Concept selection of normally unmanned installations in the North Sea

- A risk based model for concept selection of normally unmanned installations in the North Sea

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Summary

Title:	Concept selection of normally unmanned installations in the North Sea - A risk based model for concept selection of normally unmanned installations in the North Sea
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Problem statement:	Should a normally unmanned installation rely on helicopter shuttling to allow for the people working there to be accommodated at another platform during the resting periods with regards to the potential loss of life (PLL)? Would the risk the personnel are exposed to increase or decrease if the need for helicopter shuttling was eliminated due to a different design allowing for periodic manning of the installation?
Purpose:	The purpose of this study is to develop a coarse framework, a model, for risk-based concept selection of normally unmanned installations (NUI) in the North Sea by comparison of PLL. The results of the model will be used to indicate, with regards to PLL, whether a NUI should be designed to allow for periodical manning instead of relying on helicopter shuttling to an accommodation platform during.
Method:	The model is constructed through the use of historical data. The risk contribution due to helicopter flights is estimated by failure data from offshore helicopter flights in the North Sea. The risk contribution due to the crew being present on the platform is estimated through data used in QRAs for various North Sea installations. The model is based on a generic area distribution where each area has a FAR value which in turn is based on representative area-FAR values for installations in the North Sea. To use the model, inputs such as manning distributions, flight times and required work load is required.

Conclusions: The model can be used to qualitatively indicate which of the two alternatives will subject a generic crew to the lowest level of PLL. There needs to be an evaluation coupled with the results though, with regards to how the limitations of the model might have affected the results. There is room for improvements in the model, which if implemented could improve the reliability of the model and accuracy of its results.

Keywords: Concept selection, normally unmanned offshore installations, North Sea, area-FAR, helicopter shuttle risk, risk-based model

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Lund, Sweden, October, 2012
Richard Forss

Table of Contents

1 Abbreviations

Abbreviation	Description
AP	Accommodation Platform
CCR	Central Control Room
CFIT	Controlled Flight Into Terrain
FAR	Fatal Accident Rate
FEED	Front-End Engineering Design
FPSO	Floating Production, Storage and Offloading
HIPPS	High Integrity Pressure Protection System
HVAC	Heating, Venting and Air Conditioning
I/A	Incident/Accident
IR	Individual Risk
LDP	Landing Decision Point
LER	Local Electrical Room
LQ	Living Quarters
MAC	Mid-Air Collision
NUI	Normally Unmanned Installation
OGP	International Association of Oil & Gas Producers
PLL	Potential Loss of Life
PMI	Periodically Manned Installation
PSA	Petroleum Safety Authority (Norwegian)
QRA	Quantitative Risk Analysis
TDP	Take-off Decision Point
TLP	Tension Leg Platform
TO/L	Take-off/Landing

2 Definitions

Term	Description
Area-FAR	The area-FAR is the expected number of fatalities per 100 million exposed hours in a physically bounded area /2/
FAR	The FAR value expresses the number of fatalities per 100 million exposed hours for a defined group of personnel. The FAR is often used as a risk parameter. Several variants are used, mainly reflecting how the averaging of the risk level is done /2/
FAR for an entire installation	The FAR value for an entire installation is the number of expected fatalities per 100 million exposed hours for one or several specified installations. The risk level is averaged over all positions onboard /2/
IR	Risk an individual is exposed to during a defined period of time /2/
PLL	The PLL is a statistically expected nr of fatalities within a specified population during a specified period of time /2/

3 Introduction

3.1 Introduction

Today, oil is produced in almost every part of the world, from small offshore wells to water depths of 2000 meters. For offshore oil production, depending on the size and water depth, a whole range of different structures are used. Some of the common offshore structures are described below and can be seen in Figure 3-1:

- Shallow water complex

A shallow water complex is a network of several fixed platforms connected through gangways. The different platforms have different functions such as the Wellhead platform, the Accommodations platform and the Power Generation platform and so on. A shallow water complex is, as revealed by its name, useful in water depths not greater than 100 meters.

- Gravity base

The gravity base, as opposed to the shallow water complex, is one huge fixed platform that contains all functions needed, e.g. production, accommodation. The top-side structure rests on a fixed foundation of concrete which in turn rests on the sea bottom and is held in place by gravity. The concrete foundation is cast onshore and towed out to be placed at its assigned location which could be up to a couple of hundred meters in water depth. The way this is possible is through air filled storage cells in the concrete structure that helps to keep it afloat. Once these cells have been emptied, in order to place the structure, they can be used to store the oil instead.

- Compliant tower

Compliant towers are similar to the previously described fixed platforms but for its base which consists of a slender tower fixed on the seabed. The main difference of this base is its flexibility which allows for far greater resistance against the pressure the wind and waves exert on the structure. This in turn makes this type of oil platform a viable option for up to 1000 meters of water depth.

- Floating production, storing and offloading (FPSO)

The FPSO is a floating vessel designed to collect oil and natural gas from various platforms and well installations in the area, process them and store them and they can operate in waters 2000 meters deep. A FPSO can be specifically built for this purpose, or can be a rebuilt oil tanker or a large barge and they are a great advantage in regions that do not have an existing pipeline network set up.

- Tension leg platform (TLP)

The TLP is another floating structure; however, it is moored to the sea bottom by long steel pipes that not only keep the platform in location, but also provide vertical stability. They can operate in water depths of up to 2000 meters and are also found in a miniature version called a “Sea star platform”.

- Subsea Production System (SPS)

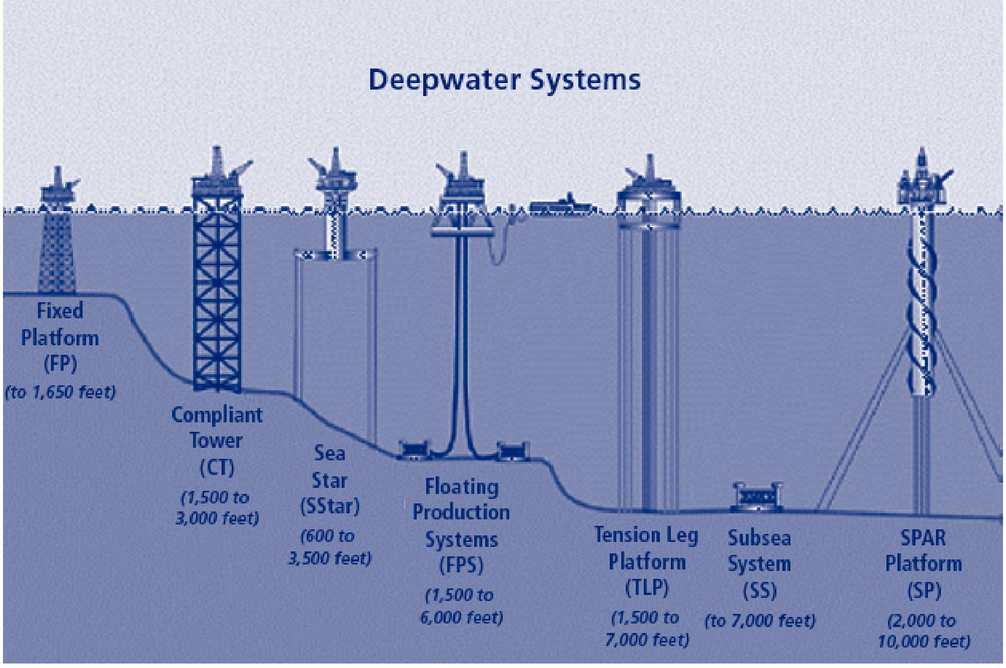
The subsea production system is unique in this context since the structure is placed on the sea bottom instead of at the surface like the previously described units. This structure does not perform any of the drillings or well completions but is dependent on help from a separate rig to perform these tasks. Once in place though, the subsea production system can retrieve hydrocarbons from several wells over a large area through pipelines on the seafloor. It transports the hydrocarbons either to another platform or in some cases directly to an onshore facility depending on the subsea facility’s location and is able to operate in very deep waters.

- SPAR

The SPAR is a floating platform used in waters as deep as 3000 meters. The floating capability is due to the fact that the top side structure sits on top of an enormous floating cylinder, which in turn is tethered to the seabed by several cables. In addition to the floating effect, the cylinder also provides stabilization to the structure even during hurricane conditions.

- Normally unmanned installation (NUI)

The normally unmanned installations are usually smaller shallow water complexes. However, as revealed by their name, they are normally not manned. Instead they are regularly visited by work crews who arrive to perform maintenance work. The NUIs are usually neither as large nor as complex as their manned counterparts.



[1]

Figure 3-1 different kinds of oil platforms and the water depth range in which they are used.

3.1.1 The history

For thousands of years man has used oil for lighting and heating purposes. However, the oil in larger underground reservoirs was still unattainable in those days and consequently the only oil used was found and collected from more accessible sources e.g. tar ponds and seepages from shallow reservoirs. This all changed in 1859 when Edwin Drake drilled a well in the north-western parts of Pennsylvania, USA, with the one purpose of retrieving oil. These early drilled wells were primitive and shallow by today's standards, but they still managed to be quite productive which made overproduction a problem to be considered right from the start.

The automobile industry, which was established in the late 19th century, soon adopted the oil as its fuel. Furthermore the maritime industry saw great advantages in using oil too since oil fueled ships could travel twice as fast as the old coal fired ones, which was found to be a great advantage for the military. The aviation industry did not just gain an advantage through the use of the new fuel but was completely dependent on it since gasoline engines were material in constructing useful aircrafts. With World War II came improved welding techniques, pipe rolling and metallurgical developments

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[1] http://www.google.se/imgres?hl=sv&biw=1920&bih=955&tbm=isch&tbnid=hi-hMiE6Sg1NKM:&imgrefurl=http://www.atp.nist.gov/eao/grc04-863/chapt4.htm&docid=KPpWkDBXI4RsuM&imgurl=http://www.atp.nist.gov/eao/grc04-863/fig8.jpg&w=634&h=425&ei=XMcgUO7pJu3S4QTYxIH4DA&zoom=1&iact=rc&dur=643&sig=102188721247895686148&page=1&tbnh=126&tbnw=188&start=0&ndsp=46&ved=1t:429,r:5,s:0,i:84&tx=92&ty=60

and these in turn brought forth the possibility of long distance pipeline constructions, resulting in natural gas becoming a viable resource. Simultaneously the petrochemical industry started increasing its production to meet the demand for the new plastic materials. Through the steadily increasing demand for oil, alternative sources that previously would have supplied oil at too great a cost are now becoming viable options.

