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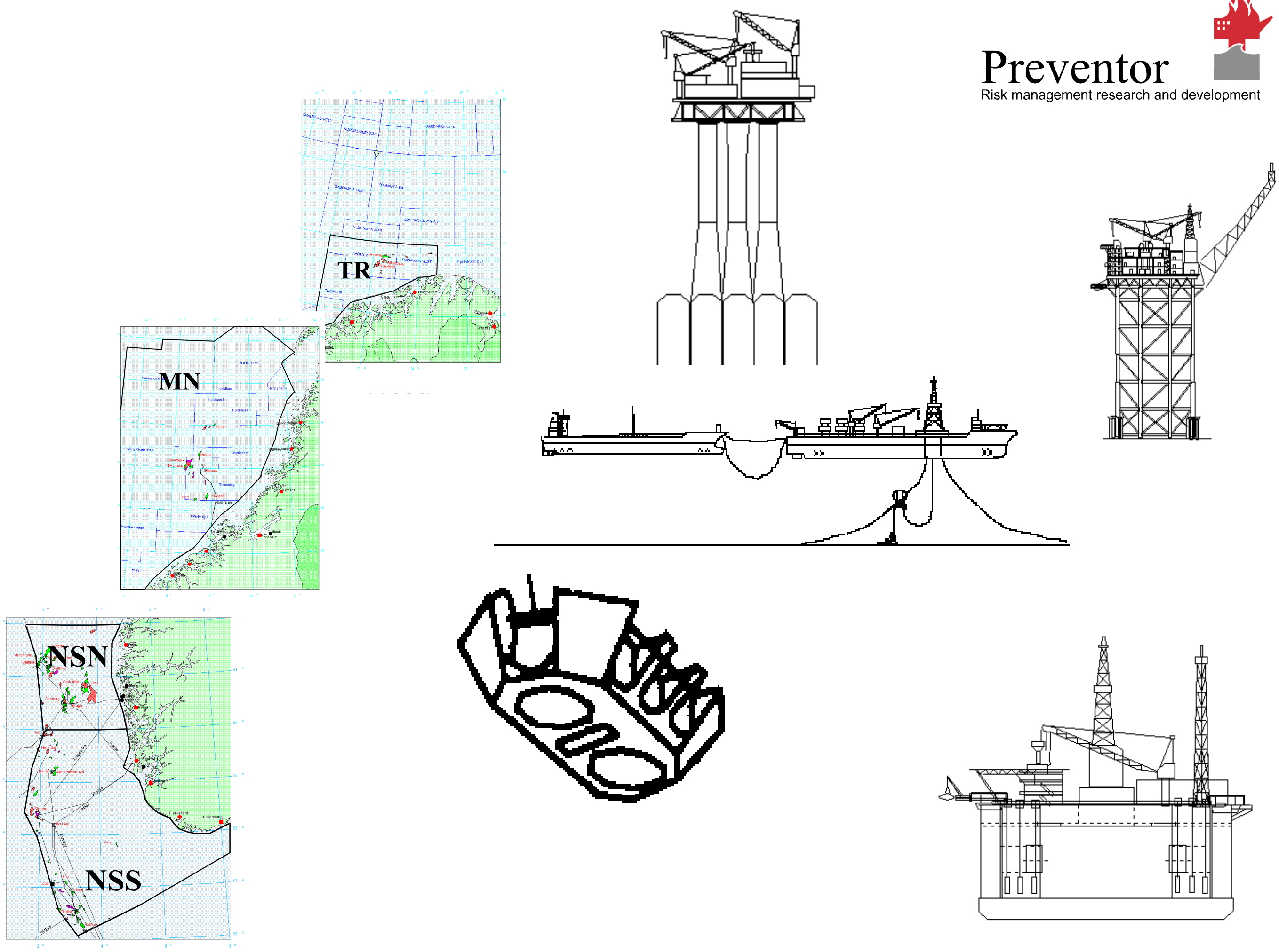

Risk Levels on the Norwegian Continental Shelf

Final Report

25 August 1998

a Study financed by
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The intention has been to present the historic risk levels and the expected risk picture on the Norwegian Continental Shelf during the next 10 years, covering fatality risk to personnel, risk to the environment, risk to assets, and focused on the following types of installations and activities:

- Fixed and floating production installations
- Mobile drilling units, including transit movements
- Standby, supply vessels, anchor handling tugs, diving vessels, pipe laying, crane vessels
- Helicopter transport to and between installations
- Pipeline transportation of oil and gas, tanker transportation of crude oil.

