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MASTER THESIS

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Summary

This study describes the risk analysis process that took place regarding the permanent plug and abandonment phase on a fixed installation on the Norwegian continental shelf.

The risk analysis was done in two phases.

Frist a series of extensive hazard identification (HAZID) sessions were undertaken in the Ready for Operation phase (RFO phase) which involved a large group of management, health, safety and environmental specialist as well as representations from the workers and workers representatives.

However, these meetings were all based on experience and surveys done during the last drilling phase, therefor, there were many uncertainties regarding the validity of the data in permanent plugging and abandonment phase (P&A phase).

The initial risk analysis produced an unprecedented number of follow up actions varying from large technical improvements that were suggested should be implemented before starting up of plug and abandonment phase to health, safety and working environment surveys that needed to be undertaken. This was done to fill in the knowledge gap on this type of operation and the consequences that it would have on health, safety and the working environment.

Nine months into the P&A phase, the review risk analysis sessions were held. This time only two sessions took place. The first was with the drilling contractor and the operator reviewing the initial risk analysis and updating it with new health, safety and working environment survey data as well as adding the workers operational expertise of the health, safety and working environment hazards the P&A phase caused.

For the second risk analysis session, the service companies that work alongside the drilling crew in the P&A phase were invited. In order to for them to identify the health safety and working environment hazards they were exposed to where there could be added risk.

This was the first time this type of multi company risk analysis was done for this operator, drilling contractor and for the service companies.

This study evaluates the synergies of this cooperation as well as the challenges that face industry in regard to the continuous monitoring of health, safety and the working environment.

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1 Background

1.1 Plug and abandonment, the reason for studying this topic now:

The Balder field in 1967 was the first discovery of hydrocarbons on the Norwegian Continental shelf (NCS). This became the start of the Norwegian oil and gas industry (Norsk Petroleum 2020). Since 1967, almost 5600 wells have been drilled on the NCS. Of these 1542 are exploration wells and 4037 development wells (Khalifeh et. al. 2020). If exploration wells that are not viable, they are plugged and abandoned right away, therefore 1480 wells have already been permanently plugged (Khalifeh et. al. 2020). After over 50 years of continuous oil and gas exploration and production, the life span of some production wells is now over as they are no longer financially viable. These wells consequently need shutting down permanently and safely.

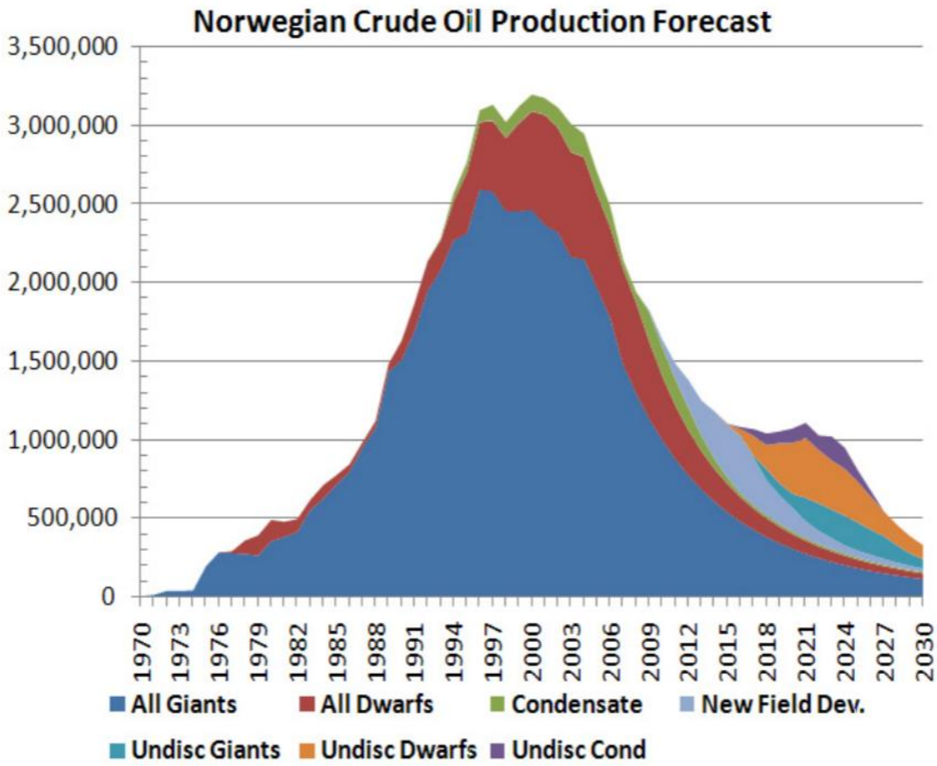

Figure 1 Norwegian crude oil production forecast (Aleklett 2010)

At this point, the government according to their local regulations, require that the wells be permanently plugged before they are abandoned (Khalifeh et. al. 2020).

Permanently plugged wells shall be abandoned with an eternal perspective taking into account the effects of any foreseeable chemical and geological processes (NORSOK 2012).

On the Norwegian continental shelf, the estimated number of wells that need to be permanently plugged in the coming years is 2637 (Khalifeh et. al. 2020).

The hydrocarbons trapped in the reservoir are kept from migrating to the seabed by the cap rock formation (also known as seal rock). Oil and gas floats on water, therefor the only thing keeping them from migrating to the seabed is the cap rock formation. If an earthquake causes a fault or when wells are drilled through the cap rock formations, pathways are created through which the oil or gas ca reach the seabed. Therefor it is essential that when the wells are permanently plugged and abandoned it is done in a way that restores the pressure balance back the “way it was” when the cap rock kept the oil and gas from migrating to the seabed.

“The objective of permanent plug and abandonment operations is to restore the cap-rock functionality, securing the well-integrity permanently. In order to succeed, an appropriate permanent barrier shall be placed across a suitable formation, through the utilization of relevant equipment to fulfill the local requirements” (Khalifeh et. al. 2020).

The double barrier principle or “hat over hat principle” is used to make sure nothing leaks out of a permanently plugged well.

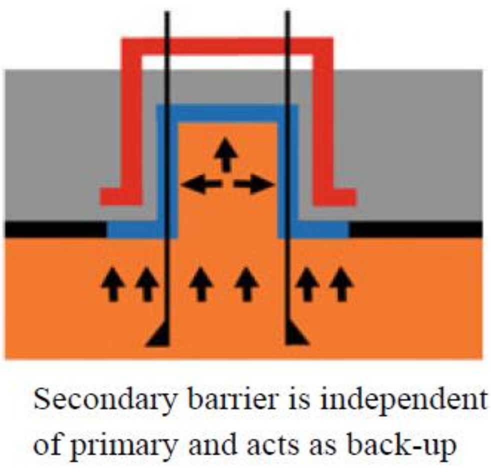

Figure 2 Illustration of double barrier function (Khalifeh et. al.2020).

1.2 *Is health, safety and working environment a plug and abandonment challenge?*

When it comes to plug and abandonment the Petroleum authorities (PSA) asked the question in 2018 if it is a working environmental risk ?" due to the fluids found in the old wells, that are due to be permanently plugged and abandoned (PTIL 2018).

The offshore oil and gas industry in Norway have for over 5O years created work for a great many people. The working environment for the offshore personnel, however, contains many challenges, with the fluids in the wells just being one of them.

"the offshore environment contains virtually all the health hazards common to industry are present offshore" (Gardner 2003).

"They include: chemical hazards (toxic, corrosive, irritant and sensitizing substances and possible carcinogens); physical hazards (noise, vibration, various forms of radiation, thermal extremes); biological hazards (legionella, food poisoning); ergonomic hazards (manual handling activities, workstations, VDUs); and psychosocial hazards associated with either the work (overload, underload, hours of work, tour patterns, work relationships, etc.) or the location (travel, being away from home, living on the job, etc.), all of which can contribute to psychological stress (Gardner 2003).

One of the aspects that is highlighted in the history of development of Norwegian oil and gas sector was how the Government insisted on Norwegian ownership of the NSC. This created the platform for the knowledge base and the development of the skills needed for the industry (Norsk Petroleum 2020). Knowledge and awareness of the consequences of being exposed to these offshore occupational hazards, has increased over the years. This has produced disciplines like: Occupational Hygienists, Health, Safety and Environmental (HSE) and risk management specialists. Their role is to help ensure that health, safety and working environment offshore complies with current regulations.

Often health exposure is left to surveys of the Occupational hygienist due to the complexity of the many chemical substances and complicating factors that are hard to understand without a degree in chemistry. However, as they only travel offshore to do surveys a few days at the time, they will only survey a "snapshot" of daily operations. Their results also have mostly a metrical viewpoint, based on what their instruments in their survey tells them.

Consequently, in order to get a complete picture of the working environment, it is necessary to put the working environment survey data into an operational context, so as to identify hazards in an operational setting.

Practically this means that if, for example, an occupational hygienists measure turbine exhaust exposure in an area of the rig. The operation team also needs to review how often work is done there, how many hours a day or a week are people in that area, as well as who or what disciplines works there? Is the exhaust affected by wind direction etc.? Only by adding all these operational factors to the equation, does one get the actual hazard to personnel and what disciplines are affected.

1.3 Regulations, another reason for asking these questions now:

The Norwegian Petroleum industry is one of the most heavily regulated oil and gas industries in the world. The goal of the oil and gas industry is to be "*world leading in health, safety and working environment"* (Ministry of Labour and Social Affairs 2006).

The principle the Norwegian working environment regulations is founded on, is a mutual trust principle between the three main parties: The Petroleum Safety Authorities (PSA), the operators /employers and the employee's representatives. A tripartite cooperation. If only two of the parties are involved it is called a bipartite cooperation.

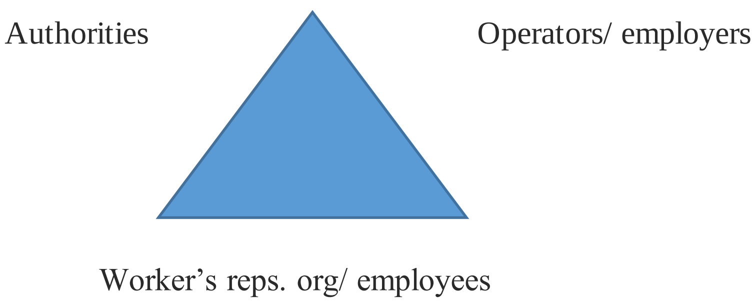

Figure 3 Model of tripartite cooperation.

When the oil downturn of the oil industry hit in 2015 there were concerns how this would affect health, safety and working environment in the Norwegian oil and gas industry? Therefor the Norwegian labor and social department invited the oil and gas industry to be part of a joint assessment of the current status of the health, safety and working environment in the oil and gas sector as well as say something about the future development Ministry of Labour and Social Affairs.

An important goal for the working group has been to arrive at a representative and agreed picture of the status for health, safety and the working environment in the petroleum industry. Furthermore, the group was to assess what is required to maintain and improve the level of safety while also achieving efficient and economic operation. (Ministry of Labour and Social Affairs 2006).

This group assessed the current health, safety and working regulations and the developments in 2016-2017, will look at this report considering the risk analysis done in this study.

The health and safety aspect of the petroleum industry is regulated through the Norwegian working environment act and is followed up with its own regulations through the Petroleum regulation.

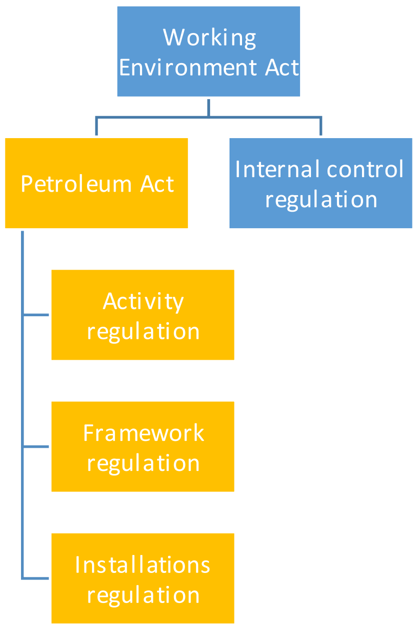

Figure 4 Model of some of the Norwegian oil and gas industry regulations.

According to the Norwegian working environment Act it is the responsibility of the employer to monitor and follow up hazards that their employees experience at work (Ministry of Labour and Social Affairs 2006). This is described in the petroleum industry is described in the Activity, Framework and Installations regulations (Lovdata.no).

The follow up and auditing of how these regulations are met, is carried out by the Petroleum Safety Authorities (PSA).

Added to this complex picture that in an average drilling, completion or plugging operation there are many different companies/employers involved: drilling contractor, cement contractor, mud-logging contractor, injection contractor and wellhead contractor. These groups work with each other in the drilling module on the rig and are on regular a Norwegian 2 weeks on 4 weeks off rotation.