3.1.2 The reservoir

Hydrocarbons, e.g. oil and natural gas, are formed when organic material is exposed to high temperatures and pressures for long periods of time. The organic material can be subjected to these conditions when it gets trapped under layers of rock through a sedimentation process. A hydrocarbon reservoir though, can only be formed if the hydrocarbons have access to some sort of porous rock, e.g. sandstone or limestone, for them to amass in. Also, to stop the hydrocarbons forming in the reservoir from escaping the reservoir has to be enclosed by a non-porous rock layer, e.g. salt, shale, chalk or mud rock. Several parameters, including time, pressure and temperature, dictate what form, e.g. heavy crude, oil or natural gas the bulk of the hydrocarbons will be in. The pressure also helps in retrieving the hydrocarbons since they are forced out of the rock. To further the production even more analyzes are performed both with 3D modeling and seismic data, however typically, more than half of the hydrocarbons are forced to be left in the reservoir.

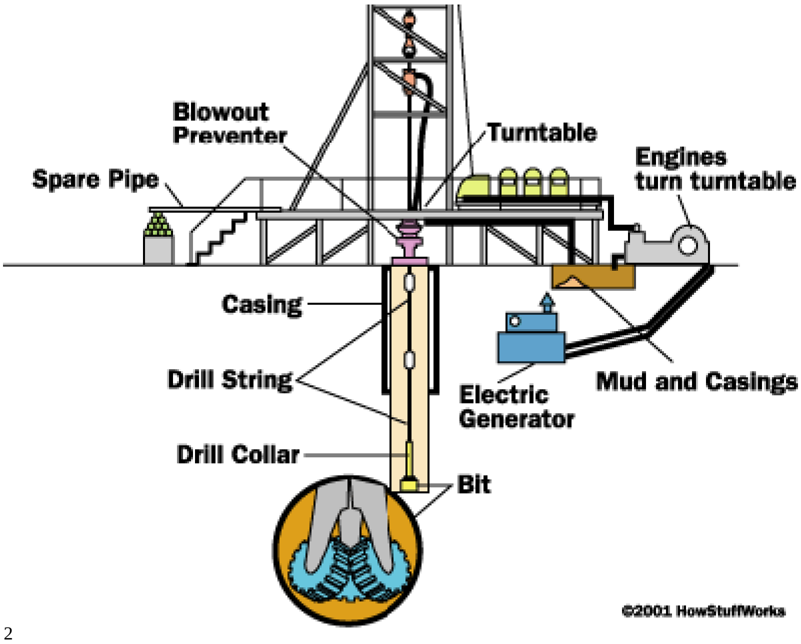
Even though the pressure helps in retrieving the hydrocarbons by forcing them out of the rock, in addition to advanced 3D modeling and access to various seismic data, more than half of the hydrocarbons are typically forced to be left in the reservoir.

3.1.3 The well

When a suitable reservoir is found, the process of retrieving the hydrocarbons begin. A hollowed out drill string, consisting of pipe segments which are continuously added to the drill string to lengthen it as the drilling proceeds, with a drill bit at the end of it is used for this purpose. The drill, which is powered by hydraulic or electric force, utilizes its empty core to pump “drilling mud” down into the well which then returns to the surface outside of the drill string. The purpose of this is to bring rock fragments to the surface as well as to clean, cool and lubricate parts. Another very important function of the mud is to balance the pressure in the hydrocarbon reservoir to prevent a possible blow out. The drill will frequently come across cavities with hidden hydrocarbons that because of the pressure will try to force themselves to the surface. This scenario can create a dangerous situation known as a “blow out”.

After the drilling part is done, the well needs to be stabilized in order to be used. This step includes the installation of well casing, tubing and a wellhead. The casing usually consists of metal tubes cemented in place in order to stop unwanted materials to seep into the well. Tubing is then placed inside the well casing and it’s through the tubing that the hydrocarbons are brought to the surface. The wellhead is an installation placed at the top side opening of the well and its main function is to control the flow of hydrocarbons through the well. The wellhead is also a safety measure, since it is designed to prevent blow outs.

/1/



[2]

Figure 3-2 Schematic picture of drilling in an oil reservoir.

3.1.4 The hydrocarbons

The hydrocarbons in the reservoir are often a mix of crude oil, natural gas and various condensates.

Crude oil can vary considerably both in appearance and composition from clear to black and from watery to almost solid. Its uses vary in the same way and crude oil is found as a main component in fuel for all kinds of vehicles, in asphalt and in lubricants. What types of hydrocarbons make up the crude oil directly affects its usefulness as hydrocarbons with very low or a very high number of carbon atoms will render the oil unsuitable to be used as fuel. However, through processing heavier crude oil in a refinery it is possible to crack and reform the heavier crude oil molecules to reduce the number of carbon atoms, making more of the oil suitable to be used as fuel. /16/

The natural gas found in the reservoirs does not completely consist of methane, as the consumer product, but also consists of other hydrocarbons. It is also fouled by other non-hydrocarbon compounds. Not much processing is done to the natural gas aside from separating the methane from other components. /15/

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[2] http://www.encapgroup.com/drilling/images/oil-drilling-derrick.gif

The condensates are separated from the natural gas in order to purify it. However, these hydrocarbons are useful in their own right. They can be sold separately and the applications range from energy sources to enhancing oil recovery in production wells. /14/

3.2 Background

All offshore production platforms except for subsea installations require manning either periodically or permanently in order to carry out various activities on the installations. The level of manning varies significantly depending on the size and complexity of the platform as well as the reservoir conditions. The manning varies from normally unmanned platforms (NUI) to permanently manned platforms with hundreds of people onboard. Since the helicopter risk is one of the main contributors to the total risk level, the concept selection of the platform plays a vital role in order to achieve as low a risk as practically possible through optimization of the frequency of manning, see section 3.2.1 below for an example.

There is no common practice as of today on concept selection of normally unmanned installations with regards to designing them for overnight stays. The practice varies between different parts of the North Sea, e.g. Danish, English and Norwegian sectors. There are also variations between different operator companies and sometimes even internally within the same operator company.[3]

The data used in this study is collected from facilities on the Norwegian continental shelf. Design and operation of installations on the Norwegian continental shelf must comply with Norwegian laws and regulations according to the Norwegian Petroleum Safety Authority (PSA) /13/.

In the Norwegian regulations there are no exact definitions as to when a platform should be designed as manned or normally unmanned. However, if facilities are designed for overnight stays (periodically manned platforms, PMI) there are additional requirements, compared to a NUI, that will make the platform more expensive to build and normally also to operate. From a strictly economic standpoint a NUI is often a preferred solution.[4] However, as demonstrated in the thesis, helicopter traffic is a major risk driver which often leads to an equivalent facility designed for overnight stays to be a safer option.

3.2.1 Example of a concept selection

To give a clearer picture of the problem statement an example is presented below:

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[3] Communication with Mr. Roy-Atle Simonsen, Senior Safety Consultant at Oilconx Risk Solutions.

[4] Communication with Mr. Roy-Atle Simonsen, Senior Safety Consultant at Oilconx Risk Solutions.

Suppose we have a NUI in the same area as a large, manned, oil platform called an accommodation platform (AP). The maintenance work crew, called crew 1, is for 30 days per year shuttled to the NUI to perform maintenance work for up to twelve hours each of those days and then flown back with the helicopter to the AP. These additional 60 helicopter flights per year will result in an increased risk level for crew 1. The crew is not allowed to stay for more than twelve hours on the platform as it is not designed for them to stay any longer.

Another option would be to design the platform to be a periodically manned installation (PMI), essentially a NUI with a living quarter (LQ). This would present the crew with a designated area for them to spend their resting time in while they were at the platform performing their work. Since this is just an example it is estimated that the work crew, called crew 2, with use of the LQ has to make six trips with each trip lasting five days. These days will be divided into twelve hours of work and twelve hours of resting time, resulting in the same total amount of work for both crew 1 and crew 2. Compared to the other option this one results in fewer helicopter trips (twelve against 60), however this option also comes with an increased risk to crew 2 due to them staying for longer periods of time on the platform. The extra time will be spent in the LQ; however it is not practically possible to design this LQ to reach the same low risk level as of the accommodation area on the AP where crew 1 will spend their resting time. Because of this crew 2 will be subjected to a greater risk level during their resting period than crew 1.

Now the question becomes, which of the two crews will be exposed to the lowest total risk level?

3.3 Purpose

The purpose of this study is to develop a coarse framework, a model, for risk-based concept selection of offshore platforms by comparison of potential loss of life (PLL) for different concepts. In more detail, the model will be based on historical data from the North Sea and use quantitative risk analytical methods to incorporate them in the decision-making process for concept selection of offshore oil platforms.

The results of the model will be used to indicate, with regards to PLL, whether a NUI in the North Sea should be designed as a periodically manned platform, including living quarters, for overnight stays or designed without these facilities and instead rely on helicopter shuttling, see section 3.2.1 for an example of the problem statement.

In chapter 9 the model will be used to estimate the risk between two fictitious concepts. This allows for greater transparency as to the workings of the model, but also as to how its results should be interpreted. However, that specific example is nothing more than an example. This master’s thesis constitutes the construction of the model itself, which can be used to generate the difference in risk between various different concepts of normally unmanned installations in the North Sea.

3.3.1 Potential

For the results of the model to be useful they have to be presented in an early phase of the platform’s development. They have to be recognized early enough to be able to make a difference as to the design. This requirement however, also puts restrictions on the accuracy of the information and data used as a basis for the model. Since not all parameters will be known by the time of utilization of the model the interpretation of the results should reflect this. The results are thereby not meant to give an exact estimate of the actual risk level, but rather be used as a tool for comparison of alternative concepts and give valuable inputs to decision makers regarding how the different concepts rank safety wise, see chapter 9 for an example.

4 Basis of the model

The reason for developing the model is that there is no common practice as of today on concept selection of normally unmanned installations with regards to designing them for overnight stays, see section 3.2. A model will allow for a more efficient process, as opposed to performing a new evaluation each time, since only the input parameters need to be case specific. Hence, a lot of work can be eliminated. It should be noted though, that it is important to make certain that the increase in efficiency does not lead to a decrease in the accuracy of the results.

This model will present a generic way of accomplishing this concept selection based on a scientific foundation built on historical data. Most other decisions made in similar situations are based on standardized methods which, though they may be harder to change, improve the safety of the overall operations. There is no reason why this should not be the case for this type of concept selection. This study naturally does not present a fully operational standardized model through which the concept will be selected. However, as stated before, it presents a generic way of doing it that could be standardized. There is of course room for improvement, see section 10.1.