The basis for establishing risk levels for historic and future periods, is a precise and detailed mapping of all activities involved in the offshore operations on the Norwegian Continental Shelf, including fixed and floating platforms, all types of vessels and barges, diving, helicopter transport and product transport by tanker or pipeline.

For personnel the most critical aspects are shown to be floating installations and vessels, which have considerably higher risk levels than the fixed installations. It is demonstrated that the risk to personnel over the last ten years on an overall level has not decreased at all, rather an increase of risk has taken place.

For the risk to environment, the Mid Norway and North Sea North are shown to be the most critical areas, and the growing use of multi bore wells is shown to be a critical aspect.

Index terms, English:	Norsk:
Risk level	Risikonivå
Risk to personnel	Personrisiko
Risk to environment	Miljørisiko
Risk to assets	Materiell skade risiko

Contents

1 Summary of Approach

1.1 Objectives and Scope of Work

The project has determined the historic risk levels -mainly in the past ten years - and the expected future risk picture on the Norwegian Continental Shelf during the next ten years, covering fatality risk to personnel, risk to the environment, as well as risk to assets. The presentation in this report is focused on the following types of installations and activities:

- Fixed and floating production installations
- Mobile drilling units, including transit movements
- Standby, supply vessels, anchor handling tugs
- Diving vessels
- Pipe laying, crane vessels
- Helicopter transport to and between installations
- Pipeline transportation of oil and gas, tanker transportation of crude oil.

The basis for establishing risk levels for historic and future periods, is a precise and detailed mapping of all activities involved in the offshore operations on the Norwegian Continental Shelf, in relation to operation of the above mentioned installations and activities. (Further details are presented in Appendix B.)

When risk estimates for the future are being addressed on the basis of historic risk levels, the following are two important aspects to consider:

- The data from the past should preferably be based on both installations and operations that are as close as possible to future activities.
- The volume of data which is used should be sufficiently large to avoid statistical randomness.

These two objectives often imply a conflict, and a compromise must be found. In the present case, most of the historical data is used from the last ten years, 1988 - 97. Only when this implies an insufficient data basis, is a longer period used. The historical accident data are presented in Appendix C in the second volume.

The study was initiated in 1997, but has been updated in 3rd Quarter of 1998, in order to implement 1997 data. The last ten years reportable are therefore 1988 - 1997. The next ten year period is taken as 1999 - 2008.

Further details of the approach are presented in Appendix A in the second volume. The most important terms and abbreviations are defined in Annex A in the present volume.

1.2 Study Method

The study method has included establishing comprehensive spreadsheets, with key data for all production installations individually, on the basis of the field and platform names, with main operational features on an annual basis, historically for the period 1988-97, and for the period 1999-2008. These spreadsheets also include known and possible future developments at specific field locations, with an anticipated field development solution. The work has been constructed as interlinked spreadsheets, which allow for quick and efficient conduct of the sensitivity studies.

The existing and future production and exploration wells in the Norwegian sector have been subdivided into four geographical regions. These regions, two of which are found in the North Sea, south of the 62nd parallel and two north of it, are considered to be significantly different with respect to environmental vulnerability. North of the 62nd parallel the fields are in average somewhat closer to shore, the prevailing wind direction is toward the coast, and there are a number of very sensitive areas for breeding of birds. An overview of the regions is as follows:

NSS	Southern North Sea sector (south of 60th parallel), including fields from Valhall in the South, up to Frøy in the North.
NSN	Northern North Sea sector (between 60th and 62nd parallel), including areas Oseberg/Brage, Troll, Veslefrikk, Statfjord, Gullfaks and Snorre.
MN	All areas in the Norwegian Sea, outside Mid Norway (Møre, Trøndelag, Nordland, Vøring)
TR	Barentshavet (Troms) area (Snøhvit and Askeladden are the only fields considered)

For the other activities (i.e. exploration, pipe-laying, installation and decommissioning, use of various types of vessels), named data has not been established, but the activity levels have been modelled with respect to volume, both historically and for the future.

The consideration of risk to personnel in the study is limited to fatality risk, whereas injuries are considered only in a few cases. When fatality risk is considered, there are mainly two categories, occupational accidents and major accidents, including helicopter accidents.

The study has taken a different approach to estimation of risk levels associated with major hazards, which is not based directly on accident statistics. The approach chosen is a ‘risk analysis approach’, i.e. failure frequencies are established for initiating events, and combined with unavailabilities of relevant barriers. These estimates have in some cases increased uncertainty, when there is quite limited operational experience. Nevertheless, this approach is in general considered to give estimates that have the lowest possible uncertainty, fully comparable with estimates that are commonly used in risk analyses.

