy of the new project.

Suggestion:

Systematize experience transfer database and establish a keyword search engine

As proposed improvement, the database should be more systematized, and an advanced search engine should be created to enable easier access to relevant experiences. In addition, the experiences should be categorized in a better way. Furthermore, these categories should be divided into relevant subcategories where these subcategories are also searchable. Place the experience under searchable areas such a product line, equipment, field, and well will make the process of experience transfer easier. One way to systematize the experience data and create a search engine is shown in the figure below. Creating an advanced search engine allows the user to cross off all the equipment/tools, categories etc., the user wants to get experience data from. This can be an easy way to filter the experience data and sort out the relevant experience data.

Search: (keyword)

Department	Tools/equipment	Category	Field	Operation	Wells
Search	Search	Search	Search	Search	Search
Select all	Select all	Select all	Select all	Select all	Select all
Wireline	Prime	Dropped objects	Johan Sverdrup	Mobilization	JSD-13
Loggging	RSS	Risk Assessment /Control of work	Brage	Rig-up	BRA-01
Tractor & Applications	PLT	Injury	Heidrun	Pressure-test	HEA-10
	Correlation	Technical information	Gullflaks	Rig-down	GFB-05
	Precision collector	Competence training	Kvitebjørn	De-mobilization	KVA-02
	Stuffing box	------------------------	Oseberg B	-------------------	OSB-14
	Grease head	-------------------------	--------------------	-------------------	-----------------
	Lubricator	-------------------------	--------------------	-------------------	-----------------
	Other	Other	Other	Other	Other

Establishment of focus areas

A unique way of extracting the experiences in the database, which bears more of the mark of occurring events in context, is establishing focus areas. An overview of recurring events is important to create awareness. For example, a focus area could be "falling objects" or "hand injury." The choice of this as a focus area may be based on the fact that there have recently been several incidents with falling objects. Another example can be a specific equipment failure that may occur often. The focus area can further be called the "theme of the month" to increase its focus and introduce measures to minimize it.

5.6.3 Risk assessment

A central part of the planning process is risk assessment. One of the most crucial tasks in well intervention planning is to provide a risk assessment that captures all the risks associated with the operation. Understanding the risks and establishing a technical risk picture is crucial in any offshore operations. Proper risk assessment and risk understanding are key factors to avoid accidents, establish a proper emergency response and decrease uncertainty [48]. Risk assessment is a systematic procedure for identifying and analyzing potential risk by mapping undesirable events that may occur during the operation. Further, the causes and consequences of will also be mapped out and overall risk associated with the operations evaluated.

To assess and prioritize the various risks, it is used a *risk assessment matrix* in an excel spreadsheet. It describes the risk in a two-dimensional image where probability and consequence are made visible separately and collectively form a measure of risk. When a detailed risk assessment is completed, and information from any HAZID or HAZOP which the client may have carried out has been captured, the risk assessment is entered into the iOPS system. To secure and confirm that risk assessment associated with the operation is read and well understood, everyone involved must sign off the risk assessment in the iOPS system. At the rig, a pre-shift meeting will be held to make sure that they are fully aware of the steps and risks involved.

						Probability				
						E Very Unlikely	D Unlikely	C Possible	B Likely	A Very Likely
		Injury / illness	Environment	Service Quality	Loss / Damage (NOK)	Freak combination of factors required for event to occur.	Rare combination of factors required for the event to occur.	Event could happen when additional factors are present, but otherwise unlikely	Considered likely event could occur during course of the work	Almost inevitable the event will routinely occur during the course of the work
Consequence	1 Major	Fatality/ Major injury with permanent disablement	Serious off-site impact, significant remediation required	Extensive delay/multiple issues resulting in loss of contract (7days +)	1M +					
	2 Serious	Lost time injury	Significant off-site impact, some remediation required	Serious delay/issues resulting in loss of job (48hrs +)	500K > 1M					
	3 Moderate	Medical treatment / Restricted Work	Release significantly above reportable limit or some local impact	Significant delay resulting in written complaint (12-48hrs)	250K > 500K					
	4 Minor	First Aid	Release above reportable limit or minor impact	Minor delay/issue, resolved on-site but further corrective action required. (4-12hrs)	100 > 250k					
	5 Negligible	No treatment / negligible injury	Small release contained onsite and no impact	Negligible delay (0-4hrs)	0 > 100K					

Figure 5.7: Risk Matrix template [8]

Challenges:

Experience Transfer in risk assessment

An important task in all companies is to form tools or methods for efficient experience transfer for continuous improvement. Currently, the risk assessment is a manual process where excel spreadsheets it used. Experience transfer from previous operations is an important contributor to proper risk management. One of the challenges today is to find experiences from previous risk assessments, what has been done before, and how the risk has been managed. This is often forgotten after the risk assessment is made on the excel file. There is currently a lack of a system that gathers all the knowledge and experience from previous risk assessments. In addition, the technical architecture of spreadsheets is usually not built for collaborative working and is very difficult to extract relevant data and information effectively and automatically from it. This makes it difficult to effectively import experience transfer from previous risk assessment into a new similar project.

Impact:

Risk assessment approach based on machine learning

Currently, all risk assessments are stored in the iOPS system. However, one must click on each individual project to find the risk assessments for that specific operation. There is currently no specific database for the risk assessments. One way to streamline the risk assessment process and secure experience transfer is to move away from static excel spreadsheets. A risk assessment software or template will be integrated into the DWI platform. An overview of all risk assessments and risk experience will be gathered in a user-friendly database in the DWI platform, simplifying the work process of finding experiences from previous risk assessments.

Furthermore, a risk assessment approach based on machine learning will be developed to automate and streamline the risk assessment process. Using advanced machine learning algorithms, it can automatically extract the relevant risks based on the operation to be conducted. For instance, machine learning can be used to extract all the previous risks linked to a specific well, rig, or tool from the risk database. This will ensure that all the risks are captured and evaluated during the risk assessment. This will reduce the work effort drastically and streamline the work process of searching manually for relevant risks assessment and experience transfer. However, it is important to mention that machine learning will not be used to replace a manual risk assessment process. It will still be necessary to clearly evaluate, verify, and signee the risk assessment by certified personnel.

Increased visibility of the risk assessment

Understanding the risk assessment by the personnel is of utmost importance in any offshore operation. One of the purposes of the DWI is to improve the risk management process. The risk assessment will be entered into the DWI platform, and it will be more easily at the fingertips of everyone involved in the operation. Since everyone is working on the same platform through the DWI, it enables increased visibility and understanding of the risks. Any update of the risk assessment will clearly be visible in the DWI platform, ensuring that everyone is aware of the new risk picture. Continues awareness of the risks during an operation is of utmost importance for HSE safety.

Increased interaction in risk analysis

As ALTUS and the client will have a common platform for knowledge sharing and communication, it will to a greater extent, create a closer and effective interaction between ALTUS and the client in the risk assessment. The client has long experience with safety and risk work. Today, there is a requirement that both the client and the service companies must have their own operational risks. Through DWI, the risk assessment from ALTUS and the client will be entered into the DWI platform. With the DWI, ALTUS and the client participate in each other's risk assessment to share risk knowledge and experiences. The client can directly see how ALTUS thinks and vice versa. Here, both partners can effectively communicate and map potential concerns and hazards and assess the risks and prepare associated plans and measures to reduce risk conditions. Closer collaboration in risk analysis provides benefits such as:

- Increased awareness and better choices for safety
- Collaboration on risk assessments provides a common understanding of risk and common plans for risk reduction
- Transfer of experience for better safety
- The quality of the risk assessment increases when risk factors and solutions are viewed from different perspectives

Another risk the crew members could face would be a lack of full knowledge and understanding of third-party equipment and the associated risks. With the open API standard in DWI, ALTUS can include service partners and allow third parties to be integrated into the DWI platform to enable seamless sharing and smart collaboration between ALTUS and service partners or third parties. It will to a greater extent compared to today, ensure that risks associated with service partners and third-party equipment are captured in the overall risk picture.

Suggestion:

Link the simulation software to the databases

Integrating the simulation software and the databases into the DWI platform will further enable linking the databases lessons learned, experience transfer, risk assessment, and best practice databases to the tools in the simulation software. A further suggestion will be to allow the DWI platform to automatically retrieve relevant information from the databases based on the tool selection. For instance, selecting the PrecisionCollector tool in the simulation software provides the OS all pertinent information related to that equipment. This will significantly streamline and simplify the previous experience analysis, where all data will be available at the touch of a button. Connecting the databases and tools in the simulation software will ensure that all relevant and crucial information about the tool is captured. An illustration of the proposal is shown in figure 5.8 below.