4.1 Structure of the model

The study will rely on the analysis of data found in various QRAs of offshore oil platforms in the North Sea, particularly unmanned installations in the Norwegian sector. Typically, the QRA addresses the individual risk, potential loss of life, fatal accident rate (FAR) and main contributors to these, e.g. ship collisions, helicopter accidents, impairment of escape routes and structural failures. Since the FAR of the entire installation is an averaged value of the entire platform reflecting the risk of fatalities among the exposed population the uncertainties are quite large. To achieve a better estimate of the risk, the platforms are divided into areas and the FAR values are calculated for the different areas (area-FAR) based on the function of the area. By doing this, different area-FAR values are assigned areas where there are a lot of process equipment and hydrocarbon flows compared to utility areas. Area-FAR values have been presented in all of the studied QRAs. When these area-FAR values are combined with a manning distribution it will give a better estimate of the number of fatalities in comparison to having a FAR value for the entire installation combined with the total number of visiting personnel.

The generic model constructed in this study is based on these area-FAR values. An extensive survey has been performed to extract them from eleven QRAs of offshore oil platforms in the Norwegian sector of the North Sea. The mean value of each area has been used as a generic estimate of the risk level in that part of a generic offshore oil platform, see section 6.1. The manning distribution needed to calculate the expected number of fatalities is used as an input parameter, since this can vary between the types of personnel visiting the platform, e.g. to perform maintenance, wire-line operations, coil tubing operations.

In the same manner, QRAs of accommodation platforms were surveyed to extract information of the area-FAR for the accommodation section of an accommodation platform. The generic value chosen for the model was yet again calculated to be the mean value of those found in the QRAs, see section 6.2.

Some parameters, e.g. flight distance, hours spent on platform for various types of work were found hard to estimate due to either time constraints or too great of a variance in the data to be used as point estimates in a generic model of this sort, see section 8.2. To circumvent this problem, they were instead used as inputs to the model, see section 8.2. The cut-off between parameters chosen as inputs and parameters chosen as generic point estimates were not evaluated beyond the point of availability, time constraints and expected results based on experience. The same reasons apply for the parameters not being subjected to review on whether they could be used as distribution instead of point estimates. With more time the different parameters would have been evaluated and suitably characterized as generically estimated values or as input parameters. This could have been done through statistical review of representative data coupled with sensitivity analyzes to see how the different parameters affected the results. What is also taken into account is how well the parameter is estimated at the time when this model is to be used. For instance, a parameter such as the flight distance, which is certainly known at the point in time when this model might be used, is unsuitable as a generic point estimate since it is known and no benefit would come from not using the true value.

The last part of the construction of the model constituted incorporating the estimated helicopter flight risk. For this estimate to be suitable in a generic context it would have to reflect both the risk contributed by the distance of the flight as well as the number of flights, see chapter 7.

4.2 Reason for the model’s structure

For the model to work in a generic context in accordance with the study’s purpose in section 3.2 and exemplified in section 3.2.1, it has been based on comparable risk levels for the contribution of presence on the installation, presence in the accommodation area of the accommodation platform and the helicopter transports. These three major risk factors are the only ones taken into account since they are the only ones that differ for the different concept alternatives. The other major risk factors are; risk due to transfers on-/offshore, risk due to presence on other platforms and the risk due to transfers to these, risk due to other types of work or risk due to time spent onshore. These are assumed not to differ between the concept alternatives and are hence, not investigated further. In other words, the model only gives a delta risk, not the total risk picture.

4.2.1 Risk due to presence on the NUI

For this risk to be evaluated information with regards to the design of the area, types of equipment and their specifications and so forth would be needed. This information might not be available at the time of the concept selection; hence the choice of using historical data to estimate the risk level. To go into so much detail as to assign risks to certain equipment and model it for different parameters such as number of wells and volumes/types of hydrocarbon flows was not possible due to this information not being available. Instead the risk levels were estimated and used in the form of area-FAR values for other platforms, see section 4.1. These were found in the specific QRAs that were developed for each of the platforms.

4.2.2 Risk due to rest on the AP

See section 4.2.1.

4.2.3 Risk due to helicopter transports

For this risk to be evaluated historical data has to be used. No information on failure rates has been found in regards to quantitative risk analyzes such as fault trees. The level of detail was chosen with regards both to how well the data represents the actual scenarios as well as having a large enough data set to present accurate estimates. The data used in chapter 7 was chosen based on these factors and the level of detail chosen resulted in data specifically from offshore helicopter travels in the North Sea. It was not possible to make any distinctions in regards to more detailed information, e.g. weather conditions during the flights, helicopter brand/model, and experience level of the pilot.

5 Established constraints as to the foundation of the model

This study is limited by the assumptions previously made in the sources this study is based on since it has not been practicable to verify them.

5.1 QRAs, chapter 6.

- The offshore platforms used to estimate the FAR values for the different areas are representative for those platforms the model is applied on.
- The offshore platforms used to estimate a generic area-FAR value for the weather deck, utility area, well bay area, process area and sub cellar deck are assumed to be without their own drilling module.

5.2 Helicopter flight accidents, chapter 7.

- The study performed by SINTEF to estimate the relationship between flight time dependent helicopter accidents and helicopter accidents dependent on the number of flights is based on representative data /12/.
- Only fatalities are taken into account when estimating the helicopter flight risk, all other forms of injuries are neglected.

5.3 The model, chapter 8.

- For a given concept scenario, the data on which the model was constructed is sufficiently representative for that specific scenario.
- The following three major risk factors are the only ones taken into account; risk due to presence on the platform in question, risk due to the personnel’s rest taking place on an accommodation platform while work is performed on the platform in question, risk due to helicopter transfers to and from the platform in question. All other risk factors are deemed not to differ between the alternatives and are hence, not accounted for, see section 4.2.

6 Review of QRAs

The review of the QRAs is an integral part of this study since the foundation of the model is based on the data found in these, see chapter 4 for the reasoning.

6.1 Review of NUIs

As described in section 4.1, the area-FAR values for the different areas in the model were all based on the mean values of the area-FAR values for same areas found in the QRAs. However, all the area distributions in the QRAs were not constructed in the same manner and with the same number of areas. The generic area distribution was a trade-off between a more detailed distribution with more areas but lower accuracy of the estimated value for each area and a distribution with a less detailed distribution with fewer areas but a greater accuracy of the estimated value for each area. The generic distribution of the model was chosen to have the lowest amount of areas, but with no merging of areas with different functionalities whatsoever. This meant that different types of utility areas were merged to result in as much data as possible to be used in the estimates, as these were thought to be similar enough to be merged. However, no areas with different functions e.g. a utility area and a process area, were merged as to not taint the integrity of the distribution. The generic distribution used in the model, chosen with the least amount of areas but without clashing functionalities within an area, is presented below:[5]

- Weather deck
  - Including crane
- Utility area
  - Including central control room (CCR), local electrical room (LER), heating, venting and air conditioning (HVAC) plant, emergency shelter, telecom room and possible living quarters (LQ)
- Well bay area
  - Including well head area, Christmas tree area, test manifold and high integrity pressure protection system (HIPPS)
- Process area

  Including gas treatment area, separation area and pigging facilities.
- Sub cellar deck
  - Including areas for knock out drums, drain tanks, drain pumps and sea water lift pumps.

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[5] The distribution was chosen with inputs from Mr. Roy-Atle Simonsen, Senior Safety Consultant at Oilconx Risk Solutions.

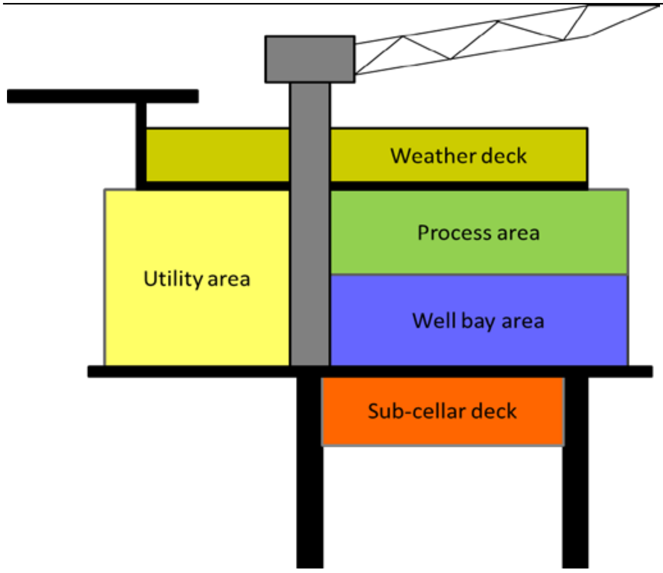

Figure 6-1 Schematic drawing of the area distribution applied in the model

This area distribution resulted in the lowest number of areas, for greatest accuracy of each area-FAR, without areas clearly clashing in regards to the function and risk level of the different areas.

The area distributions found in the QRAs did not fit this model exactly though and had to be conformed accordingly. They either did not have all five areas, in which case the areas they did have were used. In the other case, where there was a more detailed distribution, areas with similar functions were merged through the averaging of their respective area-FAR values. Because of this, information was lost in accordance with the earlier arguments on the averaging of area-FARs in section 4.1. This was still carried out though, since the alternative of using a more detailed distribution would exclude a large number of the QRAs, hence lowering the accuracy of the generic estimate. This due to the fact that if there are several smaller areas in a detailed distribution with unknown area-FAR values and one larger area in a QRA with a known area-FAR value, that constitutes the mean of these smaller areas, it is not possible to estimate the area-FAR values of the smaller areas. In other words, it is not possible to reverse a mean value to calculate the values that resulted in the mean value. Of course, the mean of the larger area’s area-FAR values could simply be evenly split, i.e. remain the same, for the smaller areas. However, there was not enough data to support performing such an action. In addition, a less detailed area distribution suits the uncertainties of the model in a better manner.

To create better estimates with this model more time should be spent on studies where parameters, e.g. installation year, size, manning levels were analyzed to see if they had an impact on the FAR values. If such connections were established the mean values of merged FAR values should be suitably weighted. To better cope with the uncertainties distributions can replace the point estimates. These would have to be verified with regards to their compliance with the data to ensure suitability.

The mean FAR-values of the areas in the generic area distribution are presented in Table 6-1.