Further details of the methodology are presented in Appendix D in the second volume. A summary of the main assumptions is presented in Appendix J. Most of the assumptions are also mentioned in the contexts (in Appendices) where they are important.

1.3 Historic and Future Activity Levels

The study has, as previously mentioned, been based on historical records and assumptions about future activities, relating to installations and operations. The details are described in Appendix B. Figure 1 summarises the activity levels, where manhours is the common measure used to characterise historical and future activities. The manhour volumes are based on NPD statistics for production and mobile drilling units, whereas the attendant vessel estimates are derived from the activity levels for production and drilling, as shown in Appendix B. Advice on realistic assumptions regarding future operations has been given by NPD.

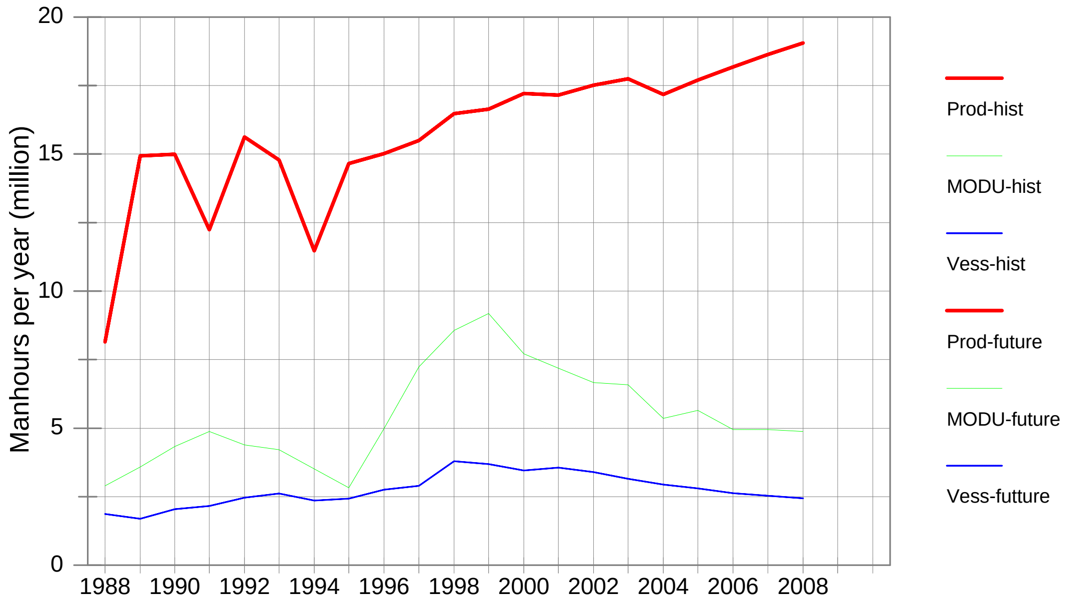


Figure 1 Historic and future manhours in on production installations, MODUs and attendant vessels

The next diagram shows a summary of the well drilling activities historically and in the future.

The historical data is based on NPD official statistics for production well drilling as well as drilling of exploration (including delineation) wells. Future drilling of exploration and delineation wells is based on prognoses made by NPD, implying that there is a considerable reduction over the next ten years.

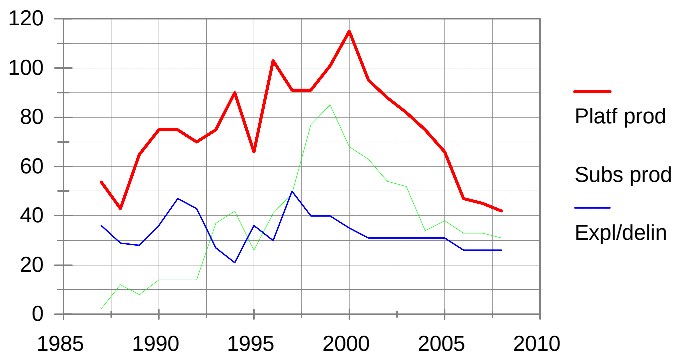


Figure 2 Historical and future drilling activities

Future drilling of production wells is based on assumed field development schemes, but the total is adjusted on the basis of the prognosis by NPD.

Activity levels for shuttle tankers have been based on an extensive study of tanker risk performed by Statoil.

1.4 Use of Risk Estimates

The risk estimates which are used in the present study, are considered to be expected values, rather than conservative estimates which often are used in risk analysis. This is considered appropriate in light of the purpose of the estimations, to present a realistic risk picture.