On top of this you have other disciplines that come out when operations require it, one example is the casing contractor. This list is just to paint the picture of the many different companies/employers involved offshore other than the and operator and therefor how many companies that require information about their employee's health, safety and working environment.

However, the majority of the personnel working in the drilling module is the drilling crew, with 29 people on average, the other disciplines might have one or up to 4 people offshore at each give point.

The employer of each individual has the responsibility through the activity regulations to survey, to monitor and put in place mitigating action where necessary in regard to the working environment hazards for their employees (Framework regulations 2002).

There is an added responsibility on the operator. It is called the "see to duty" in the framework regulations § 8 (Framework regulations 2002).

The operator shall see to it that everyone who carries out work on its behalf, either personally, through employees, contractors or subcontractors, complies with requirements stipulated in the health, safety and environment legislation".

The regulations also uses the term “main company” in this study this is called the operator. They have the responsibility to coordinate the activities including working environment offshore. This puts a special responsibility on the operator to coordinate the ongoing monitoring of the working environment (Framework regulations §33).

On the other hand, the current regulations require all the different employers to follow up their employees. The method used so far is to monitor and survey the offshore health and safety exposure of their employees, but they are limited according to availability on the rig.

Since the regulations state that each individual employer, is responsible for monitoring their employees, even though many companies only have one or two employees offshore on each given rig. The question then becomes: how feasible is it for these companies to have an accurate rig-specific status of their personnel’s exposure to health, safety and working environmental hazards and in that way be complying with current regulations?

1.4 Defining the problem

This study evaluates the method used for hazard identification in this new plug and abandonment operation. Asking the question that if a risk analysis method was an effective way of identifying safety, health and working environment hazards.

The first research question this study will try to answer is: **was the hazard identification method an effective method to identify the hazards in health, safety and working environment in a plug and abandonment operation?**

As this was the first time for both the drilling contractor and the operator to include the service companies in the hazard identification, the result of this was the second question needing to be answered.

How can the drilling contractor’s hazard identification serve the operator in their “see too duties” and the service companies in their obligation to identify health, safety and working environment hazards?

1.5 Purpose of this study

The end goal of the study is that by answering these two questions, the study can give other operators the idea of using the drilling contractors risk analysis as a starting point for a review of health, safety and working environment hazards. As well as to encourage them to take the next step and include the service companies that work in the same areas. This will produce a more complete drilling module overview of health, safety and working environment hazards for all the disciplines working there.

1.6 Framework and limitations:

This study will only examine the parts of working environment exposure that were covered in the drilling hazard identification process. This only covered the physical aspects of the working environment not the psychosocial or biological working environment. Therefor working environmental exposure in this study only cover exposure that is: ergonomic, chemical, noise or vibration.

This study looks at the method used for identification of working environment risks in the drilling module of the rig from an operational point of view. Which is very different from looking at it from an occupational health professional's point of view. The focus is not just the survey results but putting survey results into an operational setting.

However, the highlight of this study is the inclusion of the service companies in the drilling contractor's risk analysis. Therefore, the focal point in this study is on the risk analysis method used to produce the working environment overview of the exposure to risk as a consequence of this.

1.7 Outline and structure

Chapter 1 The setting for the research questions are described as well as key definitions.

Chapter 2 Introduces the central theory for answering the research questions.

Chapter 3 The method used for collecting the data for doing this study is presented.

Chapter 4 Describes the methodology used in this study.

Chapter 5 Contains the results from the informants or data collection.

Chapter 6 The discussion of the theory and the data gathered in chapter 5.

Chapter 7 The conclusion and answer to the research questions are given.

1.8 Definitions and Abbreviations:

ALARP - As Low As Reasonably Practicable. Principle for risk mitigation actions. Means that risk should be lowered as low as it is practicable (Aven 2017).

Consequence - The outcome or result of an incident.

Cost/benefit - Principle for decision making, based on the fact that the price/cost of implementing the risk mitigating action is low enough in correlation to the results it produces.

Hazard - The combination of possible consequences of an accident and the likelihood of this occurring. This only describes the negative outcome.

HAZID - Hazard identification method for identification of hazards or risks that can contribute to an unwanted incident/accident (Rausand 2011).

HSE specialist - Health, safety and working environment specialist.

Likelihood/possibility - What is the likelihood of this unwanted incident taking place.

Mitigation actions - Risk reducing actions.

NCS - Norwegian Continental Shelf.

PSA - Petroleum Safety Authorities.

P&A - Plug and abandonment.

PHA - Preliminary Hazard Identification.

RFO - Ready For Operation.

Risk - The combination of possible consequences and the uncertainties of this occurring. Can be both positive and negative (Aven 2017).

Risk accept criteria - Describes level of acceptable risk. If the risk is higher than predefined area. Mitigating actions needs to be implemented.

Risk analysis - Analytical process for identifying analysing and suggesting actions for mitigating risk. Part of risk management process.

UI/A- Unwanted incident/ accident.

2 The research context

This study is based on the hazard identifications done in regard to the plug and abandonment campaign on a fixed installation platform operated by an international company.

The field is located on the southern part of the Norwegian continental shelf. It was discovered in 1980 and produced its first oil in 1990 (Norsk Petroleum). There has been many challenging wells drilled due to the high temperature and depths up to 400m. The high temperature causes problems with the mud and cement barriers in the well. Another challenge has been scaling inside the production tubing (Rothwell et.al. 1993). The last production well was drilled in 2013 and the permanent plug and abandonment of the field was started 2019.

The rig is a fixed installation located on the Southern part or the Norwegian Continental Shelf.

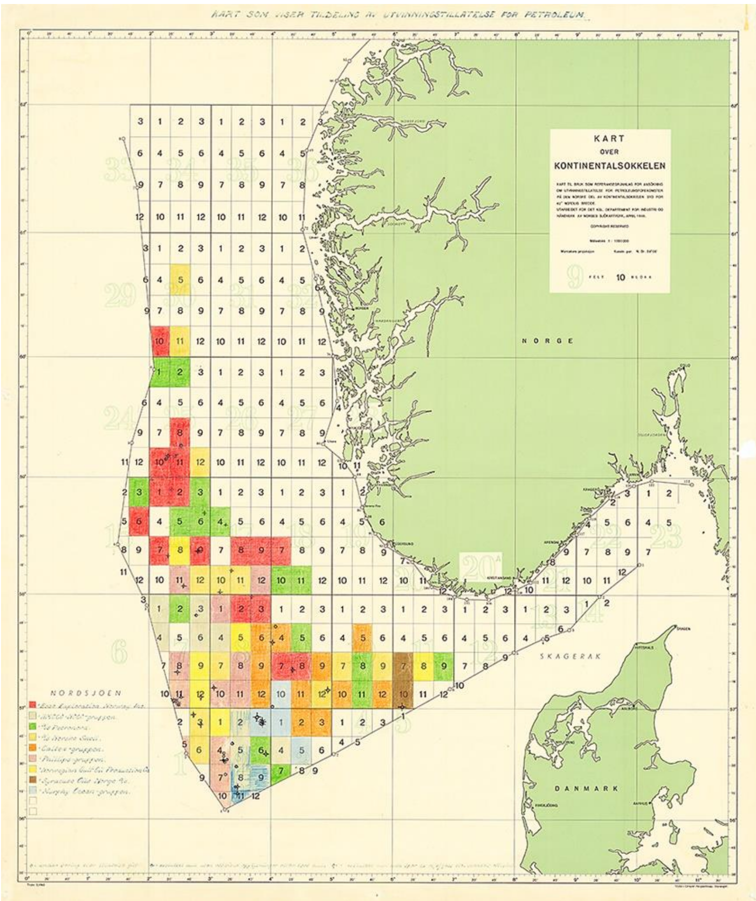

Figure 5 Norwegian Continental Shelf (Norsk Petroleum.no).

2.1 The initial hazards identifications

The initial hazard identifications were done by the drilling contractor together with the operator.

All offshore operators are required to have an overview of health, safety and working environment hazards in their operations according to the Framework regulations § 11.

The drilling contractor started doing operational risk analysis (HAZID) in their operations in 2012. However, this drilling operation shut down drilling in 2013. Therefor this operational hazard identification for this drilling module had never been done. This is the reason why it was undertaken in the Ready for operation phase (RFO) before starting up the final plug and abandonment phase, during the fall of 2018.

This initial risk analysis was done using operational input and working environment surveys done during the last drilling phase in 2013, as this was the only data available at the time. The strategy was to identify gaps and uncertainties in regard to the upcoming permanent plug and abandonment operation. The uncertainties needed to be answered in order to get the correct identification of the hazards in health, safety and working environment in this new phase. Since these were two different operations, there were uncertainties such as to differences in exposure and how small or large the potential differences would be.

There were an exceptional number follow up actions after the initial hazard identification. Some of them were to gather new operational information, others were to do several working environment surveys, trying to close the knowledge gap. Some were to upgrade systems that were not in compliance with regulations. One of the last follow up actions was to do a review of the health, safety and working environmental hazard identification. This study is an evaluation of this process and the resulting synergies.

Execution of the hazard identification:

1) Planning and preparation was done by HSE specialists from both operator and drilling contractor. Since the drilling contractor had been using this matrix since 2012 the lead engineer was experienced and introduced the operator to the approach and method. In the preparation phase the decision was made to take out safety hazards in a separate matrix. This was done in order to be complying with requirements which necessitated doing a safety hazard identification. This gave the notetaker two matrixes to fill in from the same plenum session.

Area	Task activity	Hazard identificatic	Screening criteria	Durati pr.pers	Frequer	Position	Existing control measures	Immediate risk rating			Proposed contr measures
								HEC	ER	R	

Figure 6 The Drilling contractor HSE Matrix used in the initial risk analysis.

The hazard identification matrix had a geographical structure based on the different areas of the drilling module.

Each area was defined e.g. the drill floor and derrick (dill tower), shakers, pump room, Blow Out Preventor deck (BOP deck) and wellhead etc., along with the operations performed there. Starting on the drill floor and derrick and moving downwards through the drilling module and ending on the wellhead.

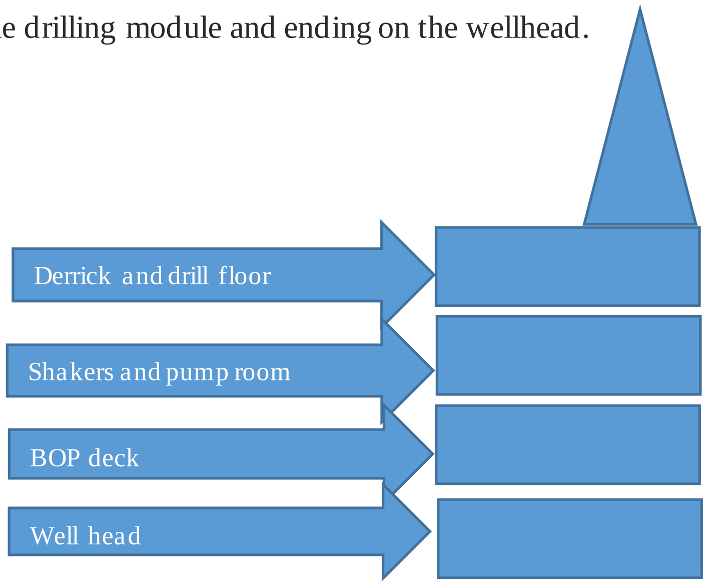

Figure 7 Model of the different rig levels.

Secondly in the matrix came the different operational tasks that were performed in that area. The hazard identification matrix was a standard HSE matrix used by the drilling contractor. As part of the planning and preparation phase the facilitators filled in the outline of the matrix with areas of the rig and the operations performed there based on other hazard identification on other fixed installations.

The facilitator was very familiar with the matrix and had done many operational risk analysis (HAZID) of drilling modules before.

In the planning phase it also became clear that an exceptional number of people wanted to take part in the plenum hazard identification sessions 16 people made up the group.

2) Plenum sessions: Every task performed in the different areas of the drilling module, involving health, safety and working environment done in the different areas of the drilling module was identified e.g. maintenance, cleaning etc.: Asking the questions: “how often do you do this?” and “how much time does it take each time?”. Consequence of a hazard and likelihood of hazards identified.
The facilitator was very familiar with the matrix and had done many plenum sessions before.

The hazard identification matrix structure kept the plenum sessions on track.

The participants were informed about the risk principle ALARP to be used in risk analysis. As well as being given instructions that the focus of the plenum session was firstly to describe and identify risk in the different areas of the drilling module. Analysis and classification would be done after by very experienced occupational health specialists. Using a consequence x likely 5x5 matrix.