Table 6-1 Summary of the area FARs used in the model

Area:	FAR (Fatalities per $1*10^8$ exposed hours):
Weather deck	4.16
Utility area	3.11
Well bay area	8.02
Process area	5.74
Sub cellar deck	6.32

6.2 Review of accommodation platforms

As described in section 4.1, the risk level contributed by time spent on the accommodation area of the accommodation platform in the generic model will also be estimated through the calculation of a mean value from the QRAs of offshore accommodation platforms in the Norwegian section of the North Sea. To improve the estimate, see the comments of the last passage in section 6.1. No additional calculations were needed, with regards to different area distributions being used, since the accommodation area was clearly separated in the area distributions of all the platforms and never further divided into more detailed sections. Three accommodation platforms were used to estimate a generic FAR value for the accommodation area, see Table 6-2.

Table 6-2 the generic area-FAR value for the accommodation section of the accommodation platform used in the model.

Area:	FAR (Fatalities per $1*10^8$ exposed hours):
Accommodation area	1.66

6.3 Validation of the data

The QRAs are developed by a third party and the estimates, results and assumptions are then reviewed by the operator. For newly built platforms the QRA might also be subjected to review by the engineering contractor[6]. There were certain restrictions as to the presentation of the data used to estimate the area-FAR values in this chapter, though not with regards to the utilization of the data to generate the estimates presented in the chapter.

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[6] Communication with Mr. Roy-Atle Simonsen, Senior Safety Consultant at Oilconx Risk Solutions.

7 Review of helicopter flight risk

The review of the helicopter flight risk is an integral part of this study since it is a main contributor to risk in any of the studied QRAs, and it is not uncommon for it to be the number one risk contributor to the personnel. The reason for evaluating it in this manner can, in addition to this chapter itself, be found in section 4.2.3.

7.1 Method for estimating the helicopter flight risk

For this study to be used in a general context it is very important to consider how the helicopter flight risk is related to the flight time and the number of flights. Some accidents are dependent on the flight time, others are dependent on the number of flights and some are dependent on both. The estimate of the helicopter flight risk must reflect this relationship or it will generate biases with regards to less infrequent but longer flights as opposed to more frequent but shorter flights.

A method, as described above, has previously been used by OGP (International Association of Oil & Gas Producers) and is presented below.

Individual risk (IR) per journey = In-flight IR + Take-off & landing (TO/L) IR

In-flight IR = Accident frequency in-flight (per hour) × Flight time (hours) × Probability of fatal accident × Nr. of fatalities in a fatal accident

TO/L IR = Accident frequency in TO/L (per flight stage) × No of flight stages per journey × Probability of fatal accident × Nr. of fatalities in a fatal accident

/11/

7.2 Dependencies on the flight time and the flight frequency

SINTEF performed an extensive helicopter safety study where they reviewed helicopter flights logs for the North Sea from 1990-1998 to determine to what extent the helicopter accidents were related to the flight time and the number of flights respectively /12/. This was done through a model where helicopter I/As (Incidents/Accidents) were divided into eight different categories which are defined to be exhaustive and mutually excluding /12/.

A1: Accident during take-off or landing at heliport/airport [Heliport]
Accidents which occur after passengers have boarded the helicopter and before TPD (*Takeoff Decision Point*) or after LDP (*Landing Decision Point*) and before passengers have left the heliport/airport.
A2: Accident during take-off or landing on helideck [Helideck]

Accidents which occur after passengers have boarded the helicopter and before TDP (*Takeoff Decision Point*) or after LDP (*Landing Decision Point*) and before passengers have left the helideck.

A3: Accident caused by critical failure in helicopter during flight [System failure]

Accident caused by critical system failure in the helicopter after TDP (*Take-off Decision Point*) and before LDP (*Landing Decision Point*), for example in the main rotor, tail rotor, engine, gearbox, etc. When a critical system failure occurs, the craft (pilots/passengers) can only be saved through a successful emergency landing.

A4: Collision with another aircraft [Mid-air collision]

Collision with another aircraft during flight, without any critical failure occurring. (*Mid-Air Collision*; MAC)

A5: Controlled flight into terrain, sea or building [Terrain collision]

Accident caused by collision into terrain, sea, or building after TDP (*Take-off Decision Point*) and before LDP (*Landing Decision Point*), with no critical failure occurring. (*Controlled Flight Into Terrain, sea or building*; CFIT)

A6: Accident with risk for persons in the helicopter [Person inside]

Accident involving danger to persons (pilots/passengers) located in the helicopter, for example caused by toxic gases due to a baggage or cargo fire.

A7: Accident with danger for persons outside helicopter [Person outside]

Accident involving danger to persons (pilot/passengers) located outside the helicopter, for example, the tail rotor strikes a person. *(Note that danger to other persons than helicopter pilots and passengers, for example helideck personnel, is not included.)*

A8: Accident caused by weather conditions, surrounding environment, or other [Other/unknown]

Accident caused by weather conditions (for example lightning strike), surrounding environment (for example collision with a vehicle at the heliport/airport), or other (for example an act of terror), in addition to accidents with unknown causes.

Citation from /12/

The distribution of the accidents into these eight categories for evaluation of each category’s contribution to the helicopter flight accident frequency was based both on historical data and expert evaluations /12/. For determining how each category’s accident frequency relates to the flight time and number of flights respectively a factor is introduced, flight quantity dependence, in accordance with the approach in various QRAs. The factor is defined as 100% when accidents occur on or in the immediate vicinity of the helideck representing a complete dependence on the number of flights. The value 0% is defined as accidents occurring in mid-air and represents a complete dependence on the flight time. The results of the different categories are the summarized to give an estimate of the extent to which flight time and the number of flights contribute to the total accident rate. A summary of the above described method is represented in Table 7-1.

Table 7-1 Summary of how the flight time and the number of flights contribute to the overall flight frequency respectively.

Accident category	Helicopter flight accident frequency /12/	Flight quantity dependency	Contribution to the flight time dependent frequency	Contribution to frequency dependent on the number of flights
A1	6.7 %	100 %	0 %	6.7 %
A2	32.9 %	100 %	0 %	32.9 %
A3	38.1 %	50 %	19.0 %	19.0 %
A4	0.7 %	0 %	0.7 %	0 %
A5	9.7 %	50 %	4.9 %	4.9 %
A6	0.8 %	0 %	0.8 %	0 %
A7	5.4 %	100 %	0 %	5.4 %
A8	5.7 %	25%	4.3%	1.4 %
Sum	100 %	-	29.7%	70.3 %

As seen in the table above the helicopter accident frequency can be coarsely accounted for by attributing 30% of the accidents to be flight time dependent and 70% to be dependent on the number of flights.

7.3 Review of helicopter flight information

The helicopter safety study prepared by SINTEF /12/ has not been used to estimate the helicopter accident rates since it is not specified what number of flights the data is based on. As previously stated this is a requirement to be able to utilize the method in the example presented in section 3.2.1, hence other data sources have been investigated.

OGP has annually released reports on performance of helicopter operations in the oil and gas industry from 1994 to 2006 (/3/; /4/; /5/; /6/; /7/; /8/; /9/; /10/). The data in these reports are well suited for this study not only because they present their accident data in reference both to the flight time and the number of flights made, but the data is also presented for the North Sea alone which is appropriate for this study since regional differences does not have to be accounted for. It also represents accidents in the offshore industry alone which further validates the estimates since there could be sectional differences between different sectors. However, it should be noted that the helicopter accident data, presented in Table 7-2 is based on very few accidents, making its use restricted due to the sensitivity of the data with regards to the number of reported accidents. These estimates will then have to be complemented by the conditional probability of a fatal accident and the proportion of fatalities in a fatal accident in order to present the helicopter flight risk.

Table 7-2 Helicopter accident rates for the North Sea from 1994 to 2006.

Period	Accident rate (per 100 000 hours flown)	Accident rate (per 100 000 flight stages)
1994 /3/	0	0
1995 /3/	1.65	0.85
1996 /3/	1.26	1.20
1997 /3/	1.78	1.08
1998 /3/	0.61	0.39
1999 /4/	1.37	0.74
2000 /4/	0.68	0.41
2001 /5/	1.23	0.82
2002 /6/	1.96	1.09
2003 /7/	0	0
2004 /8/	0	0
2005 /9/	0	0
2006 /10/	1.45	1.01
Mean	0.92	0.58

According to the earlier assumptions the results from Table 7-2 will be adjusted according to the results from Table 7-1 in order to give the estimated helicopter accident rate that reflects the relation between flight time and the number of flights made. The results are displayed in Table 7-3.

Table 7-3 Adjusted helicopter accident rates for the North Sea

Adjusted accident rate (per 100 000 hours flown)	Adjusted accident rate (per 100 000 flight stages)
0.27	0.41

The conditional probability of a fatal accident and the proportion of fatalities in a fatal accident are not presented in the reports used above to retrieve an estimate of the accident rate. However, they have been estimated in another OGP report, /11/, and are presented below in Table 7-4.

Table 7-4 OGP estimates of North Sea offshore helicopter parameters, /11/.

	Probability of Fatal Accident	Probability of death in a fatal accident
Flight time dependent	0.20	0.85
Dependent on the flight frequency	0.17	0.48

A summary of the important estimates in this chapter is presented in Table 7-5.

Table 7-5 Summary of the parameters used to estimate the helicopter flight risk

Flight time dependent	Accident rate (per 100 000 hours flown)	Probability of a Fatal Accident	Proportion of fatalities in a fatal accident
	0.27	0.20	0.85

Flight frequency dependent	Accident rate (per 100 000 flight stages)	Probability of a Fatal Accident	Proportion of fatalities in a fatal accident
	0.41	0.17	0.48

The helicopter flight risk is then estimated in accordance with the method described in section 7.1.

7.4 Validation of the method

This method is used in various QRAs (performed by different companies), and these QRAs are then reviewed by the operating companies and sometimes by a third party. There were certain restrictions as to the presentation of certain information in this chapter, though not with regards to the utilization of this information.

8 The model

The model's purpose is in answer to the lack of common practice of performing a concept selection of normally unmanned installations, see section 3.2 and the example in section 3.2.1.The results are presented as the difference in risk between the two alternatives and cannot be used in evaluations with regards to acceptance criteria based on a person's total risk exposure.

It should be noted yet again that since the model is based on data from the North Sea the representativeness could be quite poor for other parts of the world and caution should be taken with regards to this context.