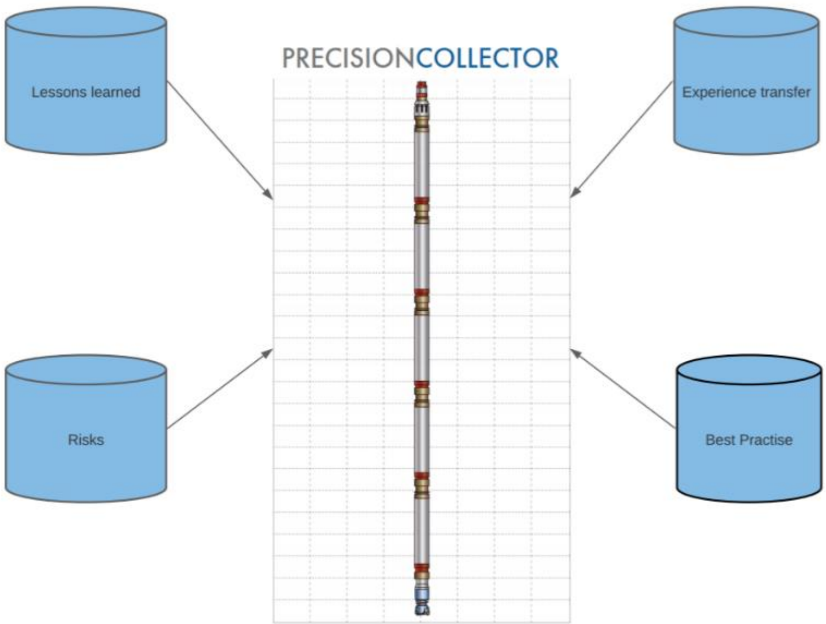


Figure 5.8: Database suggestion for given tool

5.6.4 Identify Resources: Equipment and Personnel requirements

Once the program steps have been completed, and equipment requirement will be created to carry out the request. To identify the crew requirements based on the operations and the program steps, equipment selection will be looked at to understand the competency requirements when selecting the offshore crew. This will also provide a better understanding of the number of personnel required to conduct the operation.

Impact:

Competency development and cross-training across product lines

For recent years, establishing a multi-skilled team has been an ongoing effort to increase efficiencies in the operations. Due to the continuing pandemic, personnel utilization across geographies has been restricted. Attempts to multi-skill employees have shown to be highly beneficial [50].

With the establishment of the onshore support center in ALTUS, the experienced and competent personnel will gradually move onshore. This movement will create a competency and responsibility gap offshore. Relocation of experts requires the development of a shift plan and a greater need for a multiskilled team at the rig site.

Moving the experts from offshore requires higher HSE, technical and attitude standards among the onshore crew. Higher requirements for competency development, dedication, and willingness to learn should be expected to fulfill the expert's competency and responsibilities. It is of utmost importance to ensure that the competence of the onshore crew is maintained to secure that the operation is conducted safely and efficiently and that each individual is confident in the tasks they are to perform at the rig site. In addition, the level gap of the technical competency between the onshore and offshore teams must be minimal as possible to optimize collaboration, communication and minimize misunderstanding. Poor training programs and work assignments that are too complex for multi-skilled personnel to perform safely can have a dangerously opposite effect. This is especially critical for competency related to well control.

A proper cross-training program between different services must be established to achieve an excellent multi-skilled team that executes tasks successfully in addition to their own field of expertise. Focus on multi-skilling in wireline, logging, and tractor will increase the competency level of the employees. It will also create a sense of teamwork among the staff and establishes a closer interaction between the departments in ALTUS.

Today, each department has specific competence and experience within its area. If each department needs to determine valuable tasks and skills and add them to the cross-training program, they will gather the most critical skills and focus on how to best transfer the knowledge further. Honing the skills required and focusing on transferring them effectively will allow a deeper understanding of the services and tools. The BHA for the operations is often a combination of tools from the three different services. With a multi-skilled offshore team, they will have a broader understanding and capabilities over a wide range of skills and tasks and better understand the 'whole picture' during the operation. This increases the likelihood of a project achieving its objectives and delivers more effective and high-quality service. However, being a specialist in different field areas is difficult. Thus, it could be preferable to cross-train those who have shown expertise in their current department's skills when establishing a cross-training team.

Cross-training

The establishment of a multi-skilled team is more than just a reorganization of responsibilities; it is a fundamental shift in how the crew will work in the future. To successfully implement a multi-skilled team demands more self-management and co-operation by the workforce [51].
An effective multi-training program is important for successfully building a new multi-skilled position and developing current roles to become multi-skilled. Developing a multi-service line competency requires a proper online training system and hands-on training onshore. After completing the required onshore and online training, it's important to provide on-the-job training to fully allow the crew member to acquire proficiency in a particular operation or task. Once the on-job training is finished and assessed by an expert, it is important to establish an

online training competency module to provide experience credits and track the progress of each individual's experience. It is further important to track the person's competency through a live assessment module to ensure that the competency is maintained. Practices and procedures should be properly planned and tested to form a great multi-skilled workforce. This includes:

- Field engineer's and wireline operator's assessment: Initial training should be focused on an appraisal of the field engineers' and wireline operators' present ability, skills, and experience.

- Initial training: The initial training must secure that important skills and knowledge are properly mastered. This ensures that the knowledge and skills are obtained to successfully perform the job and avoids retraining in the future.

- Progress: In order to plan future maintenance strategies, it is important to have an overview of the individual's progress by measuring and tracking the skills and achievements of each employee throughout the training and offshore practice.

- Competence status: Some skills and knowledge may be forgotten. Overview of the competency status and timeline over the courses taken is crucial. It is important to define the skills that may be forgotten and establish a program plan to ensure sufficient expertise and knowledge are maintained continuously.

- Risk and safety: Training should be organized in such a way that it steadily develops working practices with respect to safety and risk management. Specific procedures for safety and mitigating risk must be included and implemented into the training program.

5.6.5 Quote review

During the initial phase of estimation, a draft quote will be conducted based on the initial proposal and the information given within the information collected from the client. Different suppliers will have different prices, service, and tool differences. For instance, there are different methods to perform a perforation, and different methods may provide different results. This draft quote goes into the client's method choice evaluation to conduct a cost-benefit analysis.

However, once the contract is in place with the client, ALTUS will at this stage provide a detailed quote review based on the personnel list, equipment list, operational detail of the program, and any third-party equipment to get a full overview of the cost associated with the project. High-level cost estimation is important for both ALTUS and client. The cost estimate should include all the services, equipment, personnel, and materials that would be required to complete the project.

Challenges:

Complex projects that contain elements of high uncertainty are often challenging to provide an accurate cost estimate on. For instance, extended-reach wells, high deviated and horizontal wells that require a tractor and/or logging are much more complex in need of equipment. The number of days, people, and equipment list is entered manually, making it difficult to get overview of all the costs that must be captured. This may lead to the exclusion of certain things, and as a result, not covering the full costs for the execution of the job.

Impact:

As ALTUS starts to fully operate in the DWI platform, all the data will gradually be collected and will be easily available in the DWI platforms. This means that ALTUS can more easily find cost estimates and experiences/lessons learned from previous projects with the same work scope and use this as a basis for estimating the cost and time for the new project. Implementing lessons learned and comparing the cost- and time estimation previous projects will reduce the uncertainty associated with cost- and time estimation for the new project.

An SPE paper (SPE-202499) demonstrated the importance of managing lessons learned for reducing the uncertainty in cost- and time estimation [51]. Using a structured online lesson learned the system and leveraging knowledge from a past CT intervention operation (Well#1) and applying those lessons into the next intervention operation (Well #2) with similar work scope allowed the team to give an accurate cost- and time estimation on well # 2. This was observed through a steeper s-curve, as shown in figure 5.9. This example is associated with CT operations. However, since wireline and CT operations are quite comparable, the concept of managing lessons learned to improve time- and cost estimation can also apply to wireline operations.

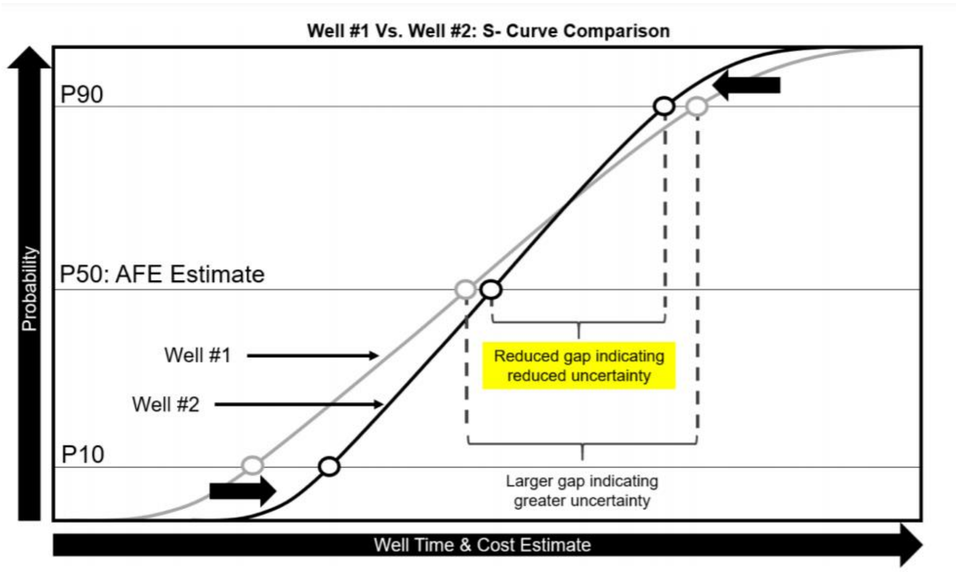


Figure 5.9: Well #1 vs Well#2 S-Curve comparison [52]

Figure 5.10 illustrates the effect of managing lesson learned for more accurate cost-and time estimations.