Health exposure category	Exposure ranking				
	A Insignificant	B Low	C Moderate	D High	D Very high
1 - HEC 1	5	10	15	20	25
2- HEC 2	10	20	30	40	50
3- HEC 3	25	50	75	100	125
4- HEC 4	50	100	150	200	250
5 - HEC 5	100	200	300	400	500

Figure 8 5x5 Risk matrix used in the hazard identification.

Representatives in the hazard identification plenum sessions were from every offshore employee group in the drilling module: drilling, deck and technical workers representatives went through the matrix. A multidisciplinary group of onshore employees. The drilling contractor’s operational management, occupational health specialists from the operator, operational management and technical management from operator as well as workers representatives from both drilling and operator.

It took 6 long, whole day sessions to go through the whole drilling module and identify the health, safety and working environment hazards and to fill in the information in the matrix.

3) After the hazard identification had taken place, the facilitator asked the occupational health specialist to classify the hazards. Based on the likelihood and possibility C x P matrix in colors of red yellow and green. As mentioned earlier this illustrates the actions needed to be taken. Red indicates immediate action is needed, yellow means assess if mitigation action needs to be implemented and green hazards does not require any action.

Green-	Acceptable / review to reduce if possible
Yellow-	Proceed only with management authorisation / hazards to be identified & risks reduced
Red-	Do not proceed / further control measures to be implemented

Figure 9 Color grading of risks used in the hazard identification.

4) The follow up actions were recorded in the operators document control system. This is the software used for following up health and safety actions.

After these initial risk analysis (HAZID) plenum sessions were completed and the whole drilling module had been assessed. The occupational health specialist classified the hazards in categories of red, yellow or green and the actions was logged in the management control system. In order to communicate the findings of the hazard identifications that had taken place to the offshore workers so that they could be aware of the hazard and put in place necessary mitigation actions like using the correct personal protective equipment. To do this a visually simplified version of the risk analysis matrix was created. Based only on the hazards identified that came out as red and yellow risks. This was done in order to print it in a booklet form to send offshore, as well to present it to all personnel in meetings before they went offshore to start the plug and abandonment campaign.

Aktivitet	Ergonomi	Kjemikalier hud	Kjemikalier innånding	Støy	Vibrasjon
Tripping	Sitter stort sett i bu+ kontinuerlig påføring gjengefett og vasking av gjenger, utfordrende statisk. Operere mudbucket	Mud, gjengefett	Mud, gjengefett	Område + impuls (smell fra rør)	
Trekke casing/tubing	Håndtere manuelle slips, drillerbu, protectorskruing			Område	
Kutte/sage tubing	Håndtering/oppspenning av kutteverktøy				
Drifte pipe					
Vedlikehold på boredekk (inkl. boretårn).	Tungt utstyr, trangt, ridebelte, utfordrende arb.stilling; knestående, liggende, over skulderhøyde	Mud, oljer, grease, varm hydraulikkolje	Mud, oljer, grease, varm hydraulikkolje	Område + muttertrekker	Muttertrekker
Demontere kontrolliner		Div. kjemikalier i kontrolliner		Område	
Boredekk BHA håndtering	Tunge løft, manuell håndtering, protectorskruing	Mye mud ut		Slegge, spinnertang	

Figure 10 Example of simplified initial HAZID matrix, presented to crews.

Several actions that came out of this initial hazard identification required substantial financial investments in order to improve health, safety and working environment. One example was the manual pipe handling on the drill floor that exposes personnel to great risk and according to regulations is to be avoided as much as possible. As a result of the initial hazards identification this manual handling was improved by a new pipe handler called "Iron Roughneck RNX". It was bought to replace a much older machine that would require more manual handling by personnel, thereby exposing the roughnecks on the drill floor to more risk.

Another follow up action was to review and update the initial hazard identification matrix after a period time in operation with occupational surveys done during the plug and abandonment campaign. This was done to close the knowledge gaps where there had been uncertainties during this initial risk analysis because this rig had never done a plug and permanent abandonment phase before. The uncertainty mostly being around the question whether this task will be done more times or fewer times during the plug and abandonment operation? In other words, would the exposure be higher, lower or the same as during the drilling phase?

2.2 The review HAZID

After 8 months in plug and abandonment operation, the review of the initial risk analysis was performed. The timing was due to the fact that most of the follow up actions had been completed at this point and the personnel had a few months of experience from P&A operations.

The decision was made to do two sessions this time. One with the drilling contractor to review the initial hazards identified and to quality assure the closure of follow up actions.

The first plenum session the review focused on the drilling personnel and the operational input that could be added after this time in P&A operation. The participation was high and several uncertainties from the initial HAZIDS were answered. The questions regarding frequency and how often an operation was undertaken was answered and added to the risk matrix. Also risks that had been mitigated with permanent solutions for example the news Iron Roughneck on the drill floor that reduced the manual pipe handling for the roughnecks were updated in the risk matrix.

The second session included the service companies and identified the hazards that they were exposed to in regard to: the areas they worked in in the drilling module during the plug and abandonment phase.

This review risk analysis sessions had as mentioned smaller a slightly different group than initially. Present were onshore and offshore management from both drilling contractor and operator, working environment specialist from the operator and workers representative from drilling contractor and operator.

However, this time in the second session the service companies that work in rotation in the drilling module during plug and abandonment were also present. This included the injection operator, wellhead specialist, cementer and mud logger. These positions were not manned in the Ready For Operation (RFO) phase when the initial hazard identifications were performed and, therefore, there was no information from these positions added into the initial hazard identifications. These service companies often work in the same areas as the drilling crew and some tasks they perform together, and some are position specific. Their participation caused new information about their individual tasks to be added to the risk analysis (HAZID) previously done by drilling as well as confirming or correcting the information in the tasks they performed together with drilling personnel.

This was the first time this operator had invited all companies working in the same area to sit in the same risk analysis (HAZID) session together, in order to map out the health, safety and working environment risks of the areas of the rig (drilling module) they work in.

It was also the first time the drilling contractor facilitated as risk analysis that included service companies. Historically only the drilling contractor has performed this risk analysis for working in the drilling module with representation from the operator present.

Previously when the operator has requested risk assessments from the service companies these have been sent over. However, these risk assessments tend to be generic for the position and not rig specific. Often each company will have only a few employees offshore on each rig. Combined with the fact that it is costly to send occupational hygienists offshore on surveys as well as many rigs have very limited bed space. It is often difficult to get helicopter and bed space to send people offshore to do surveys.

Since the drilling part was a review session and most of the hazards had already been identified it became more of a quality assurance session. Making sure that what was in the matrix was correct or if it needed to be changed. For example: do you do this task more or less in plug and abandonment operations?

The service company hazard identification was about identifying all of their risks bearing in mind some of these were similar to drilling where they work together. The others were position specific. The service companies were briefed in the introduction of the drilling hazards identification and how it followed the rig structure. From there the task at hand was identifying the hazards and describing how often (likelihood) and how long (consequence). Then according to the matrix the hazards would be categorized red, yellow and green.

It quickly became evident that they brough a great deal of quality assurance to the risk analysis (HAZID) drilling had just reviewed without them.

It went a lot faster this time. Only two plenary risk analysis sessions were held. One with the drilling contractor and one with the service companies. After the sessions the hazards identification matrix was updated with the new information.

The follow up actions after the review were also this time documented in the operator's document management system. The final action is that before the plug and abandonment campaign will commence after the Covid-19 stop a new version of the booklet of the simplified risk analysis (HAZID) matrix will be prepared and will include the service companies. This new matrix will be sent offshore, and an updated presentation will be made in the departure meetings held before the personnel travel offshore.

Boredekksarbeider

Aktivitet	Ergonomi	Kjemikalier hud	Kjemikalier innånding	Støy	Vibrasjon	Mitigerende aksjoner
Tripping	Sitter stort sett i bu, utfordrende statisk. Operere mudbucket	Mud, gjengefett	Mud, gjengefett	Område + impuls (smell fra rør)		M: Internopplæring T: RNX og I-dav ,Hvitdress ved mye søl, hørselsvern, kjemikaliehansker O:Jobbrotasjon. Kommunikasjon
Trekke casing/tubing	Håndtere manuelle slips, protectorskruing			Område		T:RNX, slips med dogcollar, floor monkey O:Sjekkliste LRA
Kutte/sage tubing	Håndtering/oppspenning av kutteverktøy					T: Noroil kutter tugger, bruk av elevator, O:Sjekkliste LRA
Drifte pipe						O: 2 om jobben, fortrinnsvis vaska og dopa rør på land.
Vedlikehold på boredekk (inkl. boretårn).	Tungt utstyr, trangt, ridebelte, utfordrende arb.stilling:knestående, liggende, over skulderhøyde	Mud, oljer, grease, varm hydraulikkolje	Mud, oljer, grease, varm hydraulikkolje	Område + muttertrekker		T:J-gun, arbeidsplattform, ridebelte, isolert utstyr, høydeverktøy, O:sjekklister
Demontere kontrolliner		Div. kjemikalier i kontrolliner		Område + Slegge på klemmer		O: måling for LRA når man trekker ut, jobbrotasjon (3+3), 2 per gang
Boredekk BHA håndtering	Tunge løft, manuell håndtering, protectorskruing	Mye mud ut		Slegge, spinner tang		O:Avviksmatrise manuell rørhåndtering. NOG 081, revidert.

Figure 11 Example of simplified review HAZID matrix, with revisions in red.

The evaluation of this new method of using the template drilling already had been using for years with general area risks already mapped out and then revising it with the information from the service companies and the synergies that came from that is the focus of this study.

This study took place about 5 months after the last plenum session was held.

3 Theory

The theoretical foundation that this study is built on is twofold.

3.1 Risk theory

The first research question is: **was the hazard identification method an effective method to identify the hazards in health, safety and working environment in a plug and abandonment operation?**

To answer this the theory used here is risk analysis theory. The hazard identification method is one of the many tools available in risk analysis. To put risk analysis into context, the risk management theory needs to be described since the risk analysis is a part of the larger process of risk management. This section of chapter 3 is based on Aven, Røed and Wiencke's book "Risk Analysis" (2017), Aven's article "Identification of safety and security critical systems and activities" (2009), Veland and Aven's article "Risk communication in the light of different risk perspectives" (2012) and another Master written about risk analysis in the oil and gas industry by Robert J. Wikstrand (2013).

3.1.1 What is risk?

There are several definitions of what risk is. One of the most used contains a relation between the consequence and likelihood:

The Norwegian standard (NS 5814) define risk this. ***"An expression for the combination of the possibility/likelihood for and the consequence of an unwanted incident"*** (Standard Norge 2008).

In this definition, risk is represented by an unwanted or negative outcome like an accident (A) or unwanted incident (UI). On the other hand: what if someone takes a risk and it pays off? For example, a financial investment can either result in loss or gain. This is an important perspective when discussing risk and instead of using the word "unwanted incident" the option of using just the word "incident" covers both negative and positive outcomes. However, in the "hazard identification" term is only focused on the negative outcome since a hazard is a negative term.

Risk describes the possibility for an unwanted incident (A) occurring and the consequences of this that could take place. In other words, it is talking about the future and that makes it uncertain if it is going to take place and what will be the outcome. The only way to describe it is to make a prediction (Aven 2017).

Including the probability and uncertainty dimension is part of the core of the risk assessment tradition and a risk analyst may consider this statement obvious. However, there are different traditions and ways of thinking (paradigms) concerning this issue (Veland 2012).

As mentioned above in the Norwegian standard (NS 5814), a definition of risk often used is: what is the likelihood/possibility (P) of this happening in relation to what would be the consequences (C) if it happened = risk (A), often written this way C, P. Another version used is consequence multiplied with likelihood = risk (A), often written like this C x P = A

This equation C x P = A requires that the consequence and likelihood is converted into numbers and requires that there is enough historical data or knowledge (K) to base this prediction on. If you do not know how often it happens or what is the likelihood of it happening or if the consequences could vary from time to time, this equation would be very uncertain (U).

Therefore, in the use of C x P = A there is a limited expression for what risk is. It is important to know how uncertain (U) the predictions are and how strong the knowledge base (K) for the input into the risk analysis is.

Another definition of risk that describes risk (A) but also incorporates both consequences (C) and uncertainties (U) could be written in this way A, C, U (Aven 2017).

What are the examples of some of the uncertainties that can affect the outcome of the risk?

Another source of uncertainty could be ambiguity. Meaning that information given is interpreted differently base on background knowledge or complexity. Perceptions of what risks are is not the same for everyone, depending on one important factor – knowledge (K). A risk analysist professional would use empirical data to strengthen the knowledge base. Lay people on the other hand may see this in a different way and the risk analysist needs to be aware of this when adding information that is brought to the analysis (Brun et. al. 2009). How strong or weak the knowledge is needs to be described in order to know how reliable the understanding of risk is.