8.1 Structure of the model

The actual model itself is built on the data analyzed through chapters 6 and 7 and with inputs according to section 8.2. The connections are made as to make the different risks comparable, i.e. of the same form. The model is currently constructed in an Excel-file[7], which allows for additions or for changes to be made to the construction or/and content. The reason for the input parameters to be used as input and not be generically estimated or the reason for them being parameters in the model at all can, in addition to section 8.2 below, be found in section 4.1. The model presents the results of PLLs for both alternatives, e.g. shuttling option or a campaign option. However, the results are not quantitatively interpreted in that manner, but according to section 3.3.1 only together with a qualitative evaluation of the model's effect on the results in that particular case used to indicate which alternative would present the lowest risk level to the crew, see chapter 9 for an example.

8.2 Input parameters

The parameters in this section are a part of the model due to the fact that they are needed to re-calculate the risks of the personnel being present at the platform, chapter 6, and of the personnel being transferred by helicopter, chapter 7, to PLL. These risks are then comparable and the total risk for the two different alternatives (NUI+AP vs. PMI) can be calculated, compared and the concept evaluated. PLL is frequently used in the oil business as a risk measure.

The input parameters are divided into one of two segments due to the nature of the crew's visit. The first one is 12 hour operations; the second one is 24 hour operations. This separation is due to the fact that certain operations such as coil tubing or wire-line may require the crew to work non-stop for 24 hours on end. In other words, some operations require continuous efforts and cannot be paused. Regular maintenance work on the other hand is more flexible and operations of this nature can be paused after 12 hours and resumed after the crew's resting period. The split of these 12 hour and 24 hour operations is motivated by the possibility of its effect on the input

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[7] Microsoft Office, Excel, 2010

parameters. The values of manning distribution, persons in the helicopter and so on, will vary depending on the type of operation and the split was made to reflect this in the model. There could still have been just the one alternative, where a mean value was estimated, but the division increases the transparency of the model which in turn makes it less likely to be misinterpreted.

8.2.1 Manning distribution

The manning distribution will easily be estimated with input from the operators at the company assigned to operate similar platforms. Since this is available information at the time of utilization of this model and the fact that the parameter value varies, the manning distribution is deemed better suited as an input parameter than a generic point estimate. The manning distribution will be put into the model in the form of fractions, where a number 1 for a certain area would signify the whole crew spending all of their time in that area.

8.2.2 Time spent on the platform

The time spent on the platform should be estimated with input from the operators at the company assigned to operate similar platforms, in the same way as the manning distribution. Since this is available information from similar platforms at the time of utilization of this model and the fact that the parameter value varies, the time spent on the platforms is deemed better suited as an input parameter than a generic point estimate. The time spent on the platform will be put into the model in the form of a specified number of hours of presence on the platform per trip and per person. The number of trips per year and the number of persons per trip will also be put in the model.

8.2.3 Persons in the helicopter

When the operators estimate the two previously described parameters the number of persons in the helicopter will be estimated in the process. There is no reason not to use this estimate since it certainly will be at least as accurate as any generic value or distribution that could be estimated at this time.

8.2.4 Flights per year

The number of flights per year will greatly affect the risk level contributed by the helicopter accidents and can vary quite a bit since different types of installations may require additional attention from a work crew. This is also easily estimated by input from the operators at the company assigned to operate the platform and hence better suited as an input parameter. The number of helicopter flights per year will be put into the model in the form of an integer. The integer will represent all flights and not the number of operations, that is to say an operation requiring one flight to the platform and one flight back from the platform will be noted as two flights. However, it should be noted that only flights transporting crew are accounted for. Trips with just the pilot are not taken into account, even if they are a result of the personnel visiting the platform. This is since the model only accounts for the risk the work crews are exposed to.

8.2.5 The flight time

The flight time affects the risk contributed by the helicopter transfers since this is dependent both on the number of flights and the time spent in flight mode for each flight. The time can vary quite a bit, and due to this it is unsuitable to be used as a generic point estimate. More so than this, the fact that it certainly will be known at the time when this model will be used makes it obsolete in regards to being a generic point estimate. The flight time will be put into the model in the form of hours. It is presented for every flight. That is to say for an operation requiring two flights there will be two flight times.

8.3 Model description

The model is constructed to use input parameters concerning the helicopter flight risk together with the estimated risk parameters to result in two PLL values, i.e. per trip and per year, see section 8.3.1.1 below. This is done for both the “NUI+AP”-alternative and the “PMI”-alternative.

The next part utilizes the input parameters regarding the risk due to presence on the platform together with the estimated parameters also regarding risk due to presence on the platform, see section 8.3.1.2 below. This results in two PLL values, i.e. per trip and per year, and it is also done for both of the alternatives.

The PLL values due to the helicopter flights and presence at the platform are comparable, i.e. of the same form, and are consequently added for each of the “NUI+AP”-alternative and the “PMI”-alternative. This results in total PLL values, both per trip and per year, for each of the alternatives which are then compared to evaluate which of the two alternatives, i.e. “NUI+AP”-alternative or “PMI”-alternative, are exposing the crew to the highest level of risk.

8.3.1 Structure of the sheets calculating PLL for the two alternatives

Since the risk is calculated in the same manner for both of the alternatives, the description in the following two sections is valid for both cases.

8.3.1.1 The helicopter flight risk part

The first section calculates the PLL contributed by the helicopter transfer. It utilizes the elements specified in Table 8-1.

Table 8-1 Elements used in the helicopter flight risk part of the model

Description:	**Classification:**
Data from Table 7-5	Generic estimates
Persons in the helicopter	Input parameter
Flights per year	Input parameter
Time per flight (hours)	Input parameter

The data and the input parameters in Table 8-1 are used according to the equation in section 7.1. The results are presented as PLL per trip (back and forth) and PLL per year.

8.3.1.2 The presence on the platform part

The second section calculates the PLL contributed by the crew being at the platform, which includes the crew resting at the accommodation section of the AP in one of the alternatives. It utilizes the elements specified in Table 8-2.

Table 8-2 Elements used in the presence at the platform part

Description:	Classification:
Data from Table 6-1	Generic estimates
Data from Table 6-2	Generic estimate
Manning distribution	Input parameter
Time spent on the platform	Input parameter

The data and input parameters in Table 8-2 are then used to estimate the PLL per trip and per year. The generic area-FAR estimates are first conformed to the unit per hour instead of per 100 million hours, whereupon they are multiplied respectively with the corresponding value in the manning distribution. Each area value is then multiplied with the number of exposed hours at the platform both per trip and per year. Lastly, these are then added to each other to present the result in PLL per trip and year due to presence on the platform.

8.4 Outputs

The model presents PLLs for each of the two alternatives (NUI+AP vs. PMI); see section 3.2 and the example in section 3.2.1. These PLLs represent the estimated number of fatalities for each of the alternatives for different periods of time, e.g. per trip and per year. This allows for comparisons between the alternatives, with regards to the risk level the personnel are exposed to. However, the PLLs are not representative of the total risk level the crew is exposed to. The model does not take into account other risk factors that are not affected by this concept selection, namely the risk due to onshore/offshore helicopter transfers, time spent on other offshore platforms including transfers to these or other locations than the NUI/PMI platform and the accommodation area of the AP or the risk due to the crew being onshore. For the results to be interpreted in that manner, these other risk contributing factors have to be added to the model's results.

Caution should be used even when the results are used in the correct manner, i.e. as the difference in risk between the two alternatives. Rather than using them in their presented quantitative context they should be qualitatively used to indicate which alternative is the better in this context, i.e. exposes the crew to the lowest risk. They should in no way be misconstrued as exact estimates of the risk difference between the two alternatives. The uncertainties are on too large of a scale for that sort of operations due to the generic nature of the model coupled with the sacrifices made to allow for it to present results in an early phase of the platform's development. It is therefore extremely important that the results are evaluated with regards to how they have been affected by the necessary sacrifices made on the model's accuracy. These matters are further discussed in the last two chapters of this study.

It should be duly noted that the model is unfit to be used for other geographical regions than the North Sea. Evaluations of how the representativeness of the data the model is based upon corresponds with the data from other regions should be coupled with the results if it is to still be used

9 Risk-based concept selection

For clarification on both how to use the model and how to interpret the results an example is given in section 9.1. As mentioned in section 8.4 the importance of understanding how to interpret the model's results cannot be overstated. They are in no way meant to be interpreted in a quantitative context as an exact estimation of the difference in risk between the two alternatives but only in a qualitative manner to indicate the better option with regards to the lowest risk level.

9.1 Example

The input parameters are given credible but fictitious values, the model will be run and the results will be presented and discussed.

9.1.1 Input parameters

The estimated input parameter values are, as discussed in section 8.2, estimated for both 12 hour operations, e.g. maintenance work, and 24 hour operations, e.g. coil tubing operations, wire-line operations. They have been given fictitious values which are deemed credible based on the experience gained through all of the QRA work. The estimated input parameter values are presented in Table 9-1 and Table 9-2 for the "NUI+AP"-alternative and the "PMI"-alternative respectively.

9.1.1.1 The "NUI+AP"-alternative

The numbers of flights per year are based on an assumed work load of 96 days of "12 hour operations" and 24 days of "24 hour operations". The distributions of visits are 24 periods with four days in each for the "12 hour operations" and three periods with eight days in each for the "24 hour operations". For the "12 hour operations" the crew is assumed to be transferred to the platform for twelve hours of work during the day after which they are transported back to the accommodation platform to rest for the next twelve hours. This goes on for four days after which there is a break until the next four day period. Since the "24 hour operations"-crews have to work continuously for eight days the crews work in shifts. One crew arrives and works for twelve hours after which it is relieved by another crew and transported back to the accommodation platform for twelve hours of rest.

A trip is defined as the two flights used to transport the crew to and back from the platform.

Table 9-1 All estimated input parameter values used in the example for the "NUI+AP"-alternative

Input parameter:	12 hour operations:	24 hour operations:
Persons in helicopter	12	10
Flights per year	192	96

Time per flight (hours)	0.33	0.33
Weather deck	0.03	0.03
Utility area	0.15	0.05
Process area	0.15	0.20
Well bay area	0.15	0.20
Sub-cellar deck	0.02	0.02
Accommodation area of the AP	0.5	0.5
Hours at the platform per trip	23.34	23.34
Number of trips per year	96	48
Number of persons per trip	12	10

9.1.1.2 The “PMI”-alternative

The numbers of flights per year are based on the same assumed work load as for the “NUI+AP”-alternative for them to be comparable. That is to say 96 days of “12 hour operations” and 24 days of “24 hour operations” per year. For the “12 hour operations” the crew is assumed to work at the PMI in periods of four days resulting in 24 annual trips. Typically, a workday consists of the whole crew, twelve persons, working their twelve hours during the day and resting during the night. For the “24 hour operations” though, the 24 days are divided into three trips of eight days each. 20 people are transferred to the platform and they work in shifts where ten of them rest for twelve hours while the other ten work for twelve hours. This goes on for eight days until all of the personnel leave the platform.