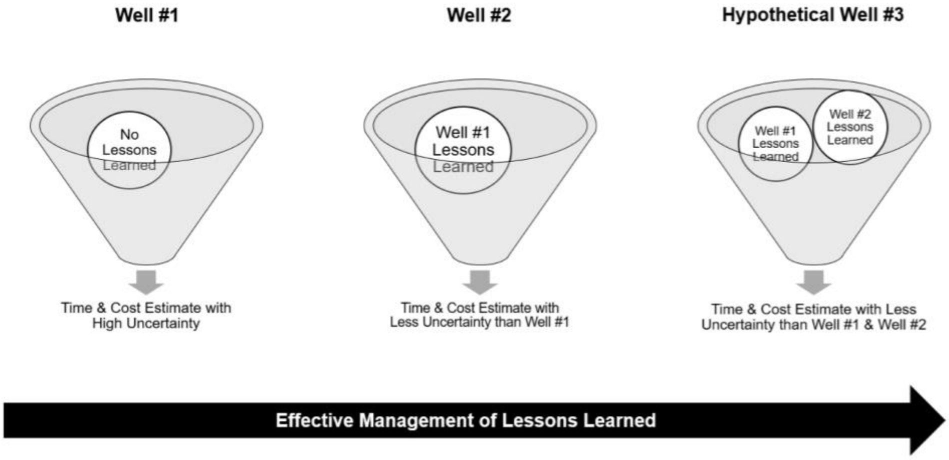


Figure 5.10: Effectively Managing Lessons Learned [52]

5.7 2C: Prepare job

Once a price quote and risk assessment are completed, all equipment and personnel requirements that have been identified in the "plan job" phase will be accumulated. Equipment requirements will be split up and sent to the relevant departments and equipment numbers selected. Further, the maintenance team will carry out the maintenance on the required equipment as per procedures, manuals, and checklists. Tests of the equipment will also be conducted onshore to make sure that the BHA string works. Once all the equipment and preparations are ready, trucks will be loaded and sent offshore.

Perform Service

5.8 3A: Pre-Job

5.8.1 Prepare Pre-job Package

Pre-job presentation and documents to be compiled once final design and program of events are confirmed. Package to contain information on the design of the job, relevant procedures, risk assessments, any drawings for laydown and rig up of equipment, simulations, lessons learned, and QHSE topics will be overviewed if required.

5.8.2 Crew selection and crew information

One of the most critical decisions in the planning process is to ensure that ALTUS, as a service company, has the right people for the well intervention operation. Identifying personnel requirements based on the well intervention service to be conducted is essential to successfully execute the operation and avoid any unwanted scenarios at the rig site.

Depending on the operation, contract handover, and the program steps. Crew members will be selected based on their competence and required skills. Competency, time off, crew make up, and the duration of the job will all be considered. A pre-job meeting will take place to go through the operation about to be undertaken but also gives the management team an opportunity to pass on any relevant information about QHSE and business plans in general.

5.8.3 Pre-training

During crew selection, a crew is normally chosen that is comfortable with the job and has experience with the service and equipment. On-the-job (offshore) training will, in some cases, be held where someone who does not have practical experience with a type of service or tool will be able to be with an experienced team for training.

However, in some cases where the service is more complex and demanding, pre-training onshore will be in place before the crew is sent offshore. Pre-training will be conducted to ensure the field crews are well trained to keep them secure and avoid any possible well control issues. It is important that the personnel get used to the equipment and that they are known with the assignment of the job they are going out to. This allows them to be prepared before they go offshore instead of starting to prepare when they arrive on the rig site. It will make the operation more efficient and the crew more secure. Prior to all operations, mobilization info will be sent out. A pre-job meeting will take place to go through the operation about to be undertaken and pass on any relevant information about QHSE and business plans in general.

Challenges:

ALTUS has a large range of products within wireline, tractor, and logging. Each service performed contains many different tools, and often the service is a combination of, for example, tractor & logging equipment. Getting an overview of all skills, abilities, and what experience the employees have with the various equipment will be a long process. The challenge today is to link skills and abilities to each individual candidate. Today, all employees in ALTUS have an individual competence profile. The competence profile states the general courses, formal education, and all the individual courses man has taken. However, the competency profile does not show the skills and abilities of the individual. This gives a poor overview of the knowledge, skills, and abilities of each individual employee.

When ALTUS is performing a service for the client, they are sending personnel with given competency. Currently, there is a lack of a system that coincides with existing reported data for re-use. A run may consist of various services delivered and tools (the tools are within each service). Each service requires unique competency; the qualities they need in order to perform the service. This competency is today not taken care of in the Personnel planer database. In addition to the service delivered, each service can consist of different tools. This means that a candidate that has delivered service with one specific tool might not necessarily have the same service experience with another tool. So per today, the tool service must be under strict control, be registered, and have up-keep of competency. Data that display crew personnel, i.e., who has the experience with the job at hand, services that are to be delivered, and the general competency (courses/training), is registered in the Personal planner today. Another limitation of the Personnel planner database is that competence is not registered between the different product lines, disabling the company's opportunity to interchange knowledge and experience from one base of operations to the other.

Suggestion:

Building a Competence database

Building a Competence database in order to analyze which candidates are better suited for the job and have a better probability of delivering work to industry standards. An individual's competency profile would display a concise, visual summary of the individual's assessment results. The input would consist of candidate performance analysis, work experience, general competency as well as remarks from previous missions. For this to be the case, an overall competency report should be established that visualizes the competency status percentage and gives a visual representation of the gaps and full assessment history, including the initial baseline and subsequent individual work that might be used for re-assessment for the planning for future work. Furthermore, it may be used for training trainees and newer employees as competency gaps can be filled by matching experienced and non-experienced candidates for the job in question.

Another application the database can be corresponded with the competency database to establish which tools from which product line has been used by which candidate. This makes it possible for the employer effectively to use the database in reverse and find the candidate based on the tool in question, meaning that candidates are automatically recommended based on which candidates have the best experience with the given tool.

DWI, together with the Competency database and a merging of the two databases, will enable smart and efficient operation. This gives a unique opportunity for the ALTUS at a higher degree to send the candidate with the most experience and competency in the field of work to do the job while at the same time also a suggestion regarding how many are needed for the job at hand. Building such a competency database will allow ALTUS to select the right candidates for the right job faster and more efficiently.

5.9 3B: Perform job

Once the crew has arrived at the rig site, all equipment will be spotted as per the agreed layout, and rig-up drawings, lift plans, and risk assessment is required to make sure that all lifts are as per plan. Task-based risk assessment is also necessary to make sure all members understand the task and their roles.

5.9.1 Test of equipment and Pre-shift meeting

All main components will be function tested once rigged up, pressure tests/leak tests will be completed on the entire system, and barriers will be tested as per procedures. All pressure tests/leak tests will be charted and marked up with pressure, equipment type, date, time, and signed. A pre-shift meeting and toolbox talk will be conducted to go through operational steps on each run and to ensure awareness and responsibilities among the crew. The risk assessment will also be reviewed to ensure that all risks associated with the operation are understood.

5.9.2 Execute program

Before any operations start, a well control drill will be conducted to ensure that everyone understands what their actions and responsibilities will be during platform muster and operational issues/emergencies. Well control procedures will be reviewed and understood by the entire crew. The pre-defined well control drills are a continuity process on the rig. It is required with at least one well control drills every week for both night and day shift crew. All the personnel taking part in the well control drill, details of the topic of the drill, and when and where the drill was carried out will all be documented and registered in the iOPS system. Once the well control drill is completed and the crew is ready, the operation will be executed as per the job program and company procedures.

Challenges:

Poor understanding of the downhole condition

Today, one of the biggest challenges in well intervention operations is the lack of clear understanding about what's happening at and around the wellbore intervention tool. There is a lack of a common system for data acquisition from the various well intervention stings to get a full insight on what is occurring at the BHA. Well intervention requires a clear, moment-to-moment understanding of the downhole conditions to successfully execute the operation. Not having the necessary data and proper visualization of the downhole condition leads to poor decision-making and limits the right decisions to be made at the right time. Lack of sufficient data and real-time data make the team guesstimate the downhole condition. This prevents the team from delivering a well intervention with precision and confidence.