Risk perception of the lay people are shaped by beliefs and conceptions of individuals and groups (Veland 2012).

Along with the strength of the background knowledge, the uncertainties this causes also needs to be described. One source of uncertainty could be the lack of available information. If the knowledge is weak and is not mitigated by actions to gather more knowledge this will determine how uncertain or strong the result or conclusion of the analysis is. This is an important awareness and the analyst needs to first describe the definition of risk that is at the base of the analysis. The secondly describe the strength of the background knowledge and the uncertainty (U) factors for the analysis (Aven 2017). Another source of uncertainty could be the lack of available information.

3.1.2 Different risk problems and the timing of the analysis

When looking at different types of risk problems it is important to be aware that these need to be addressed differently and illustrate the areas where the uncertainty is affecting the risk (A).

Linear or simplistic risk problems are where there is a low complexity and a very clear linear connection between cause and effect. Natural disasters or car accidents are examples of these kind of risk problems. Simplistic does not mean that the consequences are simple or that they can have large negative effect. However, due to the clear linear connection between cause and effect these risks can be predicted with high degree of accuracy. If a certain curve on the road is approached with a certain speed, then a, b or c will happen.

Complexity on the other hand makes it difficult to identify and quantify the connection between a host of potential causes and concrete consequences of these. Some of what makes it difficult to “pin-point” the accurate cause is the synergy between the many complex factors or that the time span between cause and effect is long or there are complicating factors on the path from cause to effect. An example of complex risk problems could be complicated infrastructures affecting sensitive ecological systems. Complex systems are not necessarily unpredictable but the number of components, their relationships and sequences are too large to be simply assessed (Wikstrand 2013).

The timing of when the risk analysis is undertaken is also important to consider and the right analysis tool needs to be chosen with timing in mind. Is the analysis done for early phase, middle phase or late phase of a project or an operation? If it is taking place so early in a project or operation when there is very little detailed information, it is recommended to use a simpler structure. As more details emerge more detailed analysis can then be undertaken. However, the balance with what support is this analysis supposed to give the decision maker always needs to be assessed (Aven 2017). A risk analysis is done early in a project phase where the uncertainties might be large and the historical knowledge weak but the opportunity to affect the risk picture with technical solutions that can significantly reduce the risk are also much greater than if you are in a late phase and the project or operation is almost over.

Lack of available information, and the uncertainty that this adds to a risk problem, contributes to the difficulty that comes with predicting incidents when the reference data is lacking and incomplete databases or surveys that make it difficult to say something about the cause and effect. Either the expert knowledge is vague or going in different directions or the context has changed. Uncertainty could also occur if attempts to simplify it are not done correctly. This can result in disagreement among the experts about the risk categorization. Examples on risk problems with high uncertainty are many natural disasters for example earthquakes or effects of environmental pollution on humans or the effect of large oil spills on marine life. The uncertainty in these examples can be what is called known “unknowns”. We know what we don’t know in other words. Meaning we know that marine life is affected by oil spill, but we do not know how or to what degree. Another uncertainty is an “unknown” this is the type where we don’t know the unknown “unknowns”. In these cases uncertainties show up in highly novel settings where there is little historical data available and there is little to base the predictions on. It is difficult to bring it in under likelihood because you don’t know that it could happen (Brun 2011).

Probability or likelihood is a way of expressing uncertainty, or another way of describing how likely is it that this incident will occur (Aven 2017).

Is it defined by the people in the group doing the analysis based on experience or background knowledge or is it an objective illustration of the data and the knowledge available? The understanding of this would have the ability to affect the decision - making process (Aven 2015).

One way of describing probability is “frequency base probability”. In this case you will illustrate the probability of the incident (A) happening as a fraction of times the (A) happens if the situation was repeated a hypothetical number of times under identical circumstances (Veland 2012).

An example of frequency base probability is the dice example as there is a given number of outcomes that have and equal probability of occurring if you roll the dices an infinite number of times and give the dices are not weighed. With the numbers 1-6 there are only a given number 6 different outcomes and the probability of each different one is 1/6. Illustrated like this P(A) = Number of positive results/ number of results (Aven 2017).

However, in a practical setting there are very few situations that are this straight forward with a limited number of outcomes and equal probability of this occurring. This is a hypothetical answer because it would be impossible to recreate the situation identically enough times to complete the experiment. A computer model could simulate the experiment however and this is how the probability value occur.

Another way of describing probability is subjective probability: this is based on adjudicated knowledge-based probability. In an incident (A) where the likelihood (P) is A/K where A is the incident and K is knowledge. This is a subjective view on future incidents and consequences seen through the eyes of the ones who make the assessment and is based on the background information and knowledge. An illustration of expressing the uncertainty is if the probability for an unwanted incident happening is said to be 10 %. This is equal to pulling a specific ball, by chance out of a jar with only 10 balls (Veland 2012).

Therefor it is important to remember that the probability only describes the risk as high or low. The predictions of probability take into consideration the knowledge base these numbers are based on. This knowledge can be weak or strong which will then relate to the strength of the probability (Aven 2017).

3.1.3 Risk management

Risk management includes all the actions and activities that are put in place to manage risk. Risk management balances the conflict between on the one hand exploring possibilities involving risk and avoiding accidents and unwanted incidents on the other (Aven 2017).

In order to put risk analysis in a context, it is important to see risk analysis as part of risk management, see model below:

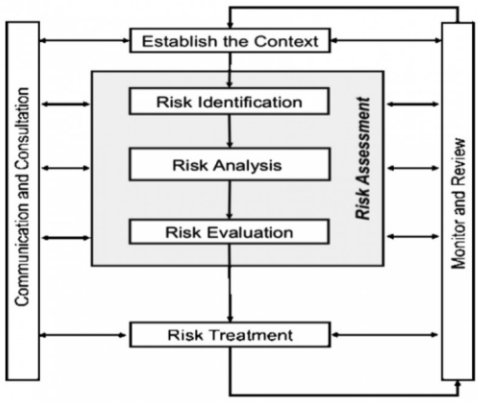

Figure 12 Risk management model based on ISO 9001.

In this model the steps of the risk process are described: The first step is to establish the context or plan. If the risk and its context is clearly established and planned well this sets the rest of the process for a better chance of managing the risk well. The second step is the assessment. This consist of the identification of the risks, the analysis process and the evaluation. When this is done the risk treatment phase is the last step where it is decided what to do with the risk (Aven 2017). On each the side of the model there are arrows to communication on one side and to monitoring and review on the other. In order to manage risk well these are significant and tools to keep the risk management updated and valid. If it is not reviewed with update input, it risks becoming absolute or outdated.

Risk management considers operational, financial and strategic risk. These different areas are where the consequence of the risk would affect the company. In operational risk it would affect the operations, the running of the operation could be hindered by accidents or fire. Financial risk would be for example a drop in the oil price or other financial risks that could affect the company. Strategic risk is when the consequence of the risk is that the long-term plans of the company are affected. Examples could be change in regulations or company mergers etc. (Aven 2017).

3.1.4 Risk analysis

Risk analysis tools are used when decision makers have come to the point in the risk management process where they have identified a problem involving risk. However, they need more information to base their decisions on. The goal of a risk analysis is to identify the risks and describe it in a risk illustration or risk picture.

Due to the different paradigms and traditions within risk analysis, it is essential before using a risk analysis tool that the definition of risk is clear. Then the foundation for the analysis is properly communicated to the decision makers that will use the risk analysis in their decision making (Aven 2017).

One frequently used method of illustrating the risk picture is a bow-tie diagram where the causes are on the left side and the consequence on the right and the unwanted incidents (UI) in the middle. If there are there barriers that can prevent the incident from happening or can reduce the consequences, these can also be illustrated in the bow-tie diagram. The intention is to give the decision maker an overview of the risk problem they are facing (Aven 2017).

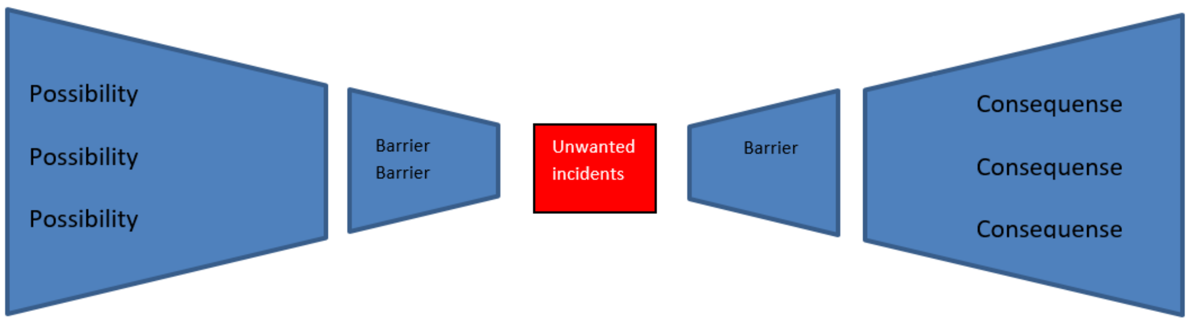

Figure 13 Model of Bow - tie diagram.

What the risk analysis process provides is support to the decision maker. The analysis is not the answer to the risk problem in itself. It needs to be put into the context of decision making that considers other aspects other than just the risk (Aven 2017).

3.1.4.1 The Risk Analysis process

It starts with **the planning phase fig 13**. Starting with clearly defining the problem that needs to be answered. Along with this comes research on the topics at hand. Collecting relevant information and organizing the analysis.

Another important part of the planning is choosing the analytical method. Historically most analyses have been done manually. However, today a multitude of software is available to aid in the process. Whatever tool is chosen it is significant that the user knows what definition of risk the tool/software uses as well as what output the software actually gives.

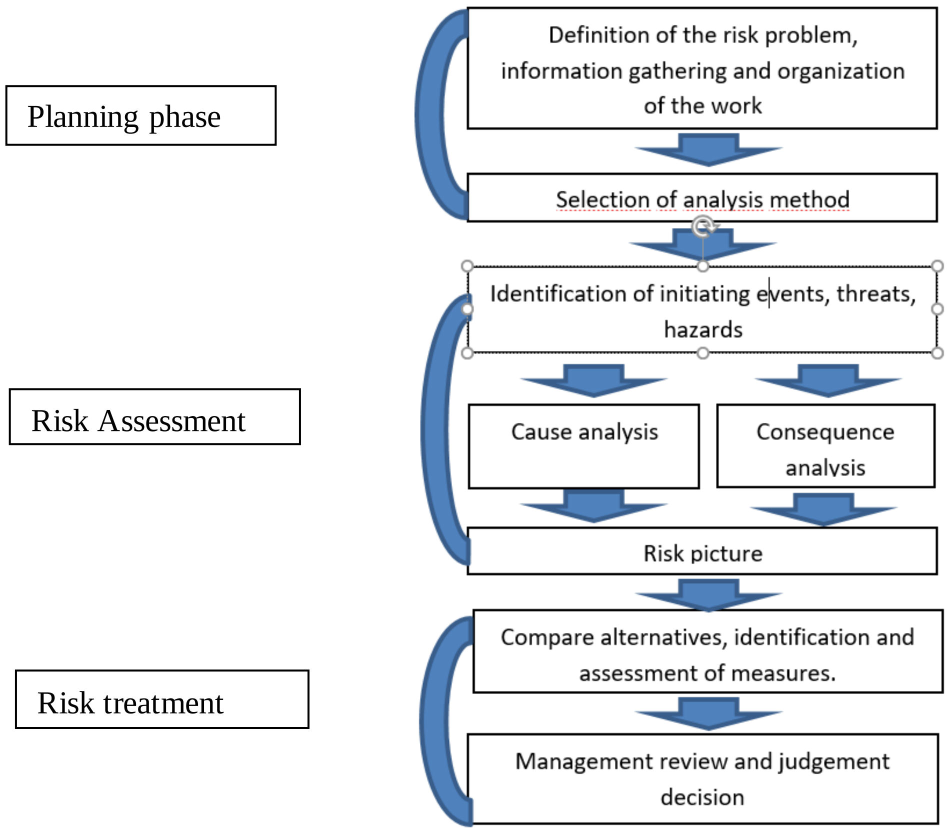

Figure 14 Risk analysis model reference.

Risk problems need a multi discipline group of experts in order to combine knowledge and even further minimize the uncertainties (Aven 2017).

3.1.4.2 Risk Assessment phase

The **second part** of the risk analysis process is called the **risk assessment** phase. The first task is to identify the unwanted incident. This is often done in group sessions where involved parties are present. Who is present depends on the risk the group is analyzing; experts on the subject matter at hand e.g. terror, could be residents in an area that the risk assessment is covering making them stakeholders or management of the company doing the job involving risk, representatives for the employers and risks experts. The composition of the group is key for the result of the analysis. If the group is too large, it makes it difficult to facilitate everyone and keep track of input. If the group is too small you might miss an important stakeholder that could bring information to the table that could change the outcome of the analysis. An example of this being the case of moving the new NOKAS location where the initial risk assessment was disregarded after not considering important stakeholders (Aven 2017).