A trip is defined as the two flights used to transport the crew to and back from the platform.

Table 9-2 All estimated input parameter values used in the example for the “PMI”-alternative

Input parameter:	12 hour operations:	24 hour operations:
Persons in helicopter	12	20
Flights per year	48	6
Time per flight (hours)	0.33	0.33
Weather deck	0.03	0,03
Utility area	0.65	0.55
Process area	0.15	0.20
Well bay area	0.15	0.20
Sub-cellar deck	0.02	0.02
Accommodation area of the AP	-	-
Hours at the platform per trip	95.34	191.43
Number of trips per year	24	3
Number of persons per	12	20

trip

9.1.2 Calculations

The calculations are presented in chapter 13 Appendix A with snapshots of the Excel file and descriptive text as to how the calculations have been performed.

9.1.3 Results

The results are presented in the form of PLL for each of the alternatives, i.e. "NUI+AP"-alternative and "PMI"-alternative. They are presented both per trip and per year, but for the alternatives to be comparable the focus is on the PLL per year. It should be noted yet again that these results does not represent the total annual PLL of the crew but only account for the parts that differ between the two alternatives. For a complete risk picture other contributions have to be accounted for, see section 8.4. The results in this example, generated through the use of the input parameters presented in section 9.1.1 are presented below in Table 9-3 and Table 9-4.

Table 9-3 the results of the example set forth in chapter 9

	"NUI+AP"	**"PMI"**
PLL per trip	$4.08e^{-5}$	$2.58e^{-4}$
PLL per year	$4.59e^{-3}$	$2.39e^{-3}$

The results presented in Table 9-3 are not to be used as quantitative estimates of the risk since not enough is known about the uncertainties but rather as a qualitative indicator, see Table 9-4.

Table 9-4 the results of the example set forth in chapter 9

	"NUI+AP"/"PMI"
PLL per year	1.92

As seen in Table 9-4 the PLL for the "NUI+AP"-alternative is almost twice as large as the PLL for the "PMI"-alternative.

Since the results, as previously discussed, are too uncertain to be used in their quantitative context they are presented as the quotient of the alternatives which indicates that there is a substantial difference between them, favoring the PMI. Coupled with an evaluation on how the construction of the model has affected the results a recommendation could be made. The recommendation could be to either suggest one of the alternatives or that there is a need for further evaluation to be able to safely base the concept selection on those evaluations.

For the model to be used without additional evaluations certain improvements have to be made. These are discussed in section in chapter 10.

To say something about the uncertainty in this case, the model was altered and the same concepts were compared two more times. In the first case the area-FAR values used in the model were all changed from being the mean values of the generic data to be the minimum FAR values found for each area. The second time around they were changed to be the maximum FAR value found for each of the areas. The results are presented in Table 9-5.

Table 9-5 Results of the example when the area-FAR values have been altered

	“NUI+AP”/”PMI”
PLL per year, minimum area-FAR values instead of mean values	2.57
PLL per year, maximum area-FAR values instead of mean values	1.48

When one uses the extreme area-FAR values, i.e. the smallest and largest respectively, the generated result represents the largest and smallest difference in risk between the two concepts. Since both of the generated results clearly state that the “NUI+AP”-alternative will expose the crew to the largest risk it is safe to say that the uncertainty of the area-FAR values, in this case, is not large enough to make a difference as to which concept is the most dangerous. A quick verification performed in this manner is not enough to account for the uncertainty in the model. It can however be enough to show that the uncertainty of the model’s results coming from only averaging the area-FAR values will not affect which concept the model presents as the one exposing the crew to the largest risk. It should be noted though, that the results of this verification are only valid for this particular concept selection.

10 Discussion

This discussion aims to examine the findings in the study, make judgments on these as well as clarify the proposed future work and research that would benefit this study.

10.1 The model

A model will allow for a more efficient process, as opposed to performing a new evaluation each time, since only the input parameters need to be case specific. Hence a lot of work can be eliminated. It should be noted though, that it is important to make certain that the increase in efficiency does not lead to a decrease in the accuracy of the results.

The model was constructed to incorporate historical data and a systematic approach to the concept selection of normally unmanned offshore oil platforms and possibly to be used as a building block for further standardization, see section 3.2.1 for an exemplification of the problem statement. As discussed in section 3.2 there is no standardized way of performing this kind of selection as of today.

Since the model is based on historical data the amount of data and the representativeness of this data are fundamental for the model to generate reliable estimates. The data, as of this study, are presented in chapters 6 and 7 according to current restrictions. Essentially though, it is based on the estimates of 14 QRAs and historical failure data of offshore helicopters in the North Sea from 1994-2006 curtsey of OGP.

For the generated estimates of the model to become more accurate the basis of the model needs to become more accurate. In other words more data is needed. Not just any data though, it is necessary to always weigh the amount of data against the representativeness of the data, and inherently the scope of the model. The representativeness is closely related to various parameters.

Below, a case is made for how geographical and cultural similarities between the data of the installations used to construct the model and the installation for which the concept selection is performed will affect the outcome. The model might for instance present different estimates when based on data from a certain geographical area and used for a concept selection in the same area compared to it being based on a larger data set collected from all over the world, but still used for the same concept selection in the same geographical area as before. The same can be said for cultural differences where a model based on data from one operator company and used for a concept selection within the company can present different estimates compared to a model based on a larger data set from several different operator companies, but the same concept selection within the same operator company. The same can be said about the data being representative with regards to the age of the data. Since the technology, equipment and procedures are constantly evolving and changing the model’s estimates will be prone to changes due to the data used with regards to the age of the data.

These factors could be probably accounted for through the utilization of Bayesian methods, see section 10.3.

The accuracy of the model is not only dependent on the representativeness of the data with regards to previously discussed parameters. The level of detail used is also very important for the model to present accurate estimates. On one hand there is the risk of being on the platform, and on the other the risk of traveling to and from the platform. The risk of being on the platform has been estimated by the use of area-FAR values, see chapter 6. Since the area distribution was constructed differently for the various platforms used to generate data the ones that did not fit the model were conformed accordingly. This was done so that the generic distribution had the minimal amount of areas, but no merging of areas with clashing functions and risk levels accordingly. The minimum amount of areas, inherently resulting in the maximum amount of useable data, and the fact that there were no clashes in area functionalities resulted in an optimal accuracy of the estimates. However, it shall be noted that the data set was quite small.

The size of the data set is not the only place for improvement though. The area-FAR values for different platforms were merged through mean values and used in the form of point estimates. By doing this, there are uncertainties left that are not properly accounted for, and these are of course also present in the results. To account for these uncertainties in some way, various distributions could be evaluated to see if the data would fit any of them and through this better account for the uncertainties, see section 10.3.

The input parameters were chosen with regards to the data the model was constructed from and the fact that a comparison was to be performed between the alternatives. For a comparison to be made the amount of work performed on the platform had to be the same for both of the alternatives. Since the difference was more helicopter flights but a safer resting area for one of the crews compared to fewer helicopter flights but a more dangerous resting area for the other crew it was determined that the same amount of theoretical personnel were to work in both of the alternatives. This would eliminate errors where the difference in flight would not be representative for the two alternatives.

Since there is a difference in the number of trips, and inherently the flight time between the two alternatives, the comparison was chosen to take place per year. This could have been altered to compare the difference in risk for a certain work to be performed or for the difference in risk for the entire lifetime of the platform. The model is built for easy reconstruction in any part whether it is in regards to removing, adding or changing content.

10.2 The applicability of the model

The first thing to note about the model is that it is solely based on data from the North Sea and caution should be taken when used for concept selection of installations in other parts of the world. If the model is used anyway, the results should be coupled with an evaluation as to the representativeness of the data that was used to construct the model, compared with the data from that region.

The second thing to note about the model is that it does not present results of the risk the personnel is exposed to, for instance during a year. Due to this the results are unfit to be used in any kind of way with regards to comparing them to acceptance criteria to evaluate whether the personnel are exposed to high levels of risk. The reason for this is that the model only accounts for factors that differ between the two alternatives since it is designed to compare these alternatives, i.e. “NUI+AP” or “PMI”. Other risk factors that add to the overall exposure of the personal, namely helicopter transfers on- and offshore, time spent performing other types of work on other platforms or other locations or time spent onshore are not taken into account. All other risk factors exposing the crew to some type of risk would have to be added to the risk level presented by the model to generate a complete risk level comparable to suitable acceptance criteria. However, the model’s results are unsuitable to be a part of such evaluations due to the model’s unknown uncertainty.

Because of the relatively small sample size and fact that no statistical inference was used to derive the generic point estimates used a basis for the model the uncertainties are not only unknown, but probably also quite large. The model’s results should therefore be used with caution. The model’s results are supposed to be used as a qualitative indication of the difference in risk. The qualitative aspect of the utilization though will instead present information such as:

“Is there a difference in risk between the alternatives and if so which alternative is preferred with regards to the personnel risk?”

and

“Is the difference in risk between the alternatives, small, large or very large?”

The qualitative results should be coupled with an additional evaluation to make certain that neither the construction of the model nor the data it is based upon will lead to poorly estimated results. Particularly the representativeness of data should be considered as discussed in section 10.1 due to the inherent dependencies between the accuracy of the model’s results and the data used for the construction of it. If no contradictions or faults due to poor representativeness are found with the model, its results can be used as arguments in the concept selection of the platform. If this is to be the case though, it is well worth noting that the model does not take any other factors into consideration but the personnel risk whether they are economic, environmental or of other sorts.

Instead of performing a thorough analysis, an uncertainty verification as the one performed in section 9.1.3, can be an alternative. The idea is that when there is reason to believe that the method of handling the data is not reliable enough the extreme values of the data can be used to generate the extreme results. If both the maximum results and the minimum results indicate the same outcome, one can argue that it does not matter that the method used to handle the data is not reliable enough since the results will show the same outcome anyway. This method can of course only be used semi-quantitatively since you will receive an interval in which you can argue that your result will appear no matter the method used on the data. However, this is a case specific method; hence you have to perform this verification for each new concept selection to make sure that the uncertainty of the data handling does not have the possibility to affect the outcome.