Onshore – Offshore Communication and collaboration

One of the biggest weaknesses of today's setup is efficient communication and collaboration between the onshore and offshore. Currently, there is no common communication and collaboration platform between onshore, offshore, client, and service partners. The frequency of communication between onshore and offshore varies from operation to operation and may depend on the crew. The communication takes place through e-mails, phone calls, video conferencing, or through the iOPS system. Some operations have a little more continuity where regular once-a-day morning meetings in Microsoft Teams are conducted to exchange important information and experiences and clarify things between the onshore and offshore personnel. Currently, the iOPS system is only accessible for ALTUS, the client and other stakeholders don't have access to the iOPS system. This limits how much information the customer and service partner receive during the operation and in the event of any updates, such as BHA.

Another weakness with today's way of communicating is the storage of historical data and information. The information and data shared or communicated between onshore and onshore through phone conversations, e-mails, and Teams meetings are currently not stored or difficult to find. This, in turn, will limit how much information can be retrieved from these operations in the future. As a result, important information and data may be faded away. Furthermore, the onshore experts are often only reached when a problem has occurred. The lack of a data acquisition system and real-time data limits the opportunity to make decisions and take actions at the ‘’right time’’.

Impact:

Increased understanding of the downhole conditions

For successful project execution, high-quality decision-making is a requirement. The DWI appears to be a key methodology for achieving this. The DAQ system will aggregate all the data from the multiple downhole sensors and surface equipment into the DWI dashboard, enabling a new era of radical visibility into the downhole conditions. Increased visualization of the downhole conditions will significantly improve the operational efficiency and productivity, allowing the offshore team to make decisions and take actions at the ‘’right time’’. As the DWI platform develops gradually, all the necessary information and data will be displayed in the live dashboard. So far, the real-time data from the Caliber and CCL from logging, stroker data from the tractor, and the data from the WL winch (speed, depth, and tension) are displayed on the DWI platform. This is a major step towards a more informed and “just in time” decision and optimization of well intervention operations.

Establishment of onshore support center

One of the main goals of DWI is to connect the planning and execution phases and create a dynamic handover that strengthens the critical link between planning and execution. The DAQ system and the real-time data will not only pave the way for increased visibility and intelligent visualization into the downhole condition, but also enable the establishment of the onshore support center to assist the offshore crew and ensure high-quality project execution. The onshore support center is currently being built and organized in ALTUS. The center will be the heart of the organization and a significant enabler for redesigning the work processes and new ways of work ALTUS and deliver well intervention services.

The DWI will establish a seamless connection between onshore and offshore, enabling a proactive decision-making during the entire operation. The center will supervise and provide support to the offshore crew consistently to ensure high-quality decision-making, prevent failures, and be more efficient. The center will allow the offshore crew to spend more time focusing on the actual operations, enables the crew to work more efficiently and enhance performance. In addition, operation safety will to a greater extent, be maintained and strengthened by having access to experts in the center around the clock.

The rig will be live-streamed to allow the onshore experts to see all the activities, enabling the offshore crew to be advised and informed about potential risk aspects at any time during mobilization, rig up, pressure control test, execution phase, etc. This will significantly reduce the risk of unsuccessful operations, re-runs, and costly mistakes. In addition, through interdisciplinary collaboration, the onshore experts can predict problems before they occur and enable the offshore crew to help detect anomalies before they become faults so that measures can be initiated or the operation halted before the situation requires extensive NPT.   All the necessary parameters will be available for the onshore experts. Fig.24 shows part of the live dashboard where information from the WL winch and the current depth of the BHA is displayed.

Figure 5.11: Snapshot of the DWI Dashboard during operation [8]

The live dashboard will be available for all involved parts; offshore, onshore, and the client. All the stakeholders will have the same data viewed simultaneously in the same platform – this will be a significant step towards a collaborative decision-making approach. ALTUS and the client The operational data will viewed and evaluated together with ALTUS as a ''one team approach'', creating a new level of collaboration between ALTUS and the client. This will secure continuity, better decisions, and efficiency throughout the entire operation. Figure 5.13 shows the new decision-making methodology paradigm in the DWI.

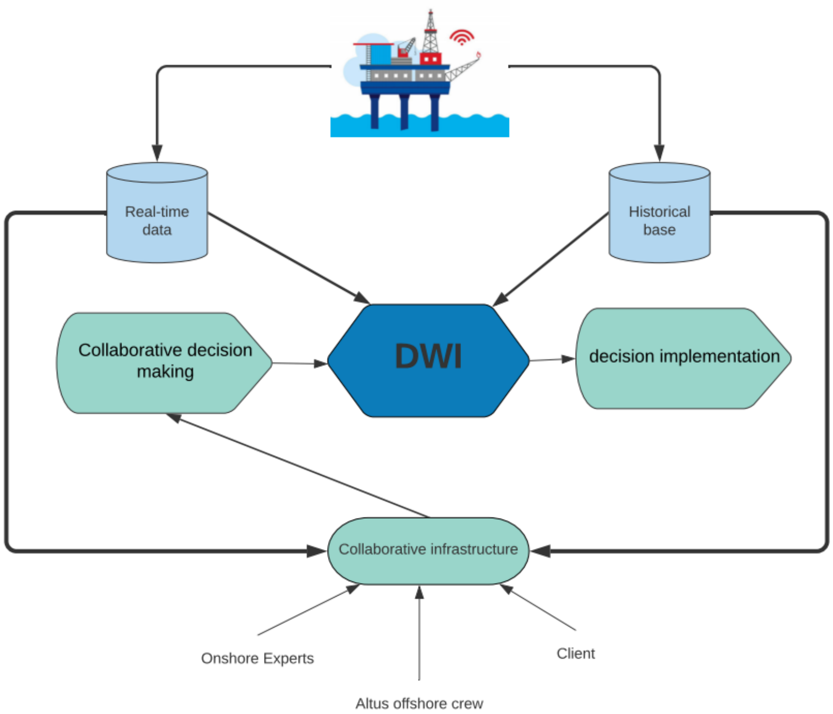


Figure 5.13: DWI's decision making methodology paradigm

Staff utilization

The support center will provide better use of expert resources in LATUS. The live dashboard with real-time data allows the experts to monitor and support several operations and offshore crews simultaneously. It will allow experts to move from one job to another quickly, and the center will make better use of their available working hours. It will reduce their unproductive time out of the office; waiting on the rig, weather, and associated travel time. Using the 4G connectivity for communication, and possibly 5G in the future, combined with the DWI dashboard to share data sets for analysis, the cooperation and collaboration will be as effective as being physically present at the rig site.

Robust handling of program changes and proper risk management

One challenge that may arise during a well intervention operation is changes that require a new plan and a new detailed program step. Updating the program step is a time-consuming process, in some cases, when the program step is updated and shared with the board, a new incident has occurred in the meantime. With the DWI, updates the program step can be made quickly with the help of the experts at the onshore support center. This will contribute to avoid significant delays, HSE risk, and NPT. This ensures efficient and robust handling of changes in the program step. Any unplanned changes are a major accident potential driver. Changes that are not appropriately managed can, in the worst-case scenario, lead to catastrophic consequences. The Macondo accidents are an appalling example of what several last-minute changes and delays can lead to. Even small changes can present serious hazards if not appropriately evaluated. In case of any change, the onshore experts will support the identification of any hazards. Thus, it will enhance the risk management during the operations.

Enhance knowledge and experience transfer

The center will consist of an interdisciplinary team. Experts from the disciplines will be integrated as one team, working collaboratively, across disciplines, and across projects. This team will jointly work in parallel to analyze and interpret common real-time information hence, they are capable of synchronizing multi-view ideas to produce better and faster decision making. As a result, improved conditions for knowledge and experience will be established in a more efficient and practical manner.

Data-driven techniques for improved decision-making

Previous historical data or real-time data may include crucial information. Combining real-time data and historical data and use data-driven techniques such as AI, machine learning, and predictive analytics to increase the performance and efficiency of the operations have been widely used for drilling operations. This has proven to be an excellent tool to provide engineers with better decision-making and situational awareness during operational execution, especially. However, due to limited real-time data well intervention sector, data-driven techniques are still lacking in the in well intervention operations.

With the DWI, ALTUS will generate an enormous amount of data. Real-time data and historical data will be flowed and gradually collected in the platform. This lays a solid foundation for data-driven techniques to be integrated into the DWI. As the real-time data flows into the DWI platform, machine learning is utilized to find patterns in large amounts of data to predict events to support the onshore experts to make a better decision, hence improve the performance and efficiency of the well intervention operations.

Reduced POB

Part of the motivation behind DWI has been to reduce POB. The establishment of the support center on land paves the way for reduced POB by re-shaping the positions through a multidisciplinary team that is being developed. Reduced POB will provide an environmental approach to well intervention by reduced carbon footprint and reduce the overall HSE risk for offshore operations.

However, reduction POB requires careful consideration. To successfully reduce POB properly without compromising security or operational performance, simplifying the offshore system and sub-systems, and reducing equipment maintenance will be needed. Today the connection of equipment offshore is far from a "plug-and-play" activity and requires unnecessary time spent in operation. To successfully reduce POB, ALTUS will gradually introduce plug-and-play replacement of certain components and activity at the platform installation. For instance, the semi-auto reporting has greatly streamlined and reduced the rig time for the reporting process. Streamlining the actions on the rig and eliminating unnecessary time spent certain manual tasks will pave the way for the number POB needed at the rig site.