The present study has used an extensive amount of numbers in order to illustrate offshore safety and emergency preparedness both in the past and in the future. It is in that context vital to note the following:

- The assessment of historic frequencies is the only ***exact*** quantification of accident frequencies which is possible.
- This report presents historic frequencies for the Norwegian sector, which can be used to consider trends and important differences.
- The report presents an extensive quantitative modelling of future risk levels, based on historic levels of failures and accidents. Nevertheless, there is uncertainty about what future risk levels that may be experienced. Sometimes this uncertainty is quite limited, but in other cases rather extensive.
- Risk estimates provide the most explicit quantification of the uncertainty about occurrence of future accidents and related effects. The implication of this view, is that the entire report is about quantification of uncertainty. Therefore, there is no separate quantification of uncertainty presented.
- The report is mainly focussed on fatality risk, fatalities are [fortunately] quite rare, implying that the data basis will always be rather limited.
- The report does not claim that these risk levels should be considered as 'truths', but should be considered as the best educated estimates of future, uncertain risk levels. For example are FAR values for occupational accidents for production installations and mobile drilling units for the future assumed to be equal to the average values for the last ten years, whereas the FAR values for attendant vessels for the future are assumed to be equal to the average value for the last five years.
- The activity levels in relation to production, exploration drilling and use of associated services and facilities have been adjusted based on the current NPD prognoses for such levels.
- The numbers, although to some extent uncertain, may be important in order to illustrate important trends and risk mechanisms.
- Quantitative results should always be considered in relation to qualitative evaluations of the same aspects. An explanation should always be sought when these two approaches do not match.

1.5 Study Implementation and Finance

The work started in mid 1997, and a draft report was presented at the end of 1997. The statistical analyses were updated with experience data for 1997, prior to preparation of the final report in the 3rd Quarter of 1998.

The work has been financed by Elf Petroleum Norge, Norsk Hydro, Norwegian Petroleum Directorate, Saga Petroleum, Statoil and Preventor.

2 Summary of Trends - Risk to Personnel

The details of the assessment of risk to personnel are presented in Appendix E (in the second volume) and (for sensitivity studies) Appendix H.

There has been 79 fatal accidents and 265 fatalities in Norwegian offshore operations since the start of oil and gas operations in 1966. This excludes fatalities on shuttle tankers, but includes fatalities on attendant vessel and other special vessels and barges that are used. Figure 3 shows a condensed summary of the development since the beginning of the operations in mid 1960-ties.

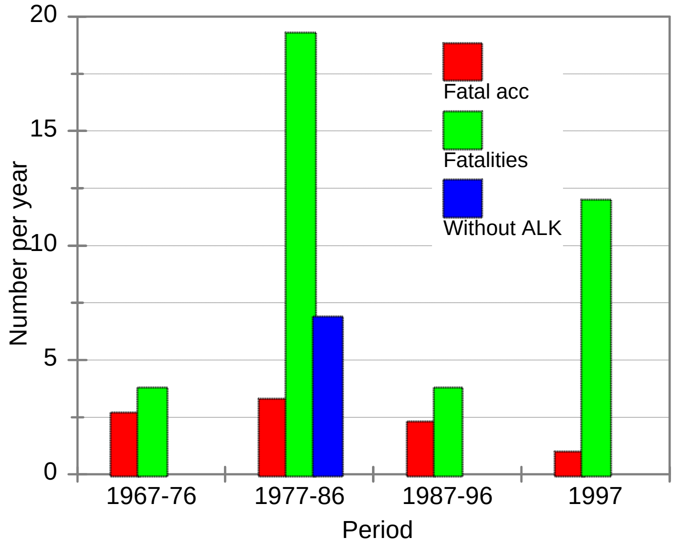


Figure 3 Overview of fatal accidents and fatalities

It should be noted that Figure 3 does not relate the number of accidents to the level of activity. This is done later in this section. The frequencies are presented for three ten year intervals, (plus 1997 separately, i.e. the helicopter accident) where the following is shown for each interval:

- Average number of fatal accidents per year
- Average number of fatalities per year

The second period is strongly influenced by the capsize of Alexander L. Kielland in 1980. The average number of fatalities per year is 19.3 if this accident is included, 6.9 fatalities per year if excluded (see distinction made in the diagram).

2.1 Overview of Accidents to Personnel

The total number of fatal accidents in the period 1988 - 97 is 18 fatal accidents with 33 fatalities. These fatal accidents on the Norwegian continental shelf have occurred on the following different platform and vessel types:

Fixed platforms:	5 fatal accidents	6 fatalities
Mobile platforms:	5 fatal accidents	5 fatalities
Attendant vessels:	5 fatal accidents	6 fatalities
Crane and pipe-laying vessels:	1 fatal accident	1 fatality
Diving:	no fatal accidents	
Helicopter accident (platform maintenance):	1 fatal accident	3 fatalities
Helicopter transportation (shuttling to shore):	1 fatal accident	12 fatalities

Accidents that have occurred inshore or atshore are excluded from the values considered in the report, even though in some few cases similar accidents could have occurred at an offshore location.