Another use of the model can be as a first building block for a standardized way of gaining argumentative ground for the concept selections. Even though standardization can lead to slower progress and growth due to the simplicity of doing things like they are always done, the perks can be increased safety and efficiency. By construction of a model much like this one, but with improvements in areas of data representativeness, data sample size and statistical inference more could be said about the results of the model due to them being more accurate and the inherent uncertainties being better accounted for. Even if the results would still be too uncertain to be used quantitatively, they could surely be used in a qualitative context without the need for the earlier discussed additional evaluations, since much of their information would have been taken into account in a more detailed construction of the model.

Since the results of the model are to be used in an early phase of development, exact estimates of the differences in risk will be hard to calculate. This may not be desirable due to the amount of time and efforts needed, and a well based qualitative argument may well serve the purpose enough of being suitable ground for argumentation in a concept selection discussion.

What is more, the model can not only be used in the concept selection phase, but also as a means to evaluate the chosen concept after the platform has been taken into use. Then accurate estimates of the risk can be used in the model which will improve the accuracy of the results. For instance, this model could change the generic area-FAR values to those specific of the platform for which the concept selection is to be evaluated. This would allow for not only an evaluation of the selection of concept, but also as a verification of the model itself. If for every concept selection the model was used in, a verification of the aforementioned sort would be performed, it would bring valuable information as to how well the model is performing. It would not only add information as to how well the model is working, but could also be used to improve the model. Simply by evaluating in what way the model's estimate during the concept selection phase erred compared to the model's estimate while using the specific values of the platform in question a good insight might be reached as to how the model could be improved.

10.3 Further development to increase the accuracy of the model

As described in section 10.1, the accuracy of the model might be increased by fitting the data used to a suitable distribution instead of just using the mean value when merging certain area-FAR values. By fitting the data to a distribution in this manner, some of the uncertainties will be accounted for. The amount of uncertainties that are accounted for will depend on the amount of data and how well it fits the distribution. This would put some additional requirements on the data, particularly in form of sample size. But it should be looked into as a means of increasing the accuracy of the model.

By the utilization of Bayesian methods data can be weighted with regards to certain aspects. For instance, as discussed in section 10.1, data taken from other geographical locations, from other companies or older data could result in poor representativeness with regards to the situation in which the model is to be used, and hence present inaccurate results. Data with good representation could then, through Bayesian methods, be awarded greater weight while data with poor representation could be awarded less weight.

Bayesian methods could also be used as a means to increase the reliability of the model by awarding different dignity to the area-FAR values of various installations used to construct the generic area-FAR values through the mean of the different area-FAR values. A study would have to be performed where parameters such as age, size and manning levels where examined to see how they affect the FAR values. When the mean values then were calculated the different area-FAR values from the various platforms would be suitably weighted to increase the accuracy of the means with regards to aforementioned parameters. This would not increase the accuracy in the same manner as using distributions do describe the FAR values, but it would not put the same requirements on the data with regards to sample size either. Hence, it is another alternative that should be looked into to increase the accuracy of the model.

11 Conclusions

A risk based model for concept selection of normally unmanned installations in the North Sea has been developed. The model was the result of a systematic development procedure focusing on producing a model that is useful for decision making. The generated results of the constructed model reflect the difference in risk of offshore personnel attending the unmanned facility, with regards to different concept alternatives. Several steps were taken to ensure that the model would be a useful aid to decision makers:

- The model is accounting for the actions performed during operations with regards to two different types of platforms on a semi-detailed level.
- The model is based on operational data from the North Sea both with regards to the offshore installations as well as the helicopter failure data.
- The model is constructed on an applicable level of detail allowing for clear distinctions between various concepts in an early phase of development without unnecessarily imposing on the user’s ability to estimate the model parameters.
- The model is easily configured to incorporate other factors not currently accounted for, or to change how the ones already used are handled to allow future users to modify as needed.

The model however, is not necessarily a finished product as of this printing, but rather still a work in development. As described in this study there are a couple of areas that, with a bit of attention would increase the reliability of the model and the accuracy of its results.

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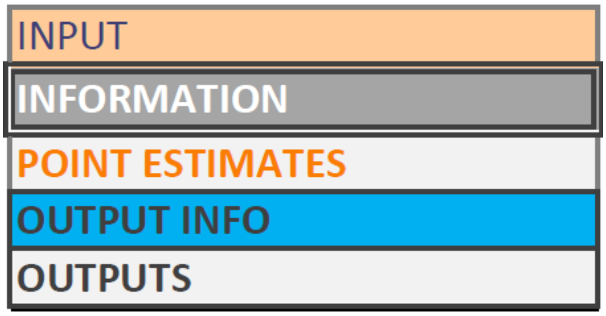
13 Appendix A

This appendix contains snapshots of the Excel model for further clarification on how the calculations have been performed. The snapshots are taken from the calculations of the “NUI+AP”-alternative, but the construction is identical to that of the “PMI”-alternative.

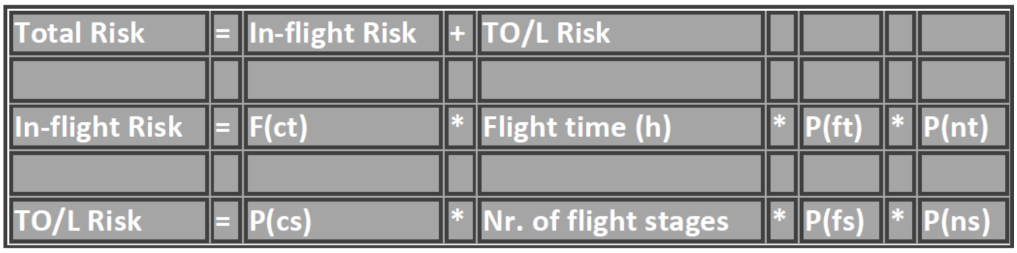
These are the color coding used in the Excel model to differ between different elements.



INPUT
INFORMATION
POINT ESTIMATES
OUTPUT INFO
OUTPUTS

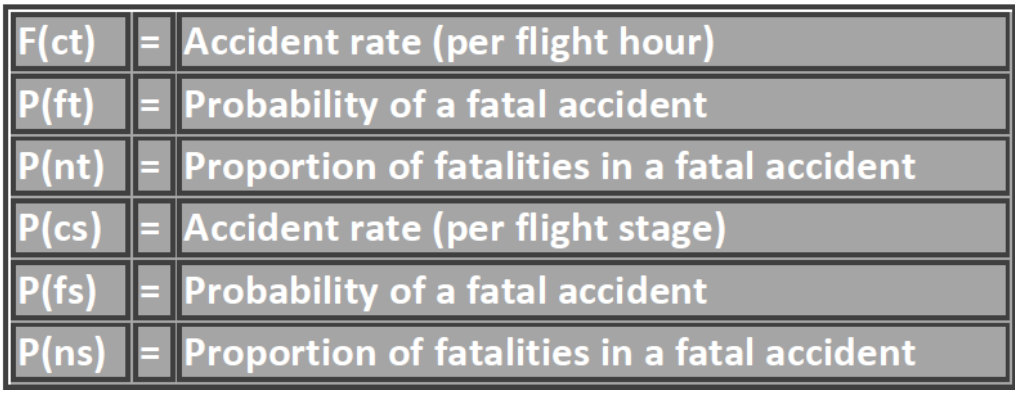
13.1 Risk due to helicopter travels

The formula used to calculate the risk from the helicopter flights for both of the alternatives.



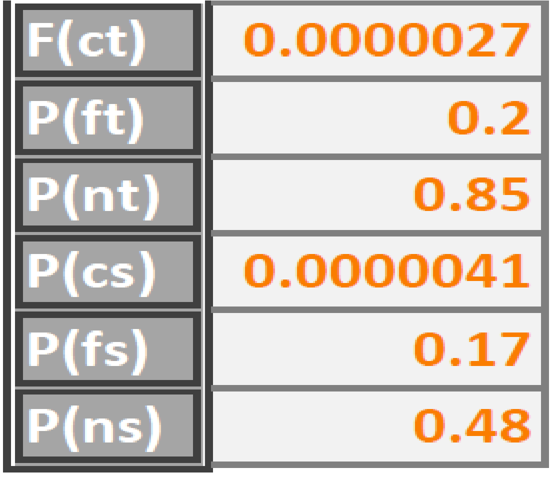
Total Risk	=	In-flight Risk	+	TO/L Risk				
In-flight Risk	=	F(ct)	*	Flight time (h)	*	P(ft)	*	P(nt)
TO/L Risk	=	P(cs)	*	Nr. of flight stages	*	P(fs)	*	P(ns)

Abbreviation used in the formula above.



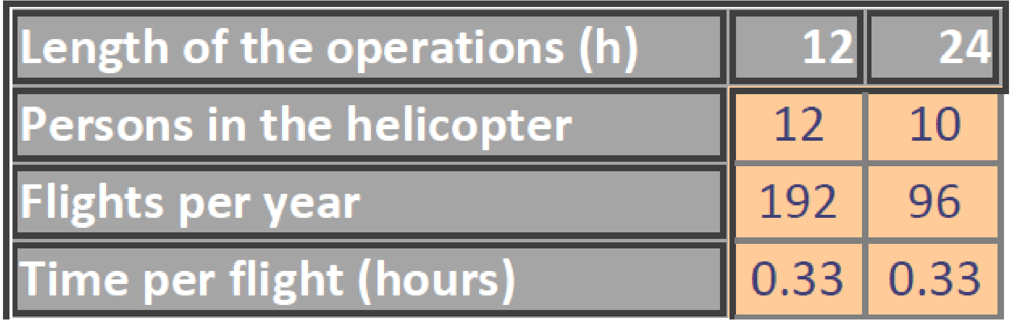
F(ct) = Accident rate (per flight hour)
P(ft) = Probability of a fatal accident
P(nt) = Proportion of fatalities in a fatal accident
P(cs) = Accident rate (per flight stage)
P(fs) = Probability of a fatal accident
P(ns) = Proportion of fatalities in a fatal accident

The estimates of the different helicopter parameters calculated in chapter 7.