Remote controlled equipment

With the full development of the DWI and the introduction of new technology in the future, some operations may be remotely performed from onshore by experts. This applies to the operations which are not critical in terms of well control. Aggregating and combining the real-time parameters such; Tractor rotation anchor, WOB, torque, RPM, and vibrations with the data from the WL winch will allow, for instance, will allow milling, precision collecting, and tractor conveyance operations to be remotely controlled from land in the future. The 4G connectivity combined with the DWI dashboard will be an excellent setup for efficient communication and common situational knowledge to ensure correct operating practices at the remote site.

5.10 3C: Post operations

5.10.1 Job reporting

During the execution of the operations, a detailed report of the operations is carried out. All the activity will be reported, all run history to be recorded and as well as any NPT. The reporting is entered into the iOPS system in an office. Each activity has its own code. As an example, *ARRIV* is the code for personnel arrived at the rig site. During reporting, the code is entered manually along with the type of run, time, depth, and department along with a description. Once the reporting is completed, it will be signed off by the client. The figure 5.14 illustrates the current activity report.

Activity code	Date & time	Department	Flag	Description	Depth (m)	Missing activities
	Run 1 - Pull DHSV				Next expected activity for run:	SRUGSE Not applicable
ARRIV	2018-02-19 08:00	Wireline		Personnel Arrive Project		
SOPS	2018-02-19 08:30	Wireline		Start operation		
CARD	2018-02-19 08:45	Wireline		STOP/Observation - Glatt dekk		
SSPOT	2018-02-19 09:00	Wireline		Plasserer WL utstyr på dekk. Tester BOP. Klargjør div. utstyr.		
FSPOT	2018-02-19 11:55	Wireline		Finished spotting		
SRUPCE	2018-02-19 11:56	Wireline		Start rig up PCE		
FRUPCE	2018-02-19 12:30	Wireline		Finished rig up PCE		
SRUBHA	2018-02-19 12:31	Wireline		Start rig up BHA		RIH
FRUBHA	2018-02-19 13:59	Wireline		Finished rig up BHA- QTS testet 20/345 bar- 5/10 min.		
RIHW	2018-02-19 14:00	Wireline		RIH m/ 6" PRS HW: 230 lbs	0	OOH OOH
PUW	2018-02-19 14:15	Wireline		Pick up weight: 260 lbs.	480	
	2018-02-19 14:18	Wireline		Latcher på DHSV. Slår opp 10 slag og er fri.	500	
	2018-02-19 14:50	Wireline		Pulling out of hole. PW: 350 lbs.	500	
OOH	2018-02-19 14:50	Wireline		Out of hole	0	
SRDBHA	2018-02-19 14:51	Wireline		Start rig down bottom hole assembly		
FRDBHA	2018-02-19 15:00	Wireline		Finished rig down bottom hole assembly		

Figure 5.14: Snapshot of current report layout [8]

Challenges:

Accurate reporting and track progress

The reporting of the activity is a very manual and time-consuming process today. It's a repetitive task performed by specialized rig personnel, taking a great amount of valuable time from the personnel. If a computer is not readily available, the reporting is written in a notebook and later reported and added to the iOPS system. Occasionally, the activity is reported on land after the operation is completed. Important records such as NPT are sometimes reported onshore after the operation is executed. This leads to inaccurate measurements in the reporting. Today, ALTUS and the customer report the activity on the operation individually into different systems. It often happens that ALTUS and the customer register the time differently. This often causes disagreements afterward between ALTUS and the client. In addition, due to inefficiency in today's way of reporting, it makes it challenging to track the progress of the operation. This makes it difficult for the crew leader to know if the crew are ahead of or beyond the planned schedule.

Performance focus in the execution of the work

As a service company, it is important that ALTUS focuses on KPI benchmarking for trend analysis. A concern highlighted during the interview process was a lack of performance focus afterward. ALTUS has an excellent overview of each project in the PowerBI dashboard system. All data operational report data is recorded and properly filed in the system. Each subfraction of the operation (i.e., mobilization, rig-up, pressure-test, rig-down, de-mobilization) is also registered. However, one of the informants pointed out that ALTUS is not very active in using the analysis tool to study operational performance afterward to see how well the operation went and analyze improvement areas. For instance, analyze the performance trend on parts of the operation or the entire operation and look at a specified time period to see an increasing or decreasing trend. Today, using the PowerBI to analyze the data afterward to find bottlenecks and improvement areas is limited to establish a continuous improvement culture. This may be due in part to a greater need for better analysis tools that can visualize the data better, little resources set aside for analyzing the data, or little training in how to use the analytic tool.

Impact:

Semi-auto reporting

With the DWI, the report of the activity will be semi-automated where a tablet is used, and the code is pressed directly. The reporting will be automatically displayed in the DWI dashboard in real-time. This will significantly reduce the time required for reporting and improve the data's quality presented in the end report. This will streamline the work process of entering the report manually and ensuring that Altus enters the correct code, time, date and that the correct department is involved. With the semi-auto reporting, the report result will be more accurate, and it will make sure that the report matches the actual activity. Once the code is entered, it will automatically register the depth, tension, and speed data from the wireline winch unit.

Planned time vs. actual time is clearly displayed in the DWI dashboard. This information will be easily accessible for benchmarks and analysis for continuous improvement. Total operation time is important for the client. If any NPT occurs, this will be reported immediately, and the reason for the NPT will be displayed directly in the DWI dashboard. Since ALTUS and the client are now working in the same system, it will to a greater extent, enable common agreement about the causes of NPT between ALTUS and the client during the operation. Figure 5.15 shows the report section in the DWI.

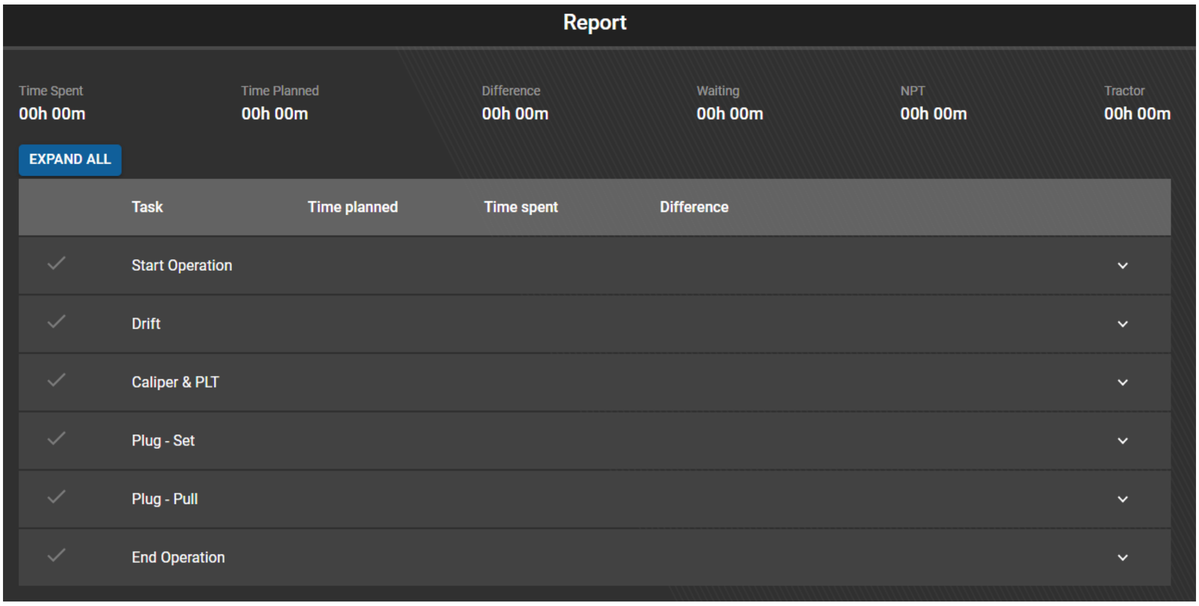


Figure 5.15: Snapshot of the report section in the DWI platform [8]

Suggestions:

Integrate the data analytic tool into the DWI platform

As a suggestion, the data analytics tool should be integrated into the DWI platform for easier access and visibility of the data. This will provide complete availability and visibility, which stimulates to increased use of the data analysis. Furthermore, the live reporting should automatically convert the input information into a generic dashboard in the form of intuitive graphs and pie charts that are easier to analyze compared to today's layout. A well-designed dashboard that makes it easy to visually analyze and compare KPIs as well as other calculations more easily with charts and other visual tools. To extract full learning from the reports, better data visualization is needed for analyzing important records such as NPT to improve, reduce time and save money.

Automatic extraction of specific KPI's

Today, there is an ocean of data and details in the PowerBI database, and it is not certain that one needs all the details, but some. To detailed database can make the analysis process more difficult to extract important details or trends. One way to streamline this process is to define the most important trends or target specific KPIs and let DWI automatically create a report based on this for benchmarking. An example of this could be to let DWI automatically compare and retrieve operations with the same work scope and extract the sub-fractions in the operations (rig-up, mobilization rig-down, etc.) to look at how the offshore crew presents in the different the sub-fractions over a longer period of time.