2.2 Fatal Accident Rates

This section presents historic FAR levels for occupational accidents (except helicopter risk), thus based on exposure in terms of working hours for all personnel onboard, i.e. 12 hours of exposure per 24 hours of offshore stay. The following are estimates of FAR levels in the period 1988-97:

C Fixed installations	2.8	fatalities per 100 mill. manhours
C Fixed installations, including helicopter accident with three fatalities, associated with flare tip replacement	4.2	fatalities per 100 mill. manhours
C Mobile drilling units	12.7	fatalities per 100 mill. manhours
C Attendant vessels	26.3	fatalities per 100 mill. manhours
C Crane and pipe-laying vessels	20.7	fatalities per 100 mill. manhours
C Diving	0	fatalities per 100 mill. manhours
C Helicopter transport	160	fatalities per 100 mill. person flight hours
C Total for all (including helicopters)	10.5	fatalities per 100 mill. manhours
C Total (excluding attendant vessels and helicopters)	4.2	fatalities per 100 mill. manhours

No diving accidents have occurred in the period. Diving is therefore not included in any of the values given above. Except in the case of the helicopter accident in 1997 the values are limited to occupational accidents, due to the fact that no major accident with fatalities had occurred. A true risk picture therefore needs to consider additional ways to estimate risk levels. This is done for the estimation of risk for the period 1999-2008.

2.3 Trends in Fatality Rates

An important aspect of the study has been to identify possible trends in historic fatality risk levels, in order to identify areas or operations where special efforts may be necessary. Trends are based on activities which are limited to the activity which takes place **on** the installations/vessels itself. Thus fatalities on Alexander L. Kielland are excluded. These trends are established separately for production installations, mobile drilling units and attendant vessels.

The fatal accidents are few in number. If just annual values were analysed, very considerable variations would have resulted, probably without the possibility to identify clear trends. The analysis has therefore been based on **rolling ten year averages** for the last ten years, (i.e. a 20 year period is considered in total) where an average FAR value is calculated based on fatalities and estimated exposure manhours (in the case of production, these values are available from NPD. For the other activities, the values are mainly derived from activity levels). The values include all fatalities that have occurred in the period. The following three diagram show two curves:

C Actual ten year rolling average values calculated for each year in the period,

- Trend curve, based on linear trend analysis.

The following diagrams are presented below:
- Figure 4 Production installations
- Figure 5 Mobile drilling units
- Figure 6 Attendant vessels

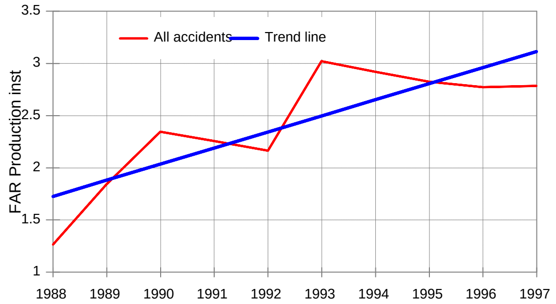


Figure 4 Trend in ten year average FAR values for production installations

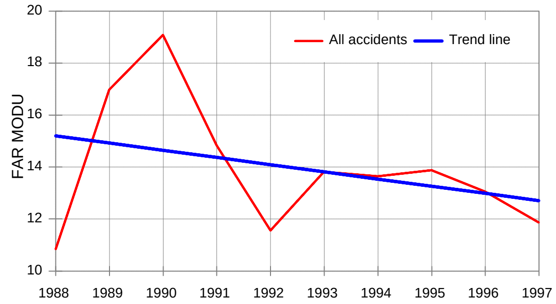


Figure 5 Trend in ten year average FAR values for mobile drilling units

For production installations, there is an increasing trend over the last ten years. If the period is split in two five year periods, there is clear increase until 1993, after which the trend is slowly falling. No fatalities occurred on production installations in 1996 and 1997.

For mobile drilling units, there are considerable variations, but the trend analysis gives a slowly falling trend over the period.

For attendant vessels, the trend is actually the clearest, in the sense that the annual ten year averages and the analysed trend line all give an increasing trend.