Through the analysis of the causes and consequences, the assessment phase ends up in the risk picture.

There are 3 types of risk analysis models.

1) **Simplified analysis:** no use of a formalized tool, risk presented as great, medium and small.
2) **Standard analysis:** Hazard identification (HAZID), Hazard operability analysis (HAZOP), Failure Modes and Effect Analysis (FMECA).
3) **Model analysis:** Fault tree analysis or Event tree analysis

It is important to use the right tool for the right analysis. Faced with complex situations where there are many variables and possible outcomes a risk analysis can help compare different alternatives and possible solutions (Aven 2017).

This part of this section is based on the book “Risk Assessment” by Marvin Rausand 2011.

Preliminary hazard analysis or (PHA) is a semi-quantitative analysis and one example of a PHA is a hazards identification analysis (Rausand 2011).

The purpose of a hazard identification analysis is to:

identify hazards that might led to an accident,

rank the identified hazards according to their severity, identify required mitigating action and follow up action,

Since accidents are mainly caused by release of energy. The goal of the hazards identification is to identify where this energy might be released and what unwanted incidents or accidents it may result in (Rausand 2011).

Part 1: To establish the hazard identification team it requires an experienced facilitator that is familiar with the method and can create an environment that includes and encourages participation. At the same time having the discipline to pull sometimes large groups through long exhausting sessions without letting discussion and distract the progress of the hazard identification.

The complexity of the system as well as the objective of the analysis determine how many people should participate (Rausand 2011).

In this first part one also needs to define and describe the area that is to be analyzed. Here the focus is to divide the area for the hazard identification into smaller sections and identify boundaries to the areas that are not to be included.

It is usual to use a checklist or matrix in order to identify the different areas where hazards need to be identified. Checklists that are used to get a complete survey as possible in order not to forget or leave something (Rausand 2011).

The hazard identification is done in plenum sessions where a multi - disciplined group of people with experience on the subject matter, stakeholders, experts and risk assessment expertise note down the hazards or risks. The leader of the risk analysis needs to be someone who is familiar with the hazard identification method (Rausand 2011). The person taking notes or filling in the matrix needs to also be acquainted with the matrix ahead of time.

The key factor in this phase is structure and a systematic approach so that the unwanted incidents can be identified, with their causes and consequences. The main point is that the hazards can be systematically approached often by the use of lead words (Aven 2017).

An analysis matrix covering the different categories of the hazard identification as well as the analysis of the likelihood and the consequences if the incidents were to occur, gives a useful overview. The incident should be defined in a way that makes the accuracy of describing the consequences higher. In regard to likelihood, words like often and rare should be avoided, it is better to use a number like 15 % chance that this could occur during a year (Aven 2017).

Part 2 *Is where the hazards are analyzed. To determine the risk we have to estimate the frequency and the severity of each hazard* (Rausand 2011).

The analysis matrix covering the different categories of the hazard identification as well as the analysis of the likelihood and the consequences if the incidents were to occur gives a useful overview.

The severity of an indecent can be categorized as: catastrophic, critical, major and minor.

As the frequency is assessed it is important to consider what category consequence is being considered. In some cases, a worst-case scenario is to be considered, in other cases it is a daily operation that is to be considered (Rausand 2011).

Part 3: As the risk analysis is expressed as the result of the combination of the likelihood (P) and consequence (C) of an incident comes out and concludes in a risk picture. This picture is what is needing to be conveyed to the decision makers. If the analysis has been straight forward and all the questions has been answered in regard to the likely hazards that could occur. The risk picture can be clear. In other case when there is a lot of uncertainty and many questions are left unanswered. The background knowledge could also we weak. The Risk picture could come out with rather unclear. Another example is significant stakeholders have been left out as in the planning of the new NOKAS location. The risk analysis had to be performed again because the first one did not meet the objective and gave to weak a foundation to make a decision (Aven 2017).

There are many ways to portray a risk picture. One of the most frequently used ones is a 5 x 5 matrix (fig 14).

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Frequency/ consequence	1 Very unlikely	2 Remote	3 Occasional	4 Probable	5 Frequent
Catastrophic					
Critical					
Major					
Minor					

Figure 15 Risk matrix (Rausand 2011).

Level	Name	Description
H	High	High risk, not acceptable. Further analysis should be performed to give a better estimate of the risk. If this analysis still shows unacceptable or medium risk redesign or other changes should be introduced to reduce the criticality.
M	Medium	The risk may be acceptable, but redesign or other changes should be considered if reasonably practical. Further analysis should be performed to give a better estimate of the risk. When assessing the need of remedial actions, the number of events of this risk level should be taken into account.
L	Low	The risk is low and further risk reducing measures are not required.

Figure 16 Example from Norsk Hydro 2002, (Rausand 2011).

The matrix indicates required action risks that ends up in the red area in regard to likelihood and consequence; these need mitigation action. If the risk ends up in yellow one needs to consider if mitigation is needed. If the risk ends up in green the risk is acceptable and in most cases no action is needed (fig 15).

3.1.4.3 Risk treatment

Risk **treatment** is the last phase of the risk analysis process. This is when the analyses are over and the risk analysist has presented the risk picture to the decision - makers.

1. In the first phase of the risk treatment phase is the decision-makers consider alternatives and make comparisons.
2. In the second phase the management decide on what solution they will choose of the risk problem that was the starting point for the risk analysis.

After a risk analysis has been performed the decision-maker have several options.

1) Avoid risk. If the risk comes out as unacceptable the choice of cancelling the project or operation that is in consideration.
2) Reduce the risk. The decision-makers can put in place mitigation actions or barriers in order to reduce the consequence or likelihood of the unwanted incident. Can require increased use of resources.
3) Accept the risk. It has been reviewed by the decision-makers and they have concluded that this risk is something they are willing to take.
4) Transfer the risk. Share it with others. One example of this is insurance where the insurance company shares in the risk.

5) Increase knowledge and research. This will reduce the uncertainties and can also reduce the risk. Simulation can also predict outcomes.

Part of risk management is making decisions that involves high risk and large uncertainties. This makes it difficult to predict the consequences of the decisions (Aven 2017).

Aven lists what goes into these decision-making processes are:

1) Decisions-making situation and Stakeholders interests:
   What is the problem?

   What are the alternatives?

   What is the framework conditions?

   Who is making the decision?

   What is the strategy being used to make the decision?

2) Goals, preferences

   What does the different parties want?

   How to weight pros and cons?

   How to express and survey the benefits of the different alternatives?

3) Use of different tools, including different forms of analysis
   Risk analysis
   Cost - benefit analysis
   Cost - efficiency analysis

4) Review of assessments by the decision-maker (Aven 2017)

In order to make decision where there are uncertainties Aven referrers to this model when:

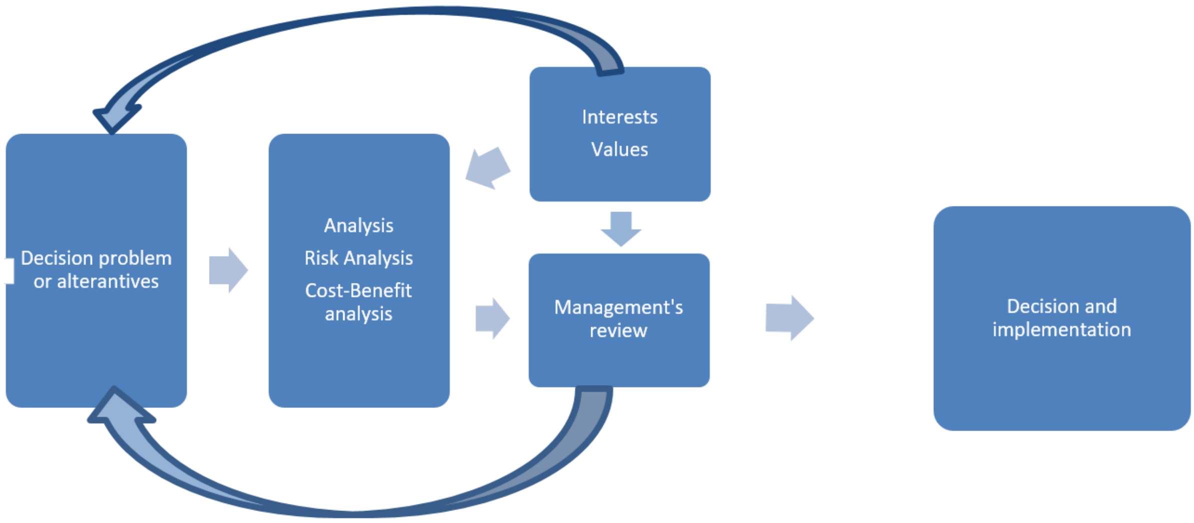

Figure 17 Decision making under uncertainty (Aven 2017).

Among other things that affects the management's decision making than the Risk analysis that has taken place are:

Cost- efficiency analysis are based on the estimated price of a statistic life or a statistic set unit. This index value of a statistic life can be used to calculate the price of development of for example medicines. If the statistic value a barrel of oil, the cost efficiency of how many barrels an oil spill on a certain size cost etc. (Aven 2017).

Cost - benefit analysis is often used in making decisions. In this type of analysis all risk needs to be transformed into cost or sums. The expected cost can be predicted using a formula and in regard to this method mitigating actions needs to be implemented if the expected net present value is positive (Aven 2017).

This can sometimes be difficult if there is no index value in a certain industry for a certain risk it can sometimes be troublesome and transform the risk into sums or cost (Aven 2017).

Values interest or Risk acceptance criteria:

There are also predetermined risk acceptance criteria that give the decision-makers guidance after the analysis has been completed and they have to consider if they need to put in place mitigation actions or if the risk is acceptable. One example of such criteria is the ALAPR principle (As Low As Reasonably Practicable).

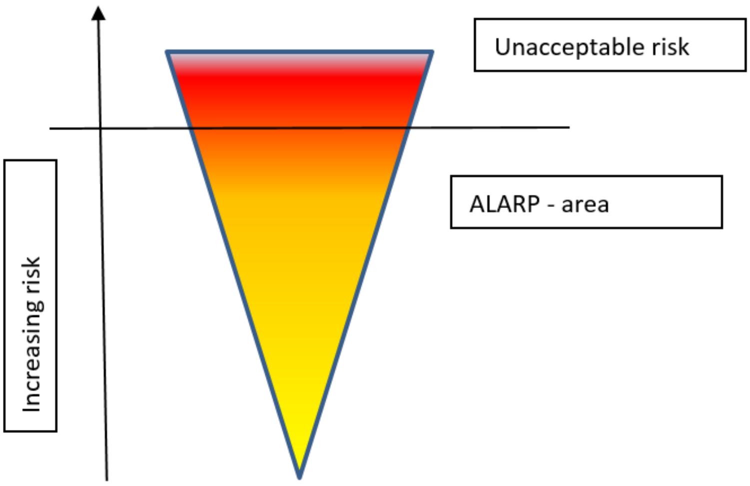

Figure 18 Model of ALARP principle

In this model the risk acceptable if it is below the horizontal line.

The ALARP principle considers advantage of implementing action in relation to the disadvantage or the cost of implementing the action. ALARP contains a "reversed evidence" which means that unless there is a "gross disproportion" between the cost/benefit and the benefits should be put in place. The advantages of ALAPR principle is that it can be used in regard to people, environment and finance. The ALARP principle is introduced in the Norwegian oil and gas Framework regulations as a requirement for the industry (Framework regulations §9 2002).

Mitigating or risk reducing actions. As hazards or risks have been identified one of the terms often used is "mitigating actions". Mitigating actions are actions that will reduce or remove the risk to an acceptable lever. Depending on which side of the bow tie they are put in place. Are they likelihood reducing actions like taking down the consequence? In order to decide what actions to choose it is significant to see what actions will have the most impact on the risk (Aven 2017).

3.2 Part 2 legislation and regulations

For the second research question:

How can the drilling risk analysis method contribute to:

a) **The operator of the "main company" being in compliance with current regulations in their quest for identifying rig specific health, safety and working environment risks?**
b) **The service companies being in compliance to current regulations in their quest for getting an overview of rig specific health and safety risks?**

The theory that will be presented is the Norwegian working and environmental law described in the Internal control regulations. Then the oil and gas sector's own regulations. Finally, the assessment done by the government and the oil and gas industry in 2016 - 2017 in order to get a status on the health and safety and predict the direction the industry was heading.