Analyzing crew performance

The personnel infrastructure or performance of a service company has a significant impact on the success of a project. During the project starts, the project's leader will build a team in the DWI platform. This means that all the data and report from that project will automatically be tied to team members. This connection between the collected data and the team members will make it possible for ALTUS to identify crew performance trends upon which they can act. This data can be reviewed to analyze the different team performances to find whether performance is poor during all or specific parts of the operation.

This analysis can be used to see if there are any general or specific training or procedural issues that need to be addressed. For instance, if several teams are seeming to experience similar performance issues at a specific part of the operation, it is possible to adapt performance improvement programs to target that specific issue. However, if the analysis indicates that the issue is linked to a specific team, specialized training should be implemented for that crew. This analysis is important to further establish a continuous improvement culture in ALTUS.

Calculating the cost of NPT in real-time

The live reporting will also enable the establishment of a system that can calculate the estimated cost of the NTP in real-time. To achieve this, one must establish a database for the various expenses related to all parameters such as people, equipment, travel, etc. Then create an algorithm that uses values in the database to provide a real-time cost estimation based on the duration of the NPT event. With such a system in place, we can analyze the costs associated with each NPT event and separately deduce the NPT event that is of more significance, thus, enabling a clearer path of streamlining and see the most expensive NPT events for the company.

Chapter 6: Value creation with Digital well intervention (DWI)

This chapter will present how DWI will contribute to value creation. Quantify the value creation by implementing the DWI is challenging. However, this chapter will present several SPE case studies that have proven to create business value by adopting a similar approach as the DWI.

6.1 Digital well intervention for value creation

For optimal value creation, high-quality decision-making is a requirement both in the planning- and execution phases. The DWI appears to be a key methodology for achieving. The establishment of DWI, allows significant cost savings to be achieved. Finding efficiencies and cost savings at any phase from planning to execution is vital to maximizing value creation. The DWI's potential for value creation can be described along two axes:

1. The potential to reduce costs
2. The potential to increase production in a well

6.2 The potential to reduce costs

6.2.1 Reduced planning time

Implementing the DWI will contribute to is reduced planning time. The work processes and workflows will significantly be streamlined when the communication and collaboration occurs in a single platform. In addition, necessary data will be easily accessible for the ALTUS engineers. Instead of manually searching through different systems, spreadsheets, databases, etc., and sending e-mails back and forth both internally and externally, the engineers will now plan, discuss and have access all relevant data in a single and more systematized system. This will drastically free up time and allow the team to make faster and more informed decisions.

In addition, with reduced planning time, the same engineering team will be able to use the time saved to compare, make crucial decisions, or plan new projects. As pointed out earlier, planning a well intervention operations will anywhere from a few days to a few weeks. During one of the meetings with key personnel involved in the planning process, the informant believed that ALTUS would achieve a reduction of 40%-50% in the planning time. This reduction of planning time in each planning process will allow the ALTUS team to plan more well intervention over time, hence increase the intervention intensity. Increased intervention intensity will in turn provide significant revenue for ALTUS as a service company.

A case study demonstrated the importance of easy access to relevant data on the planning time. A drilling project manager in Ante Creek, Canada, was tasked to plan 6-well pad in the area [53]. Quick and relevant data from a two previously wells drilled in the same area, offset well data and data such as; drilling fluids, bits, motors, well design, and best practices, the drilling project manager estimated a reduction of research and planning time by 80 percent for the 6-well pad project in the Ante Creek area.

In addition, the data helped the company to make key drilling decisions and reduced the project's AFE by 27 days relative to the planned time and approx. $3.4 million under budget. Figure 6.1 presents cumulative cost and the report days for each of the 6 wells compared to the 2 previously drilled wells along with the time and cost-savings made.

Figure 6.1: The graph shows the cumulative cost vs report days for the 6 well pad compared to the 2 previously wells [53]

6.2.2 Lessons learned for value creation

With the DWI, the process of using lesson learned and transfer experience will be significantly improved. There is a tremendous amount of cost-saving potential by capturing experience knowledge and learning from mistakes, avoiding rework at the rig, saving time, and reducing NPT. A survey conducted by Aase (1997) pointed out that experience transfer will have the following advantages: (a) Cost reduction, (b) Improved utilization of resources, (c) Improved efficiency, (d) improved HMS, (e) better service quality [54]. Capturing new learnings and implementing them into upcoming projects is an important catalyst for increased value creation through more efficient intervention services, reduced NPT, increased probability of success, and reduction of double work.

An SPE paper (SPE-202499) demonstrated the importance of lessons learned to increase operational efficiency, performance, and value creation [55]. Hess Corporation, a global oil company, implemented a system for managing lessons learned in order to improve operational performance and efficiency for subsea well intervention operations. The Oil Company gathered all the lessons learned from spreadsheets and systems and established a structured and effective web-based database to manage lessons learned. It was for the first time conducted CT intervention in the field on two wells with similar work scope, where minimal CT-specific lessons learned were available for the first well. The lessons learned from Well #1 were further applied to Well #2. The result in demonstrated significant improvements in time and cost estimation accuracy and improved operational performance, resulting in time and cost savings. The result is shown in the figure 6.2, the company reduced 32% of the total NPT, reduced the job duration by 22.2 days, and made a total cost saving of $10.2 million by applying the lessons learned from well #1 to Well # 2.

Parameter	Well #1		Well #2		Well #1 & Well #2 Comparison
	AFE	*Actual*	*AFE*	*Actual*	
Total job NPT	16.5%	48.0%	16.5%	16.0%	Well #2 (-32%)
Total job duration (days)	22.5	46.1	25.1	23.9	Well #2 (-22.2 days)
Total job cost ($MM)	12.8	23.1	14.9	12.9	Well #2 (-$10.2 MM)

Figure 6.2: Summary of the result [55]

6.2.3 Value creation by increased collaboration and knowledge sharing – One Team Approach

DWI creates an integrated organization with the client, this paves the way for a more efficient decision-making process through closer and continuous dialogue. ALTUS can solve operational challenges and develop efficient solutions together client where they bring their expertise and experience to create the most optimal candidate selection and best technique for the intervention job. The DWI will allow the ALTUS and the client to work in harmony during the planning phase. The new collaborative approach to well intervention will pave the way for faster, better, and cost-effective solutions.

An SPE paper (SPE-183111) demonstrated the importance of a collaborative approach during a drilling and casing installation operation in the southern sector of the North Sea [56]. After three failed attempts by applying conventional drilling methods, which ended up with two sidetracks and a well suspension, the operator decided to take a collaborate approach with a service company to establish a detailed well engineering analysis to meet the well construction objectives. By working together from planning to execution, they operator managed to successfully execute a 9 5/8-in. x 11 3/4-in. drilling with liner (DwL) operation in very challenging over-pressured and depleted formations. The paper concluded that a everything is achievable trough a collaborative approach.

6.2.4 Operational efficiency improvement and NPT avoidance

The new approach to well intervention, through DWI, will contribute to efficiency improvement in all stages of the intervention project. In any well intervention operation, time is costly. Efficiency and cost are directly linked, and any improvements in efficiency can be converted into cost savings [57]. The longer a well intervention operation takes, the more the intervention will cost. Any NPT avoidance is directly proportional to cost-savings. Avoiding unnecessary NPT through operational efficiency will provide significant cost-savings for both ALTUS and the client. Increasing operational efficiency will contribute to increased intervention intensity, hence an increased revenue for ALTUS and increased field recovery on NCS.

A SPE case study paper (SPE-185914) illustrated the effect of efficiency improvements that were made over the last 10 years by using riserless light well intervention (RLWI) vessels to perform well intervention. With the focus on continuous improvement during all stages of the intervention operation, the result was significant cost reduction, improved operational efficiency and field recovery, and increased intervention intensity. According to the paper, the contributory factors to these successes, among other things, was due to following improvement areas [58]:

Process improvement areas

- *Improved planning*
- *Continuous improvement of "best practices lessons learned"*
- *Implementation of new technologies*
- *Choose the right jobs for intervention*

People improvement areas

- *Stable crews and stable working patterns.*
- *Intensive and proper training and multi-disciplinary crewing*
- *Improved communication and collaboration*

Figure 6.3 shows the efficiency improvement over the 6-year period from 2011 to 2016. In addition, the average days per operation was reduced from 19.3 days in 2006 to 7.8 days in 2016, which corresponds to a reduction of 60%. This achievement in efficiency increased the intervention intensity and significantly reduced the average days per operation. As a result, more wells were serviced at a lower cost per well. Figure 6.4 shows the number of well intervened from 2012 to 2016. This corresponds to an increase of 345% from 2006 to 2016. (from 11 wells to 49 wells)