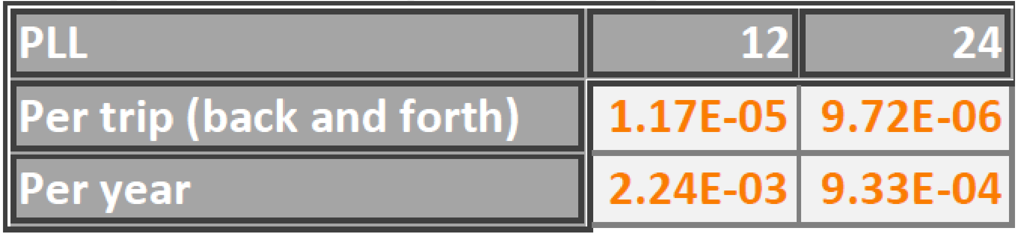
F(ct)	0.0000027
P(ft)	0.2
P(nt)	0.85
P(cs)	0.0000041
P(fs)	0.17
P(ns)	0.48

Fictitious but credible values of the input parameters used in the example.



Length of the operations (h)	12	24
Persons in the helicopter	12	10
Flights per year	192	96
Time per flight (hours)	0.33	0.33

The PLLs calculated both per trip and per year for the”12 hour operations” and the”24 hour operations”. The PLLs are calculated according to the risk formula above but multiplied with the number of persons in the helicopter.



PLL	12	24
Per trip (back and forth)	1.17E-05	9.72E-06
Per year	2.24E-03	9.33E-04

The total PLL contributed by the helicopter travels. They are simply the sums of the “12 hour operations” and the “24 hour operations” above.

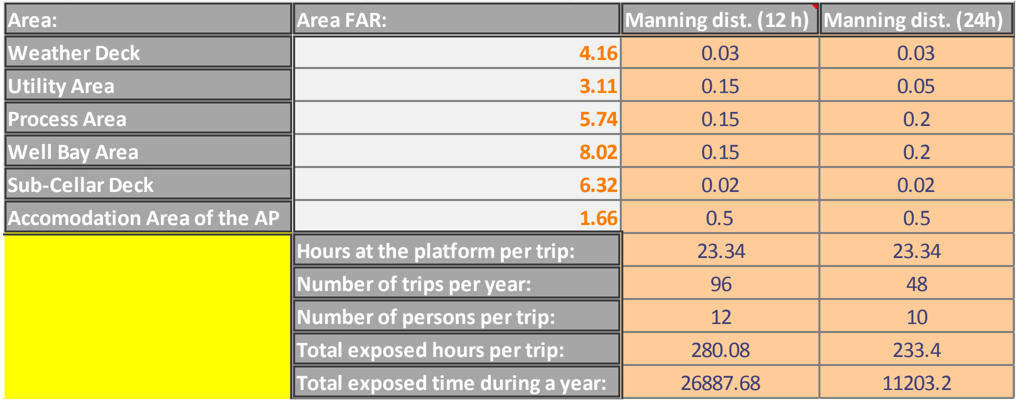
	Total PLL:
Per trip (back and fourth)	2.14E-05
Per year	3.17E-03

13.2 Risk due to presence on the platform

These are the estimated area-FAR values from chapter 6 and the input parameter values used in the example in chapter 9. The manning distribution is presented in fractions and represents the manning distribution for each trip. The “Hours at the platform per trip” is simply 24 hours minus the helicopter flight time for two travels. However, it also contains time spent on the accommodation section of the accommodation platform. This due to the fact that this time constitutes as exposed time and is to be compared with resting on the PMI.

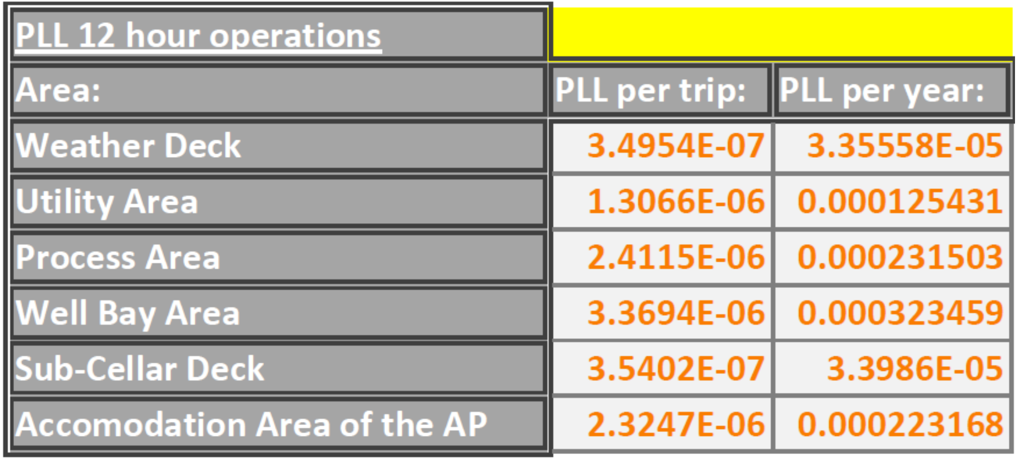
Number of trips per year is based on the visiting distribution explained in section 9.1.1.

The total exposed hours per trip is calculated as “Hours at the platform per trip” multiplied with the number of persons on the trip.

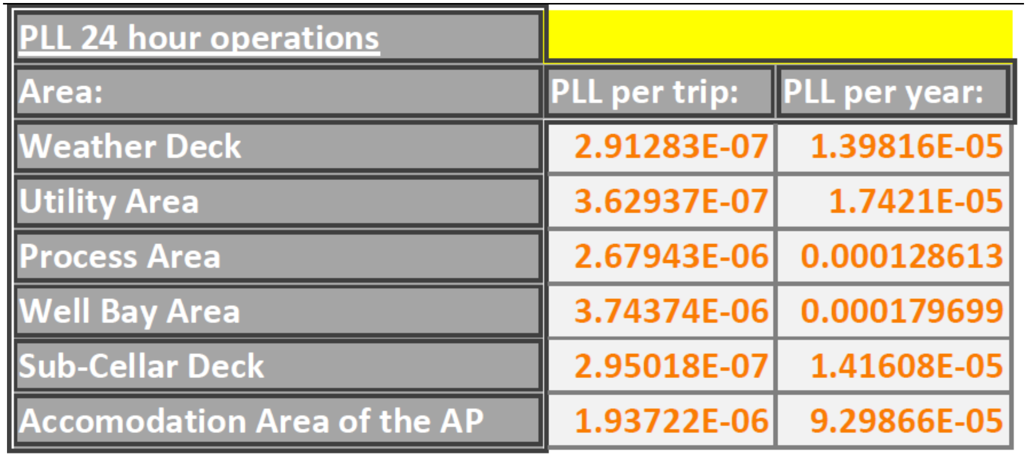


Area:	Area FAR:	Manning dist. (12 h)	Manning dist. (24h)
Weather Deck	4.16	0.03	0.03
Utility Area	3.11	0.15	0.05
Process Area	5.74	0.15	0.2
Well Bay Area	8.02	0.15	0.2
Sub-Cellar Deck	6.32	0.02	0.02
Accomodation Area of the AP	1.66	0.5	0.5
	Hours at the platform per trip:	23.34	23.34
	Number of trips per year:	96	48
	Number of persons per trip:	12	10
	Total exposed hours per trip:	280.08	233.4
	Total exposed time during a year:	26887.68	11203.2

The PLL per type of operation and area is calculated by dividing the area-FAR by $1.0e^8$ hours multiplied with the manning distribution seen above and also multiplied with the respective hours per type of operation, i.e. per trip or per year.

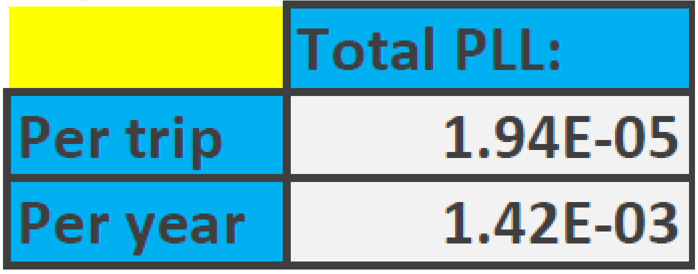


PLL 12 hour operations		
Area:	PLL per trip:	PLL per year:
Weather Deck	3.4954E-07	3.35558E-05
Utility Area	1.3066E-06	0.000125431
Process Area	2.4115E-06	0.000231503
Well Bay Area	3.3694E-06	0.000323459
Sub-Cellar Deck	3.5402E-07	3.3986E-05
Accomodation Area of the AP	2.3247E-06	0.000223168



PLL 24 hour operations		
Area:	PLL per trip:	PLL per year:
Weather Deck	2.91283E-07	1.39816E-05
Utility Area	3.62937E-07	1.7421E-05
Process Area	2.67943E-06	0.000128613
Well Bay Area	3.74374E-06	0.000179699
Sub-Cellar Deck	2.95018E-07	1.41608E-05
Accomodation Area of the AP	1.93722E-06	9.29866E-05

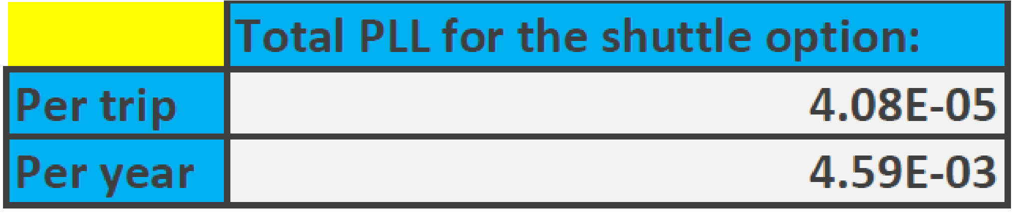
The total PLLs due to presence on the platform are calculated by summarizing the PLLs either per trip or per year respectively for both “12 hour operations” and “24 hour operations”.



	Total PLL:
Per trip	1.94E-05
Per year	1.42E-03

13.3 Total PLL

The total PLL for an alternative, i.e. either “NUI+AP”-alternative which is shown above and below or the “PMI”-alternative, is the calculated by summarizing the PLL due to helicopter travels and the PLL due to presence on the platform for each alternative respectively.



	Total PLL for the shuttle option:
Per trip	4.08E-05
Per year	4.59E-03

13.4 Summary

The summary presents the results of both the alternatives as well as the quotient between them. They should not be used in their quantitative context but rather as an indication which of the two alternatives exposes the personnel to the least amount of risk, see section 9.1.3.

	Total PLL Shuttle	Total PLL Campaign	Shuttle/Campaign
Per trip	4.08E-05	2.58E-04	1.58E-01
Per year	4.59E-03	2.39E-03	1.92E+00