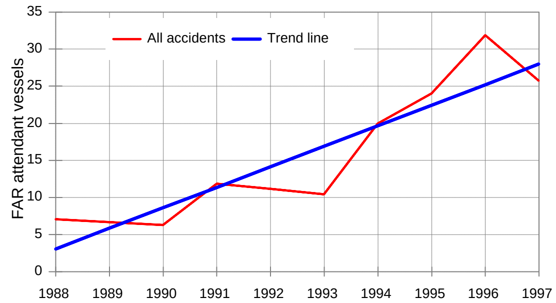


Figure 6 Trend in ten year average FAR values for attendant vessels

It could be noted that if the trend analyses are repeated based upon **five** year rolling averages (as opposed to ten years which is used in the diagrams above), then the following trends result (not shown in the diagrams):

- Marginally increasing for production installations after 1993
- Clearly decreasing for mobile drilling units after 1993
- Strongly increasing for attendant vessels after 1993

What do these trends imply for expected future risk levels? This is uncertain, and will also depend on actions that are taken by all parties involved. It should be noted that taking the value calculated for the last year in the period, actually implies taking an average over the last ten years, due to the rolling average calculation. Taking this average may be too optimistic, where there is a clearly increasing trend. Where the trends are close to constant, this may be more realistic.

On this basis, it has been chosen to assume **constant trends in the future**, based upon the average of the last ten years for production and mobile drilling installations. In the case of the attendant vessels, a value reflecting the average over the last five years is chosen, a FAR value of 39.4 per 100 mill manhours.

2.4 Risk Levels for Drilling Crew

Section 2.2 demonstrates clearly that there is a considerable difference between production installations and Mobile Drilling Units. This difference may be further exemplified by comparison of fatal accident levels for drilling crews on fixed installation, (including TLP) and MODUs.

Appendix D has reported a fatality risk level for drilling/well operations personnel on production installations (so far involving fixed platforms and two TLPs), equal to:

5.0 fatalities per 10^8 manhours (for the period 1988 - 97)

Similarly an assessment for MODUs, will reflect that all personnel who have suffered fatal accidents on MODUs have been drilling crew members. This gives a considerably higher FAR level as follows:

21.1 fatalities per 10^8 manhours (for the period 1988 - 97)

The value for MODUs is thus well over four times higher than the level which applies to production installations. It should be noted that the difference between injury rates for drilling the crews on production and mobile drilling units are considerably more limited, around 30%.

2.5 Risk Level for Helicopter Transport

The Helicopter Safety Study (by SINTEF, 1990) estimated a fatal accident level of:

$3.8 \cdot 10^{-6}$ per person flight hours

The present study has divided the accident frequency in separate values for cruising and landing/takeoff, but a comparable value may be given as:

$1.6 \cdot 10^{-6}$ per person flight hours

This may seem as a considerable reduction in fatal accident frequency, but there are several factors that need to be given consideration in this context:

- The SINTEF study covered the period 1969-89. It has been documented in the report that the period 1975-86 was a period with more than 125 fatalities in helicopter accidents in the North Sea. After 1986 only two fatal accidents with 23 fatalities occurred until the end of 1997.
- The impact from the period 1975-86 was considerable in the Helicopter Safety Study, but the study did not attempt to consider if any trends could be identified, or whether there was basis for making distinctions between Norwegian and UK operations.
- It is an established fact that improvements were introduced in the helicopter operations in the 1980-ties because of the accidents, reduction in accident frequencies would be expected.
- The SINTEF study is being updated in 1998, but this is not available at the time of completing the present study.

It might be argued that taking a ten year period after the period with the high number of fatalities leads to too optimistic an estimate. However, it would be impossible to define how much of the earlier period that would need to be included to avoid the optimism. It is also noted that one of the most severe helicopter accidents in the Norwegian sector (in 1997) is included in the period which is considered in order to establish a historic risk level.

2.6 Comparison Offshore - Onshore Activity

A brief comparison has been made between the average offshore fatality risk level and the most similar onshore activity, namely onshore oil refineries. The comparison is based on actual occupational risk during the last ten years, and has been restricted to offshore production installations, which are considered to be closest to refineries.

All estimates are based on actual working hours, i.e. 12 hours per day offshore, and 7.5 hours per day onshore. The total number of working hours per year should be about the same per person, for both industries.