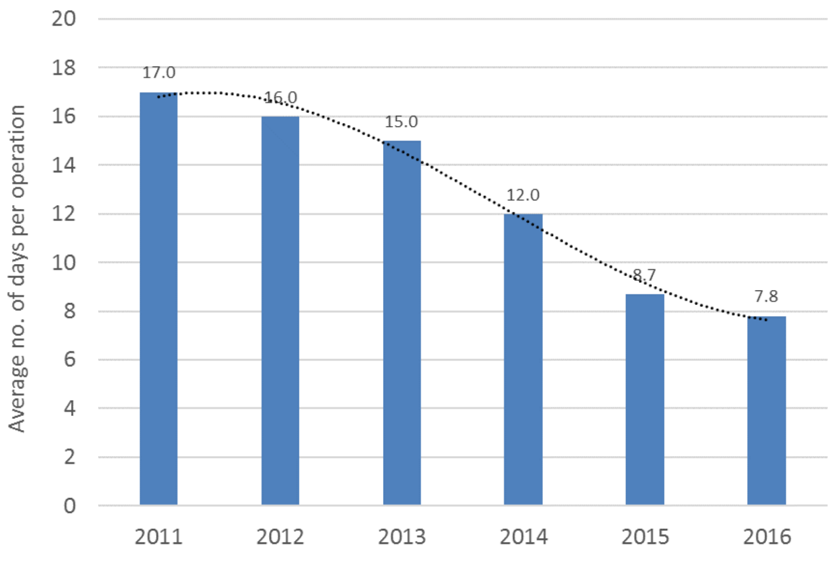


Figure 6.3: illustrates the improvement achieved from 2011 to 2016 [57]

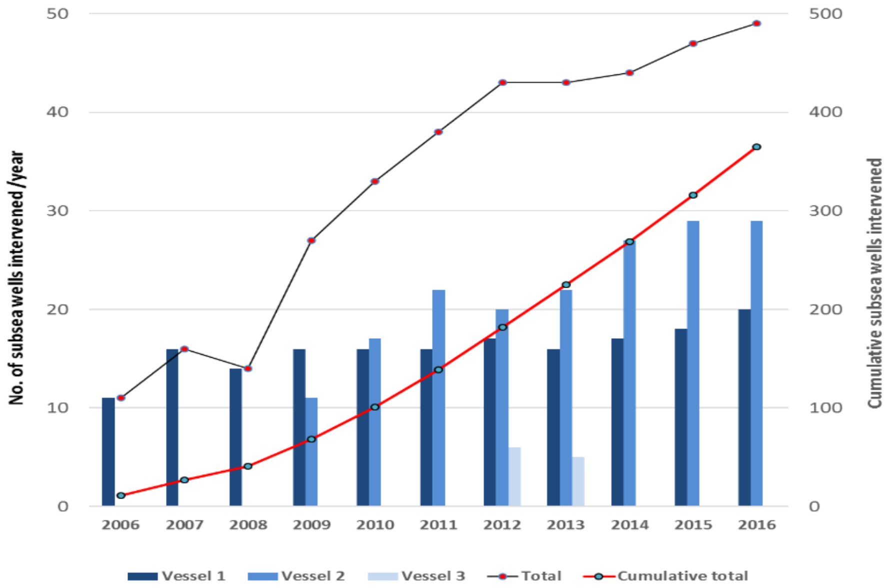


Figure 6.4: Shows the intervention intensity from 11 wells in 2006 to 49 wells in 2016 [57]

6.3 The potential to increase hydrocarbon production

6.3.1 Improved recovery rate through proper planning and selection of best intervention candidate

Proper planning and efficient candidate selection play a crucial role to improve efficiency, increase success rate and maximize the hydrocarbon production from the well (increased oil recovery/IOR) from existing fields. There is no doubt that new framework through DWI will ensure better performance in the planning. The time savings during the planning process will allow the ALTUS engineers to use the time on the actual engineering problem/analysis.

With the DWI, ALTUS engineers from different domains can come together in one environment along with the client to choose the best candidate selection, share knowledge, and implement the ''best practice'' and lessons learned into the planning program. This new approach will to a much greater extent, secure that the right candidate is selected for the well intervention.

Choosing the right candidate for well intervention operations that aims to maintain and enhance the production from wells or restoring wells back to its normal is essential to maximize the hydrocarbon production from the well. In addition, choosing the right candidate to minimize the runs needed to perform a job and or avoid re-runs will result in significant financial savings for ALTUS.

Chapter 7: Discussion

This last chapter aims to discuss around the objectives of this thesis and provide a conclusion. The first research question defines a desire to study how the DWI will impact the current work processes in ALTUS Intervention. The aim of the second research question was to study how the DWI contributes to values creation.

7.1 The planning process in the oil and gas industry:

In the past 30 years, technology in the oil and gas industry has significantly evolved. Technology innovations and digitalization in the drilling sector have enabled new sources of oil and natural gas. However, the theory showed that the industry still seems to have a major improvement area to maximize efficiency and productivity at every stage of the O&G project. In general, there has been a little area of improvement in the planning phase of a O&G project in the industry. Looking at the well intervention sector, it seems that little effort has generally been made in both the planning and execution phases.

The planning process during an O&G project is generally still a time-consuming and inefficient process which seems to be a common issue in most oil and gas companies. This is mainly due to lack of a common platform that gathers all the planning process activities and systems in one single place. However, due to a new wave of digitalization and technologies advanced developed in recent years, the industry will experience a drastic change in the work processes and work habits. By implementing the DWI, ALTUS will introduce several radical functions and changes in the way the company is delivering a well intervention service.

7.2 The planning process in ALTUS:

During my interviews and discussions with ALTUS, all the informants claimed that the current work process in the planning phase is a very time-consuming and manual process. Excessive effort and time are used to collect relevant data and information. Gathering data and request information from other engineers and departments in ALTUS requires time and effort. The reasons for this mainly due to outdated systems and software with little transparency and harmonization between them. Critical analysis, important insights, and data are stored in siloed systems, databases, and spreadsheets, making the planning process further difficult and demanding. As a result, the well intervention planning process has been sub-optimal.

With the DWI, the work processes and workflow in the planning processes will be drastically improved. The DWI platform will provide coherent, well intervention planning. All three departments will now plan together in a single platform, allowing the three departments to function as one integrated team. Necessary data and information will be at the ALTUS engineers' fingertips in the DWI, which will significantly improve the work processes of searching for necessary data and information. Furthermore, as all the information and communication flows in one direction, it will to a greater extent secure important data and information are considered during the planning process. This will streamline the work process of searching for relevant data in multiple systems, spreadsheets, and databases. Important data and information, which used to be lost between in both the planning processes and the execution phase, will in the DWI be systematically stored and re-used to improve future plan processes.

7.3 Communication infrastructure:

As pointed out in the theory study, efficient communication is still lacking in most oil and gas companies, especially when planning an O&G project. This is mainly since the communication channels are spread across various disconnected systems in most of the oil and gas companies, which also has been the case for ALTUS. With the DWI, a new level of communication infrastructure will be introduced, eliminating communication inefficiencies both internally and externally at every stage of the well intervention project, from planning to execution. Time spent on e-mails back and forth both internally and externally and wait for approvals will be eliminated. The engineers in ALTUS can instead use valuable time on other productive things. As shown in the snapshots of the DWI platform in this thesis, the communication process will be significantly streamlined by allowing everyone to communicate on a single platform, which will create transparency and harmonization among all the involved stakeholders. Allowing all the involved stakeholders to communicate in one place will ensure that critical information and lessons learned are exchanged.

7.4 Smart collaborative work environment:

For collaboration to prosper and become an established fundament in the O&G industry, having an efficient communication system is essential. Traditionally, service companies and operator companies have had little cooperation in the industry. The collaboration between the three departments in ALTUS is currently sub-optimal. This is again due to the lack of a common platform to collaborate on. The employees and departments are working in different systems and computers, thus making efficient collaboration extremely difficult. In addition, the client does not have access to ALTUS 'communication and storage system, hence limiting the collaboration between ALTUS and the client.

With the DWI, it will be established a new level of collaboration between all involved stakeholders. Communicating in one platform will significantly boost the collaboration between the engineers and the three departments in ALTUS. The client will also have access to the DWI platform. This will immediately strengthen cooperation between ALTUS and the client. The client will be able to be involved both in the planning and execution phases. Early in the planning phase, the experts from the client side see the solution (BHA) with ALTUS and share their ideas and experiences to find the best optimal solution for the intervention. Furthermore, the client will also participate in the operation. The live dashboard in the DWI platform will also be available for the client, enabling a new level of collaboration during the operation between the ALTUS and the client. This seamless collaboration between ALTUS and the client will contribute to mote efficient and production well intervention operation in the future.

7.5 Dependent of physical location to independent of location:

Due to the lack of real-time data and onshore support centers, the decision-making process has mostly depended on location. However, the deployment of DWI allows decisions to be made independent of location. Furthermore, the DWI live dashboard onshore and the 4G connectivity will enable the onshore team to support the offshore team on a continuous basis despite geographical distances.