3.2.1 The Norwegian working environmental law

The Norwegian working environmental law is built on a mutual "tripartite cooperation". Meaning that the relationship between employers, employees and government is truly mutual. This is a significant aspect because it requires trust from all 3 parties that everyone has the best interest of the other parties in mind. If the employees do not trust that their employer will work to provide them with the best working environment possible or the employer thinks regulations are too strict and safety regulations slows down operations the temptation might be to take shortcuts.

The Internal control regulation clearly states that it is the employer's responsibility to have an overview of all health, safety and working environment activities.

The managing director is responsible for the efficient functioning of health, environmental and safety activities (Internal-control-regulations 2005).

It also defines how often it should be reviewed:

A thorough assessment and review should be undertaken once a year at a meeting of the managing director, the safety delegates and a representative of the safety and health personnel (enterprise health service) (Internal-control-regulations 2005).

It also defines what in occupational hazards or risk analysis language should be identified as an unwanted event or incident:

"Identifying health, environmental and safety problems ranges all the way from investigating employees' wellbeing and teamwork to investigating physical conditions" (Internal-control-regulations, 2005).

Another phrase that is repeated throughout the internal control regulations is **continuous improvement**. This means that health, safety and environment conditions should not remain as they were but should continuously improve.

3.2.2 Oil and gas specific regulations

The Petroleum Act holds the overall requirements for the Norwegian oil and gas specific regulations. The Act addresses 3 parties. The license owners, the operators and the contractors. There are high requirements in the law that the industry shall maintain the highest level of safety and this level shall also be developed in tune with the development of technology (Ministry of Petroleum and Energy 1996). In accordance with the working environmental Act the employer is responsible for the health, safety and working environment in their company. However, the Operator and the license holder are added an extra responsibility to follow up anyone who works for them according to the health safety and working environment regulations. This responsibility is called "see too" regulations (Petroleum's Act §10-6 and Framework regulations §7).

Under the Petroleum Act there are many regulations, however, there are a few red threads that weave through them for example the tripartite cooperation and the responsibility of the operator or the responsible party.

Figure 19 Example of regulations links on the PSA website (PTIL.no)

However, when it comes to working environment the employer's responsibility is stated as: Activity regulations chapter VIII §33:

"***The employer shall reduce unfortunate workloads and risks of injury and accidents based on conducted analyses, mapping and gathered information on the employees' own experience of work-related risk and workload conditions***".

In section 44 it is pointed out the role of the employees and their workers representatives right to be made aware of risk information, and risk analysis related to their work as well as their own role to obtain health, safety and working environment information.

Activity regulations chapter VIII § 44:

It shall be ensured that the employees are provided with information on health risk and the risk of accidents during the work to be performed. The results of assessments, analyses, measurements, mappings of causes of work-related illnesses, investigations of work accidents and near-accidents, and the importance of these results for work execution, shall be available. The employees and their representatives shall familiarize themselves with this information.

3.2.3 Historical development in Norwegian oil and gas regulations

The Norwegian petroleum's health, safety and working environment regulations are mainly based on functional principles and on internal control. Giving the individual company the responsibility to make sure they are in compliance with regulations and to review quality management systems. This responsibility also includes risk management, risk analysis process and establishing risk accept criteria (Ministry of Labour and Social Affairs, 2017).

Depending on the different roles a company can have on different fields e.g. can be a partner on one and an operator on another, the responsibility to the authorities will also be different.

The Norwegian regulations for the oil and gas industry have developed and progressed in response to severe accidents nationally and internationally that have brought about changes (figure 18).

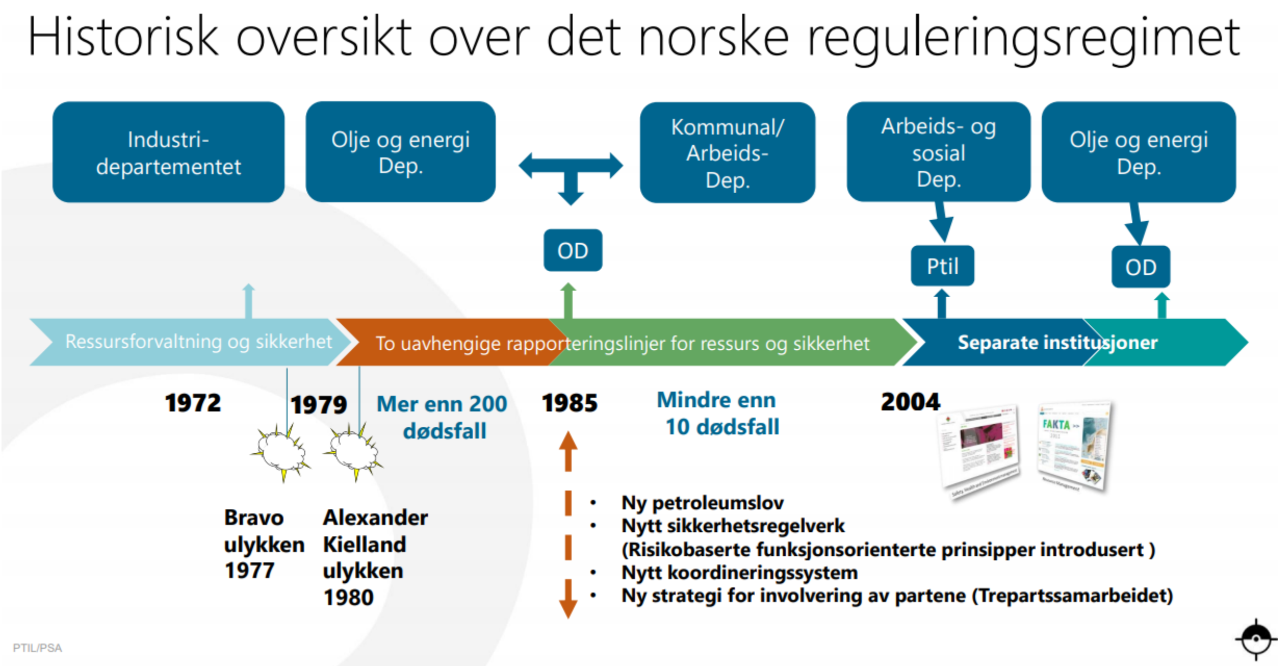

Figure 20 Historical overview of the Norwegian oil and gas regulations, PTIL 2019.

The working environment act was the basis for establishment for the national industry regulations for the oil and gas industry. This ensured that the offshore employees were regulated to the same level as employees in other industries (PTIL 2017).

The oil and gas regulations have moved from being detailed regulations about construction and technical requirements to become a “functional requirements”. Placing the responsibility for compliance revision and internal control on the companies. Giving the companies the opportunity to manage details. This also changes the auditing of the industry from being very detailed focused to be more goal oriented and focused on holding the companies responsible (Ministry of Labour and Social Affairs 2017). The move to a regulation based on functional requirement was to avoid the micromanagement from the authorities and give the companies the opportunity to come up with their own solutions. Facilitation for a level of flexibility within the regulations in choice of method and approach as well as for technology development (Ministry of Labour and Social Affairs 2017). Within this framework the parties can challenge each other and the authorities on how the regulations should be interpreted.

As well as the regulations that are legally binding there are several guidelines within specific areas of the oil and gas industry. These are not legally binding but guidelines that describes acceptable standards. One example is American Petroleum Institute (API) or Norsk sokkels konkurranse posisjon (NOROSK) (Ministry of Labour and Social Affairs 2017) (figure 19).

Kategori	**Hovedgruppe**	**Eksempler**
Rettslig bindene normer	Lover	Petroleumsloven, Arbeidsmiljøloven
	Forskrifter	Rammeforskriften (Kongelig res.) Spesifikke forskrifter (Petroleumstilsynet m.fl.): -Styringsforskriften -Aktivitetsforskriften -Innretningsforskriften -Andre forskrifter
Ikke-rettslig bindene normer	-Veiledning -Ulovfestede virkemidler -Faglige notat	-Veiledning og fortolkning til forskrifter -Henvisning, likelydende brev, kampanjer, offentliggjøring etc.
	Industrinormer (Standarder og prosedyrer)	NORSOK-standarder – Anerkjente industristandarder, ISO, CEN, IMO, API, DNV-GL, etc. -Virksomhetenes egne krav, prosedyrer og retningslinjer -Prosjektspesifikke krav, prosedyrer og retningslinjer

Figure 21 Oil and gas industry regulations, Ministry of Labour and Social Affairs 2017.

4 Method:

4.1 Qualitative Method:

The method chosen to answer these research questions is a qualitative method. The study is based on feedback from a selected group of participants. They represent the different disciplines that were involved in the hazard identification process.

The target group for this study were representatives from the last hazard identification plenary session. There were representatives from the 6 different companies that were present. The goal was to get a response from as broad a group as possible. In regard to, age the variation was from the twenties to the oldest in their sixties. Both male and female responders are represented and the whole “tripartite cooperation” with management, workers as well as the workers representatives.

Qualitative methodology also meant the research questions will not be yes or no questions but rather questions that will bring more reflective answers. The goal of the evaluation was to ask questions that would improve this process and method if it was to be done again.

4.2 The drilling hazard identification method

In the questions asked of the participants in the survey the phrase “the working environment hazard identification (HAZID)” referrers in this study to the plenum sessions described in chapter 2.1 and 2.2.

4.3 Survey Method

At the start of the study the plan was to do live interviews with the individuals in the participating group. However, as the Covid-19 (coronavirus pandemic) arrived it shut down the country just as the data collection was due to start. The questions were, therefor, sent to the group via e-mail (fig 20).

Hei,

I oktober 2019 var du med på en operasjonell hazid av arbeidsmiljø i P&A operasjonen på
Dette var en revisjon av en systematisk operasjonell hazid utført før oppstart.

Jeg utfører nå en studie for å evaluere om det å utvide en operasjonell hazid for boring, til å inkludere serviceselskaper som jobber i samme områder, er en god og kvalitativ måte å fange opp HMS eksponering på? I den forbindelse ber jeg om din tilbakemelding. Kan du være så vennlig å svare på spørsmålene under?

Ingen navn vil bli nevnt, men studien er en del av en masteroppgave på UIS, slik at de overordnede funnene vil være en del av master oppgaven.

1) Hva har fungert bra ved denne arbeidsmiljø haziden som er gjort under P&A operasjonen på

2) Hva har ikke fungert/ kan blir bedre ved denne arbeidsmiljø haziden?

3) Har din arbeidshverdag blitt påvirket som et resultat av arbeidsmiljø haziden? Hvordan?

4) Har du sett direkte resultater av arbeidsmiljø haziden ute på riggen (eventuelt andre områder en dine)?

5) Dersom du skulle vært med i en annen operasjonell arbeidsmiljø hazid, hva burde vært gjort annerledes?

Figure 22 Questions asked of the participants in the survey.

The replies came back via email as well. They were then organized and analyzed and will be presented in the next chapter. Twelve people were present at the review hazard identification plenary session and 50 % of them answered the interview e-mail.

4.4 Quality of the method

The interviewer or surveyor has a dual role as the one who lead the two plenum sessions for the review hazard identification and the one doing the survey. It is important to be aware of this as it can affect a study in regard to objectivity and is, therefore, important that it is considered during the progress of the study.

Another important part of the method is that it is deductive, meaning you already have a thesis and use theory and empirical evidence to prove this premise. As if the interviewer has an idea of what the answer will be but asks the questions anyway.

Anonymity is another factor when the group is small. The informants were briefed in the interview email that their answers would be part of a study but there would be no names attached to their answers. The answers will also be grouped in three, Management, Specialist (Health, safety and working environment specialists) and Workers.

Because this study was only being done on one operation there are many factors that may be rig or operator specific. It is also important to consider the possibility for subjectivity since the one who lead the review sessions also undertook this survey.

On the objective side the feedback data that was returned from the interviews, were given without any interviewer influence. In an interview there is the possibility that the person being interviewed could have been made nervous or stressed. Since this was a written response without influence from an interviewer one can say that the quality of the data was strong and the quality of the study, therefore, good. The fact that it was done a few months after the session itself gives room for improvements. Ideally it could have been done at the end of the plenum session. However, because it was done that long after they really had to sit down and focus; if it was done right after it could have been rushed.

5 Results

In this section of the study the findings or answers the informants gave will be presented in the same order the questions were asked. For the sake of anonymity of the participants in the study, the replies will be categorized in 3 groups: Management, Health, Safety and working environment specialist (HSE specialists) and Workers and workers representatives.

1) **What worked well during the working health and safety HAZID that was done during the plug and abandonment operation at this rig?**

The Management all stated that this risk analysis had worked well. Examples of was mentioned was good representation from all disciplines. As well as a good mix of people with experience from the rig and new people that came with a “fresh” set of eyes to bring up important issues.