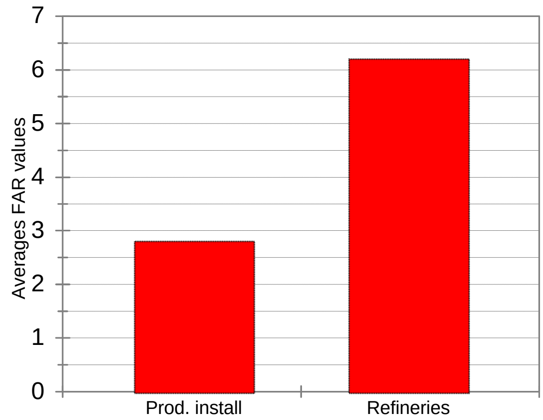


Figure 7 Comparison of occupational risk levels for offshore production installations and onshore refineries

Two fatalities and 619 injuries have been reported for refineries in the period 1988-97, corresponding to six fatalities and 5,855 injuries on offshore production installations. It should be noted that the number of working hours in the ten year period are very different in the two activities, 32.2 vs 215.5 million hours, respectively for refineries and offshore production installations.

The Norwegian Directorate for Labour Inspection is generally faced with low reporting reliability, to the extent that they often consider that they only receive about 25% of the actual number of accidents. The refineries report also to this directorate, but are in contrast to the general trend, considered to be considerably more reliable with respect to reporting. No adjustment of the reported values is therefore required. The reporting of fatalities is in any case likely to be reliable, which is a second reason why no adjustment is required.

Figure 7 presents a comparison between ***fatality rates***. Also ***injury rates*** have been briefly considered. The average number of injuries per million manhours are relatively similar for the refineries and production installations. Different definitions of “injury” may influence such comparison significantly. Further, the decline of injury rates in refineries over the ten year period may also be influenced by reporting reliability. This observation is therefore disregarded.

Figure 7 shows that the average FAR value in refineries is a factor of 2.2 higher than the average FAR value on offshore production installations. The difference is clearly visible in the diagram, but not significant in a statistical sense, due to the [fortunately] low number of fatal accidents.

It is considered that offshore production installations and refineries generally are quite similar with respect to occupational hazards, if anything, the offshore installations should be more exposed to falls from a higher to a lower level, because refineries generally are more laid out on the ground level, where the offshore installations have modules stacked on top of each other and several floor levels. Thus, the results give some indications that safety management is implemented more effectively offshore compared to similar onshore industry.

3 Future Risk Levels - Personnel

3.1 Future Overall Fatality Risk Levels

This presentation is split in two:

- Initially all offshore activities except shuttle tankers are discussed.
- Risk for crew members on shuttle tankers is presented separately at the end of this subsection.

Figure 8 is different from the previous illustrations in two respects, first of all because it applies to the future. Secondly, estimates of occupational risk as well as major accident risk and transportation risk are included.

The diagram presents a summary of future fatality risk levels for personnel on production installations, Mobile Drilling Units and attendant vessels. These estimates are based on **average** values from the previous period, as discussed in Section 2.3, on Page 7.

The occupational and transportation risk elements are based on previous levels, whereas the major accident risk estimation is performed on the basis of on a concept generic failure frequency estimation.

The values shown in Figure 8 are based on total annual offshore exposure, i.e. 24 hours of exposure per 24 hours of offshore stay. This is required in order that the contributions from the different activities may be added. The values are therefore half of what is shown on Page 6.

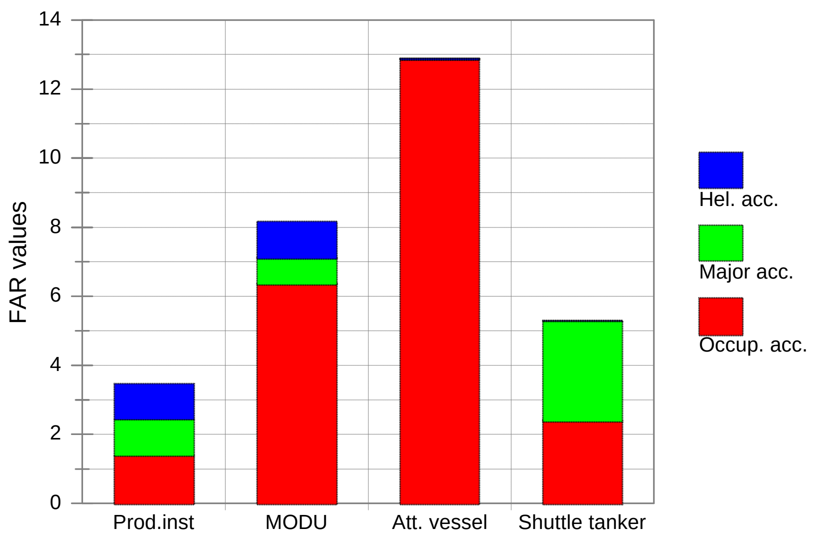


Figure 8 Fatality risk levels for installations and vessels, 1999 - 2008

The most extensive differences are related to occupational accidents, the level on MODUs is 4.6 times higher than on production installations. On attendant vessels, the occupational risk level is 9.3 times higher than on production installations.