7.6 Single-discipline into multi-discipline:

Deployment of the DWI will eliminate the "functional silos" and allow ALTUS to move from serial work processes to parallel work processes. The new work processes will gather all the single-discipline experts and establish a multidiscipline environment in the onshore support center where the team can jointly collaborate in parallel. This is a huge step towards more collaboration between service companies and operators, which stimulates to increased efficiency and productivity at NCS.

7.7 From reactive to proactive:

Due to the lack of real-time data and an onshore support center, the well intervention operations can be perceived as reactive and less proactive. With real-time data flowed into the DWI dashboard and onshore expertise analyzing the data and supporting the offshore team, ALTUS Intervention will provide a proactive approach towards the well intervention operations in real-time. In addition, integrating AI and machine learning capabilities into the DWI platform will further strengthen the proactive approach.

7.8 Lessons learned:

As pointed out earlier, lessons/experience transfer in the oil and gas industry still a problem. The biggest barrier to effectively capturing lessons learned from previous operations is outdated databases and little systematized lessons learned databases. This has also been the case for ALTUS. With the DWI, there will be a single place for the lesson learned, which will be systematized and easily accessible for future planning processes. The work processes of finding lessons learned will be significantly improved with the DWI. The manual process of searching in several systems to find relevant lessons learned will be eliminated. Critical lessons learned data, which used to be lost between multiple systems and spreadsheets or could previously only be based on the individual experience, will now be available for everyone in the team and the client. This is an important step towards ensuring that lessons learned are re-used for future well intervention operations, creating a continuous improvement culture in ALTUS.

7.9 Execution phase:

One of the biggest challenges in the execution phase today has been poor understanding and visualization of the conditions down the hole during the intervention operation, which is critical for whether the operation will be successful or not. The lack of sufficient real-time data prevents the offshore crew from making informed decisions and bring in experts. With the DWI, the DAQ system and real-time data will allow the offshore crew to have extended visualization and understating of the downhole conditions during the operation. This will in turn significantly improve the decision-making processes in ALTUS.

With the DWI, the experts will now be moved to onshore centers to form a multidisciplinary team and monitor multiple operations simultaneously. Data-driven techniques such as AI and ML have proven to be essential for operational efficiency and performance in drilling operations. AI and ML can be integrated into the DWI platform to improve the decision-making processes and increase operational efficiency by supporting the onshore support center with predictive capabilities.

Communication and collaboration will occur in one place, where everyone will be updated about the latest information and changes, including the client. The client will also have access to the live dashboard, and ALTUS can together with the client consider all relative views when making decisions. The collaborative work environment will lead to a collective understanding of problem-solving between all the involved parts and increases situational awareness among all involved parts.

7.10 Value creation

The second research question defines a desire to study how the new approach to well intervention through the DWI will contribute to value creation. Several case studies conducted by other companies were reviewed that had a similar approach to the DWI.

Case study 1:

The first case study presented a drilling company project to drill a 6-well pad project in Ante Creek, Canada. The result was reduced planning time, cost, and estimated execution time. This successful result came from the benefit of easy access to relevant data using a digital tool that streamlined research processes. The planning time was reduced and thus rather spent on valuable engineering analysis. The case study presented the importance of extracting relevant and good quality data in the least possible time.

Case study 2

The second case study presented the value of lessons learned. Spreadsheets and unstructured databases for lessons learned were eliminated, and a web-based database were created for effective lessons learned extraction. By applying all the lessons learned from a previously conduction CT intervention operation into the new intervention operations. Significant improvements in NPT, cost-saving and job-duration were made.

Access to relevant and quality data is among the areas that DWI will contribute to during the planning phase. As all lessons and relevant data are gathered in DWI, more and more decision-making in the planning phase will be based on previous historical data and lessons learned. This will lead to more robust planning and significant cost-savings potentials in future projects.

Case study 3:

The third case study presented value creation by increased collaboration and knowledge sharing between a North Sea operator and a service company - "One Team Approach." Service companies often have highly skilled knowledge that is crucial in solving complex operational problems and vice versa. Thus, collaboration, knowledge sharing is very important to maximize hydrocarbon production in NCS.

Development of the DWI, ALTUS, will create a new level of collaboration with clients(operators) and other service companies on a scale never seen before. During a well intervention project, the DWI allows internal and external stakeholders to proactively participate in the BHA selection, risk assessment, execution, and final report. Specialists from the client's side can bring their own expertise to a problem and provide a comprehensive solution to deliver smatter and better well intervention service quality. It enables ALTUS and the client to work together and seamlessly share ideas, knowledge, and experience to solve unique challenges and operational problems together.

Case study 4:

The fourth case study presented the value of operational efficiency improvement and NPT avoidance by focusing on a continuous improvement culture. Creating a continuous improvement culture among a team requires that you find as many areas for improvement as possible and take concrete measures. Over the 10 years, this was the case where concrete measures were taken in process improvement areas, people improvement areas, and equipment/operations improvement areas. The result was an overall improvement in operational efficiency, team efficiency, NPT avoidance, and increase intervention intensity.

The DWI will contribute to operational efficiency through the benefits from the real-time data and the establishment of the onshore support center. However, another important part of the DWI is to establish an improved continuous culture in ALTUS. This has been pointed out several times during the interviews and discussions I have had with the employees of ALTUS. However, the manual reporting of activity on the rig and little visualized analysis tools have made the process difficult. With the DWI, the live reporting of rig activity and better analysis visualization/tool will be a key step in finding benchmarks and gaps in operational efficiency.

Suggestions have previously been made in this thesis to extract important information from the report to establish an improved continuous culture in ALTUS. An enhanced continuous culture will contribute to value creation by increased operational efficiency, team efficiency, and NPT avoidance.

Chapter 8: Conclusion

This master thesis deals with an innovation project developed by ALTUS. A series of interviews and discussions with employees in ALTUS was conducted, and several SPE papers reviewed to answer the following main objective of this thesis:

Research question 1: How will the Digital Well Intervention (DWI) impact the work processes in ALTUS Intervention?

Research question 2: How will the DWI platform contribute to value creation?

Implementing the Digital Well Intervention (DWI) platform profoundly affects the work processes and workflow in ALTUS. It will totally transform the work habits and work processes in ALTUS. From the interviews and discussions with the key personnel in ALTUS, it can be concluded that the current work processes and workflows are inefficient and demanding. The lack of a common platform has prevented efficient communication and collaboration internally and externally. Candidate selection of the intervention and design of the BHA is a time-consuming process. This is due to fragmented and outdated systems and databases, as well as poor data management. As a result, tremendous amount work and time is used on accumulating data manually.

The planning process will significantly be simplified and streamlined with the DWI. The entire well intervention planning process, which is managed using multiple systems, excel spreadsheets, and shared folders, will with the DWI be carried out in a single platform. This will save many hours of manual work searching for relevant data, lessons learned, experience transfer etc. The communication and collaboration will occur in the same platform, enabling seamless communication and cooperation between the engineers, the departments in ALTUS, the client, and other service companies.

The real-time data and the establishment of the onshore support center will relocate the personnel and establish a multi-skilled team for future well intervention operations. This will pave the way for reduced POB. In addition, with real-time data and an onshore support center, the well intervention operations will enter a new area of operational efficiency and productivity. The DWI will enable more proactive decision-making during the well intervention operation. Furthermore, the real-time data will pave the way for data-driven techniques such as AI and ML to further improve the efficiency and performance of the operations.

The semi-automated reporting system significantly streamlines and reduces the reporting processes at the rig site, allowing the offshore crew to focus on the operation. Based on the innovation study and the discussion, it can be concluded that DWI will significantly improve the work processes and workflow in ALTUS. The following conclusion can be made:

Planning phase:

- Reduced planning time and Improved decision-making at every stage of the planning process
- Seamless communication and collaboration both internally in ALTUS Intervention and externally with client and service partners
- Improved interaction and transparency between the wireline and tractor & logging departments in ALTUS Intervention
- Efficient data and information management
- Easier access to historical data and lessons learned from previous projects

Execution phase:

- High-quality decision making during the entire operation
- Improved decision-making through real-time data and onshore support center
- Increased visibility and understanding of the downhole condition during operations
- Proactive decision making during the entire well intervention operation
- Increased workforce competency and flexibility through the multi-skilled team
- Seamless collaboration between ALTUS and the client during the operation

Value creation:

As previously mentioned, it is difficult to quantify the value creation by implementing the DWI. However, the ALTUS will operate in a much safer and more efficient way with the DWI. Combining real-time data, onshore support center, better communication, and interaction internally and externally, capturing lessons learned, and focusing on improved continuous improved culture suggests a vast improvement potential in ALTUS Intervention. The drilling sector, which has used real-time data and onshore support centers for many years, has gained tremendous cost-saving yearly and operational efficiency. With the DWI, ALTUS Intervention will improve both the planning and execution phases, which can correspond to enormous value creation for ALTUS.

In addition, all the case studies illustrated that lessons learned, operational efficiency, better data and information management, better collaboration and communication between all involved parts will significantly reduce the planning time, increase operational efficiency and provide tremendous amount of cost-saving. With that being said, the ALTUS can be confident that the DWI platform will pave the way for tremendous amount of cost-saving and value creation in the future.

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