One leader mentioned that it was an essential for involvement from the workers was seeing the operator’s commitment in taking health, safety and working environment seriously from the beginning. Adding that these risk analysis sessions were also an opportunity for the management to demonstrate their commitment to implement improvements to improve health and safety.

Another aspect that was addressed from the management was the facilitator’s ability to keep the discussions on track as well as creating a relaxed atmosphere.

The continuous references to regulations and standards in the matrix was clarifying and was another example of what went well. As was as the way the follow up actions carried over to the management control system which was mentioned as a plus.

The health, safety and specialists mentioned that what had worked well from their perspective was that it created a shared understanding of the hazards for the health, safety and working environment, for the groups working in the same areas.

The Workers and their representatives were all also positive in their feedback and had a similar feedback to the Specialist. They noted that the gathering of personnel from different companies, that work in the same area gave many good inputs. Stating that “it has become clearer for all parties working in the different areas what assistance they can get in order to make their workday simpler". Another mentioned that important questions were raised and answered.

2) What did not work well or could be done better with this health and safety HAZID?

Most of the management participants mentioned that the HAZID was good. However, one management representative said: "in general the HAZID were good but should have included service companies from the initial HAZID".

One of the health, safety and working environment specialists mentioned that it would have been better if every company present would have had the same level of preparation.

The majority of workers and their representatives had no comments here, but one person mentioned that "more time could have been given to the service companies".

3) Has your workday been affected by this health and safety HAZID? If so how?

The management all addressed how the HAZID created a lot of work for them. "Was handed many health and safety issues after these HAZID". The addressed how many follow up cations were solved before start-up as well as some were ongoing when the plug and abandonment started. Due to the involvement in the HAZID, the input from one leader was that "it made it easy when things came up". Another comment was "The thorough HAZID and the actions followed up afterwards has built a good foundation for the continuous health and safety work afterwards".

One leader listed how the HAZID had contributed in a good way to the implementation of many smaller and larger health and safety improvements some could be mentioned like:

- *Purchase and implementation of new Iron roughneck with remote doping of pipe, module for changing sub as well as separate casing module.*
- *Purchase of improved lifting equipment*
- *New signs in the drilling module*
- *Improved working environment in drilling offices.*
- *Remodeling and improvement of breakroom.*
- *New pump unit for emptying of BOP and Risers.*
- *Improved equipment for access to connect kill and choke hoses*
- *New access work platform to BOP*
- *New unit for washing pipe below drill floor*
- *Better lights on drill floor*
- *New CCTV installed*

The health, safety and working environment specialists addressed how the HAZID had improved the follow up of actions and better dialogue with the service companies.

Focus from all the workers was on having the right personal protective equipment. This had improved both with the operator and contractors. Some mentioned that ergonomic survey had been undertaken, others mentioned masks with filter units, that were placed in their areas in case exposure to dangerous things should occur.

4) Have you seen direct results of this HAZID on the rig, maybe in other areas than you work in?

All participants from the management answered that dedicated and engaged crews was a direct result. One mentioned the technical improvements as the new pipe handling machine RNX, density flowmeter and improved mechanical workshop.

Another from the management mentioned that the crews are still engaged and keep on giving continuous feedback from offshore in suggested improvements. “Maybe that comes from seeing things being improved when addressed”.

The workers and their representatives have noticed “that personnel have become more concerned with complying with improvement actions that they have been made aware of”. Everybody that had been involved with these HAZID have been very happy with being included in this and the actions that have been implemented.

5) **If you were to be part in another operational HAZID, what should be done differently next time?**

One of management representatives again mentioned the involvement of the service companies from the start. That this should be compulsory and maybe could from the beginning have been more firmly led making sure all kinds of input came forth. “Maybe some of the participants were introverted and might feel inferior to more eloquent senior personnel?”

The health safety and working environment specialists mentioned again: **“**Better preparation”.

From the workers one of them mentioned that “the participants” could have been emailed the matrix ahead of time so they knew what they were going to be addressing and could prepare ahead of time”. Another suggested “If anything, to bring everyone to the table earlier in order to implement these improvements earlier in the operation”.

6 Discussion

6.1 Was the HAZID method effective

6.1.1 Effective as in fast?

The first research question asked: **was the hazard identification method an effective method to identify the hazards in health, safety and working environment in a plug and abandonment operation?**

The answers given by the participants in the study to the first question are interesting in more ways than one.

> The management found that the mix of people in the plenum sessions and the fresh set of eyes brought important information.

Rausand refers to this as putting together the team. If this is done well it adds important information to the hazards identification (Rausand 2011). However, Veland brings to attention that lay people have a different risk perception than risk specialists (Veland 2012). Therefor in this large group where there are many different disciplines it is important that the whole team understands the hazards as being sources of energy and what the consequence of the release of these would cause. In order for them to give the same output about like likelihood (Rausand 2011). As well it was made clear from the start that is was likelihood and consequence in daily operation that was the common base, not worst-case scenario (Rausand 2011).

> The HAZID format was a good way for them as leaders to convey to the other participants their commitment to health and safety improvements.

In regard to the fact that the framework regulations VIII § 33 puts the responsibility of “seeing too” the compliance of the health, safety and working environment regulations on the operator. It seems as this was a good arena for the operator to convey not only the responsibility but also the commitment to this to the drilling contractor and the service companies.

> The specialists found it beneficial in order to introduce the health and safety status of the rig to all involved parties.

The fact that many of the operator's operational and technical management as well as drilling contractor's management participated in the initial and the review HAZID. Caused them to already be literate about the status if the health safety and working environment hazards in the drilling module. Therefor if something happened in regard to health, safety or working environment, the management already was aware of the potential challenges and it made the work of convincing them of the problem was non existing due to the fact that they already knew the risk picture.

> The workers found the HAZID format helpful in the way that they got to hear input that came from their colleagues that are working in the same areas as them during the plenum sessions.

The fact that someone from the service companies who works in the same area as the drilling personnel, identifies other hazards than the ones who have been working there the whole time. Was the greatest synergy that came from inviting the service companies. Suggested team size is 2-6 members in the team depending on the complexity and the object of the HAZID (Rausand 2011). In these plenum sessions there were 12-20 people. The fact that the whole drilling module was to be covered requires participants with operational experience from the whole are. As well as the objective being adding the service companies to cover more area of the drilling module.

What was not expected, was as the hazards identification progressed through the drilling module. The areas where the service companies work alongside the drilling contractor, they gave new input and added hazards that had not been identified initially. As Rausand describes the first reason to identify all potential hazards (2011). It became clear that this was not fully done. Therefor they became a quality assurance to the hazard identification process. In regard to putting together the team Rausand addresses how impotent it is to consider what "What is the system dependent upon of inputs (2011). As this experience proved the quality of hazard identification input improved with including the service companies.

In regard to the word effective used in question one if that were to mean fast? The answer to the question, would be no. The initial HAZID required 6 whole day sessions to cover the drilling facility. This is a cost that many operators will not take in a day and age where the oil price is low. It makes it even more impressive that this was performed for a plug and abandonment operation that was scheduled to last two years. If it is done for a 25year field extension the investment, spread out over this timespan the cost would look very different. However, looking at the review HAZID was only two session and gathered higher quality information. If there already is a solid foundation such reviews can be effective.

6.1.2 Effective as in served its objective?

In other words, if effective means served its purpose or did the job?

The specialist's statement that it gave a common understanding of the health and safety challenges is a yes to the question of effectiveness in this context. One of the challenges as required in §44 of the activity regulations is to convey findings of completed surveys and facts of the subject to the employers or stakeholders. Making them aware of the exposure their employees are surrounded by. Another challenge is making the management aware of facts around the health and safety surveys while they often just want brief summaries and the conclusion. From the specialist's answer it sounds like this format served both these purposes.

In regard to the risk analysis theory was this method effective?

Since the formula consequence multiplied with likelihood understanding of risk was used in this risk analysis it might seem that this could be a very limited understanding of risk since a C x P = A does not illustrate uncertainties (U) or knowledge (K).

However, the comment field in the matrix actions were noted as uncertainty or knowledge gaps were identified. In this way documenting where the new surveys needed to be undertaken or operations needed to be verified when plug and abandonment operations had started. This is the very issue with a C x P = A risk matrix as mentioned it does not illustrate where the uncertainties (U) are or where the background knowledge (K) is weak (Aven 2017). Nevertheless, as the uncertainties were documented and the need for more information was put in to follow up actions they were still captured and followed up in the management control system. As part of the follow up actions one of them was to do a review of the whole hazard identification matrix and analysis after some time in plugging operations according to Framework regulation which prescribe describes that if there are any changes new risk assessments need to take place. Also, in line with Aven's model for decision-making under uncertainty. As the process keeps lines going from the management review back the original risk problem. If there are more data that needs to be gathered in order to answer the risk problem, then another process or further analysis needs to be undertaken (Aven 2017).

Another question along these lines raised in the risk analysis theory is the use of a 5 x 5 risk matrix, with probability values in each square. Does this add value to the risk analysis? Does adding 5 times to the likelihood or consequence, illustrate the hazard more accurately?

The same effect could most likely have been illustrated just with other colours and the words high, medium and low (Aven 2017).

Expected consequences	high			
	medium			
	low			
		low	medium	high
		Likelihood		

Fig 23 3 x 3 Risk Matrix (Aven 2017).

The advantages with this graphic illustration is that it quickly shows what risks need immediate attention. A disadvantage with the C x P matrix is that it does not illustrate the knowledge (K) or uncertainties (U) behind the color. Is the background knowledge strong or are the uncertainties large? It gives only a number and a color and does not illustrate what lies behind the conclusion? There are ways of bringing these into a matrix but very often a standard C x P = A is the preferred result and risk picture communicated to management due to its clear presentation format.

Despite the regulation Framework regulation VIII §44 putting the responsibility on the individual company the operator in his responsibility as the main company, along with the drilling contractor invited the service companies to the table. To be part of a multi - company hazard identification. In that way also sharing health, safety and working environment survey information as well as knowledge. This made the data input into the hazard identification much more reliable as well as the quality for the results was improved as well.

However, the process if it has to be done from scratch is labour intensive and the question is if other operators are willing to invest this kind of resources?

Another option that would be less labour intensive would be to just do the last review and include service companies in that. All operating drilling facilities already have a basic working environment HAZID, in theory this option could work. However, it would require that operator helps facilitate and brings all stakeholders to the table and that the facilitators are familiar with the method (Rausand 2011)

In regard to the question if the HAZIDS identified all the health, safety and working environment hazards? (Rausand 2011) The management brought the list of issues that are improved and the list of technical equipment which was long but not linked to the exposures it was improving or the action point it mitigated. From the management point of view the long list of follow up actions that the HAZIDS brought to the table was evident. In that regard the risk analysis gave them an overview of the size or scope of their health and safety challenges in the drilling module.

Looking at the Risk management process where the analysis is followed by the risk evaluation and risk handling. A common theme throughout the review responses that came back was that there were things that should have been done earlier. Service companies should have been involved earlier; actions should have been closed earlier. Even though the HAZID format was effective in giving the overview of the health and safety challenges for the plug and abandonment the rest of the risk management process had room for improvement.

As far as categorizing the hazards in the HAZID in red, yellow and green also gives them an impression of the seriousness of the challenge. According to Rausand this is the second reason why the HAZID analysis is performed (2011). Theory discusses if this is a good way to classify risks. In certain instances, a risk that at the time of the HAZID was green can over time or due to changes fall into a yellow or red category or the other way around. It is therefore imperative that HAZID are not a static risk assessment tool but that it is reviewed on a regular basis in line with also the Internal regulations requirements of review (Internal control regulations 1996).

In this HAZID the only the risks that were red and yellow were presented to the crews. One could argue that as a weakness knowing that risks can change overtime and some risks that are green today could become yellow or red in a year or two. In this case in order to keep from overloading them with information the green risks were taken out. That will then require that health and safety specialists to monitor green risks as well and the possibility of risk status changing.

6.1.3 Effective in aiding decision making?

Since the actions were followed up in the management control system, there was good documentation accompanying the risk analysis model going into the risk action phase. This is according to Rausand the third purpose why hazard identifications are held (2011).

This is where the initial hazard identification has a huge advantage. Since so many decision makers had been part of the process. What is a bottle neck in many risk analysis processes is where a complicated analysis needs to be presented to very busy decision makers? In this case this job was done live during the process. Therefore, when it came to follow-up actions, they were very concrete because the understanding of the risk problem was clear, and the risk picture was clear. Probably also the reason why there were 138 follow-up actions. It could have been another possible stumbling block to keep track of these, however, it was all documented in the management control system and though it took some time all the actions were followed up.

However, in this transition from risk analysis to risk management. Where the risk analysis is presented to the decision makers and they must decide what to do, there is another factor that is just as important to the ongoing operation and that when they are going to do it. This is where a suggestion of a timeline could be helpful improvement.

The management has the choice of accepting the risk, mitigating the risk or ignoring the risk. This could have been a very helpful tool after a hazard had been identified both for operations and health, safety and working environment specialists. As they continue to follow up hazards that were identified, this would have been even more vital if the scope of the operation is longer than 2 years operation of permanent plug and abandonment.

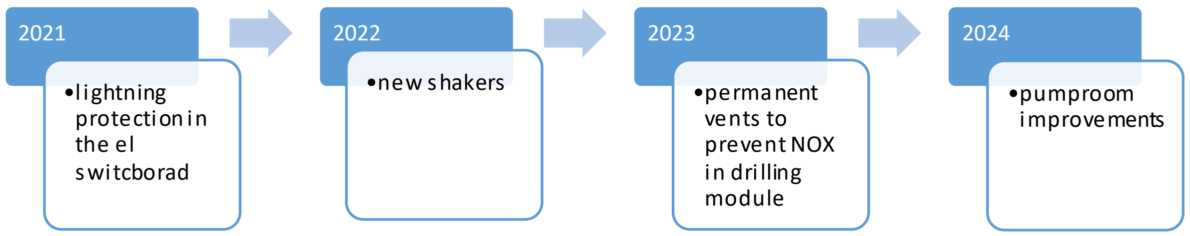

Figure 24 Suggested timeline to run parallel with risk to the follow up action plan for actions that will not be followed up immediately.

If there was such a timeline created after the hazards had been identified and analysed and given a category, this timeline could be useful in the planning and implementation of improvements and mitigating actions. This could have been used by health, safety and working environment specialist in knowing how to put in place mitigating actions until improvement was completed. It could have been communicated to authorities as a plan for continuous improvement and it would help the workers in the operation to keep motivated while they wait and continue to report improvements and not despair that anything will happen. There is, however, one big challenge with this and that is that the risk analysis is not the decision, it is support for the decision maker. They must consider all factors of the risks identified not only the health, safety and working environment risk. Therefor such a timeline would be more appropriate along the risk management process not the risk analysis process.

The health, safety and working environment specialist mentioned in the feedback that the HAZID plenum format had made dialogue and follow up of actions easier. This falls in line with the previously mentioned understanding that such a high number of people had been involved in the hazards identification and therefor had an extensive knowledge of the condition of the drilling module and where the hazards lie.

This significantly improved the level of risk communication. The knowledge gap that often occur between the specialists and the lay people (Veland 2012) in this case was narrowed. The HSE specialists got a broader understanding of the health, safety and environmental conditions of the drilling module and the operations personnel understood that the HSE specialists had solutions that could improve the working environment. Another benefit the risk communication improved was the way the workers "had the ear" of the HSE specialist and the management in the hazard identification plenum sessions as they shared. They understood that this was the time to come with their suggestions for improvement.

The workers mention exposures. Several of them mentioned masks that have been stationed in their work area. Others mentioned ergonomic surveys being undertaken, another mentioned noise as an area that had been focused on.

In regard to the HAZID format actually giving direct results one of known factors is that group sessions can provide ownership also part of the though behind stakeholder principle ISO 9001 2015 rev. This was evident in this study as well. The ones that had been involved in the analysis had a great ownership. Therefore, it was also unique that so many of from the management (decision makers) were involved in the analysis. This is rare and can be part of the reason why so many resources were dedicated to this process in this case.

In the risk management process, the analysis is the foundation for decision making. It made an easy case for presenting the findings of the analysis when the decision makers had been part of the process. Since the ALARP principle also is already the foundation for the industry Framework regulations it was also helpful the follow up actions were written together with the management upon seeing the risk picture that came out of the hazard identification.

They were also able to track the follow up of actions and any development of health, safety and working environment surveys. When top management has such a detailed knowledge of the operations and health, safety and working environment hazards it is likely to conclude that is a great benefit for the employers. The tripartite and bipartite cooperation has worked in this case in being truly mutual.

6.1.4 Challenges with this method, the operational drilling HAZID

If this risk analysis had taken place in a lager operator where the distance is further to the decision-makers, the consequences might have been a slower decision-making process.

The two first questions asked of the informants were what questions? What went well and what did not go well? In order to create an even deeper reflection in the answers given, these could also have been followed by a why question. What went well in this workshop and why? However, some of the informants have answered why even if it was not asked. This is one of the challenges in written interviews, there is little place for follow up questions.

In hindsight it is clear that this question 3 could very well have asked specifically for health, safety and working environment improvements. In order to connect the technical improvements to their health and safety origin.

Question 4 asked if they have seen changes on the rig? The answers points back to the risk analysis process. As the theory describes the significance of having important stakeholders as part of the process (Aven 2017).

One of the unanimous outcomes of this study in everyone’s opinion was that service companies should have been part of the initial HAZIDS, or at least included much earlier in the process. As important stakeholders in the drilling module they brought valuable input that should have been included in a much earlier stage. When one then considers that it is not customary to include them at all it is an improvement to include them. Upon seeing what an asset they where it will be a significant improvement to get their input earlier. Since this was an exceptional HAZID where the representatives participated and were highly committed, this impression could have been very different if the initial HAZIDS would have been a failure. It could have been a failure? If there had been little participation or wrong inputs were given.

When asked in the plenary session if they, the service companies had ever been part of anything like this? The answer was unanimous no, and this was also the reason for research question 2.

Another real challenge with any risk analysis tool used to describe working environment is that it is a static tool describing a dynamic reality. The working environment offshore changes during operations as described in this study. However, it is also affected by temperature, wind, humidity etc. What an occupational hygienist measures in the few days they are offshore is snap - shot of the whole operation. There is technology used today to detect dangerous explosive gas several places on the rig but most of them are there to prevent explosions not to detect exposure for personnel.

Why was this health, safety and working environment effective?

Key people:

1) The selection of the right team though it was over the suggested size it was the right size for the objective.

2) The facilitator and person taking notes prepared well in order to let the discussion flow. In many cases people remember things after one area has been assessed. In order to go back and add the correct information in the right place it is significant that the facilitators and notetakers knows the matrix well.

3) It is important to note no matter how well qualified participants in plenum session are it is most likely that not all hazards will be identified. Therefor revisions are important in order to quality assure the content.

6.2 Can the method serve the operator and the service companies?

How can drilling's HAZID plenum method used in this study aid the contractor's "see to duty" towards the service companies in their quest for continuous monitoring of health and safety risks?

6.2.1 Pioneering

Based on the feedback during the HAZID with the service companies. It became apparent that the participants that have worked in the industry for many years, from both operators, drilling contractors as well as service companies. Has never been part of a health, safety and working environment risk assessment of the drilling module that included operator, drilling contractor and service companies before. It became clear that was taking place was groundbreaking.

However, due to its labor-intensive format, it is not very likely that others will copy this format but as stated earlier there are simpler formats and a host of software available to make this job less labor intensive.

The essential factor is that the people facilitating the risk analysis know the tool they are using and the information they get out of it is part of a larger process of risk management process.

In the follow up actions there were also a synergy that came out of the initial HAZIDS were the need for completing more HSE surveys. In this cooperation the drilling contractor and the operator ended up sharing the survey responsibility and including service companies that worked in the same area. Due to the difficulty in getting bed space offshore the specialist that got space performed survey actions of for operator lamination survey and cement dust survey for drilling contractor and service company personnel. In regard to contract responsibility of the lights fall under the operator but the personnel exposure fall under the company they are employed in. However, with the cooperation and the operator that facilitated, a new and much more efficient way of doing surveys were used and this what the functional regulations opens up for (Framework regulations).

As the review HAZID was performed there was a high level of ownership and outstanding participation. This certainly is not always the case when a group session HAZID is performed. As this was a small operator many of the participants knew each other and the service companies had selected some outstanding participants as earlier mentioned. They were passionate about their working environment and came prepared.

6.2.2 Challenges with making this work elsewhere?

It is an important fact that the quality of the input (Rausand 2011) decides the quality of the analysis. If the group is not engaged or the plenary sessions are very unstructured it makes the long sessions ineffective. As Aven points out the structure of risk analysis and the step of identifying the unwanted incidents, sets the direction for the progress (Aven 2017).

The fact that this study evaluates the HAZIDs and the fact that the first initial HAZIDs were incredibly structured set up the review part for a great start and when the service companies came with their excellent engagement, it made it easy facilitating the review. As previously mentioned, this could very well have gone the other way, if the initial HAZID was a mess and the huge number of participants in the review did not participate.

This is one of the weaknesses of this HAZID format and is why it might not produce a quality analysis each time. If the plenum session goes poorly and the participation is low it might not accomplish the first purpose of risk analysis and identify all health, safety and working environment risks (Rausand 2011).

Another weakness of this research is that objectivity to both the reviewer and the informants can be challenged. The interviewer knows the informants well due to the size of the company and close working relations. Since the feedback was overwhelmingly positive it is important to highlight that this could also be partly because of the working relationships. Maybe a more neutral feedback would have been given to an unfamiliar interviewer? As well as the feedback being from a small group, and only one operator.

This would be an interesting study to carry out with other operators. Since all the drilling rigs already have a similar operational HAZID. Then review HAZIDS with operator could be conducted to include service companies to see if the feedback is similar or very different.

Another review HAZID using the drilling contractor hazard identification method described in this study will be performed the fall of 2020 with another large operator and on another field.

However, this study will be submitted first and then the review will be carried out later so the results from that is not part of this study.

What became clear during this process is that there is a need for a continuous information flow from contractors and the operator not a onetime health, safety and working environment survey and risk analysis.

As well as a desire for involvement in an ongoing working environment improvement process from the service companies.

6.3 Summary

The main finding in this study was how the drilling contractor and their tools can be a useful bridge in aiding the operator and the service companies in identifying health, safety and working environment hazards and then be in compliance to framework and current regulations. The service companies and drilling often work shoulder to shoulder either on the drill floor, in the pump room or on the wellhead. In this regard much of the risk assessment is already done now and only the gathering and compiling of the information is what is left. And the continuous follow-up and monitoring of the operations and changing working environment exposure.

What also became clear was that within the current regulations there is room for the operator, drilling operator and service companies, by helping each other, to get to do thorough identifications of health, safety and working environment. However, this requires that the operator initiates and facilitates such cooperation as well as opening up for the sharing of working environment surveys and resources.

As the working environment field develops both in stronger knowledge and even better maybe live monitoring the working environment on the Norwegian continental shelf will continue to improve.

This is an urgent matter. The Petroleum Safety Authorities just last month published a study on the cancer hazards diesel fumes represent for offshore personnel (PTIL 2020). It is an urgent matter for technology to invent gas sensors that pick up these hazards. Today different sensors pick up different things and as mentioned earlier the sensors that pick up explosive gasses with potential for large catastrophes are not the same that pick up the fumes that causes cancer of the lungs.

As the PSA asked the question in 2017 is plug and abandonment a working environment challenge (PTIL 2017). As this study has shown the hazards can be identified and mitigated to a certain level but that only with respect to the knowledge we have today. After the current risk analysis was done the study on engine fumes was published (PTIL 2020). That is not addressed in this risk analysis. And there are many diesel fumes sources on old rigs that will have plug and abandonment campaigns in the coming years.

Therefor the hazards identifications done in connection with the permanent plug and abandonment phase on this rig were effective and served the objective of identifying the known hazards at the time it was undertaken.

However, it is a static tool used in a dynamic operation and therefor as we know and learn of new hazards a hazard identification is a tool that works as an indicator for health, safety and working environment but this needs live monitoring with new technology that someone needs to invent so that in the not too distant future. This was an offshore worker can click on a sensor when he goes to work that will continually register his noise exposure, many types of gas exposure and give an indicator when he is over exposed. Utopic says occupational hygienists however we need to keep on improving.

The installations also needs to have monitors and sensors of the same caliber that indicates on the pipe deck today and with this wind and humidity the exposure for turbine exhaust is too high to work there.

7 Conclusion

The conclusion is that the drilling contractor's HAZID method can be effective if:

1) The HAZID teams is right meaning that the right people are participating with the right skillset and the willingness to participate.

2) The planning and the structure of the plenum sessions encourages progress and participation.

3) The uncertainties and possible weak background knowledge are followed up in actions after the plenum sessions in such a way that the definition of risk also includes uncertainties.

4) The risk picture is clearly communicated and understood.

In this study it was an effective method and answered the risk questions.

Can the drilling contractor 's HAZID be the bridge between the operator and the service companies?

Yes, with structure and a willing operator that will facilitate and invite the different parties to collaborate. Today's functional regulations accommodate for such cooperation.

There are however challenges facing health, safety and working environment that needs to be addressed. There is also an urgent need for further in research and inventions that will further the knowledge of what today are unknowns.

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