The FAR value for all shuttle tankers is reported as 5.3 (fatalities per 10^8 manhours), corresponding to an annual average of 0.10 fatalities per year, or 1.0 during a ten year period. Occupational accidents contribute with 45% of the total FAR value.

3.2 Comparison of past and Future Risk Levels - Risk to Personnel

Figure 9 shows a comparison of the number of fatalities in the previous ten year period, compared with projection of fatalities in the coming ten years.

The prediction of future fatalities has been shown in two different ways:

- 'Future' prediction, reflection of changes in extent of exposure as well as possible changes in frequencies.
- 'Adjusted future', where the prediction is adjusted to reflect what would be the case if the volume of activities is the same as in the past.

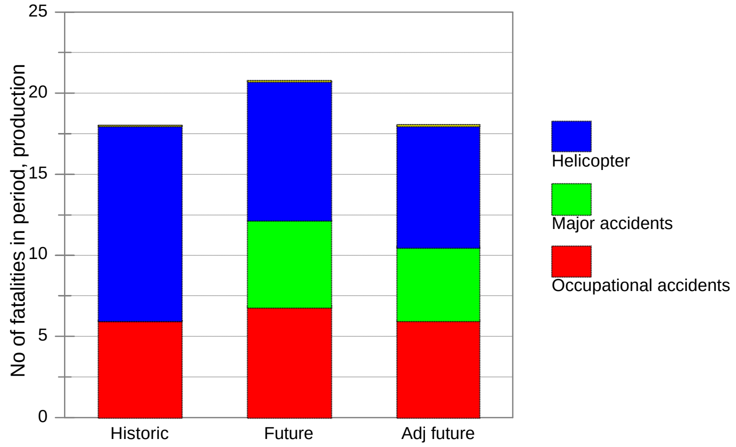


Figure 9 Historic and future number of fatalities on production installations

The adjustment has been based on a slight simplification, in the sense that the number of manhours in the activity is taken to be the same.

If a comparison is made between the historic values and the adjusted future level, then this also shows how a comparison of the FAR values would appear.

In the last ten years, only occupational fatalities have occurred on production installations. The 1997 helicopter accident occurred during platform installation and commissioning, but is nevertheless associated with the production installations.

Figure 10 shows a similar comparison for mobile drilling units. The principles used for the illustration are the same as used for Figure 9.

Occupational accidents are the only fatal accidents that did occur in the previous ten years.

The increase in activity is the main reason why the expected number of fatalities is higher in the future.

Other sources are major accidents and helicopter accidents, which both are unlikely to happen on mobile units.

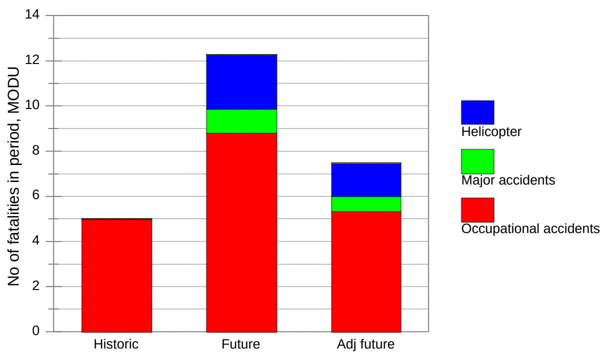


Figure 10 Historic and future number of fatalities on MODU installations

Figure 11 shows a similar comparison for attendant vessels. The principles use for the illustration is the same as used for Figure 9.

Occupational accidents are the only fatal accidents that did occur in the previous ten years.

The expected type of accidents in the coming ten years are also occupational accidents.

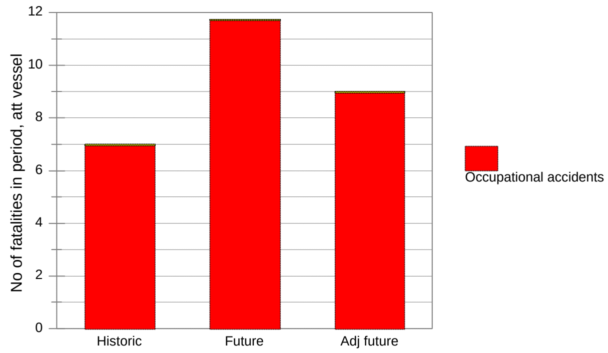


Figure 11 Historic and future number of fatalities on attendant vessels

The reason for the adjusted future being higher than in the previous period, is the fact that the frequency of occupational accidents has been increasing for a number of years. This has been reflected in the estimates.

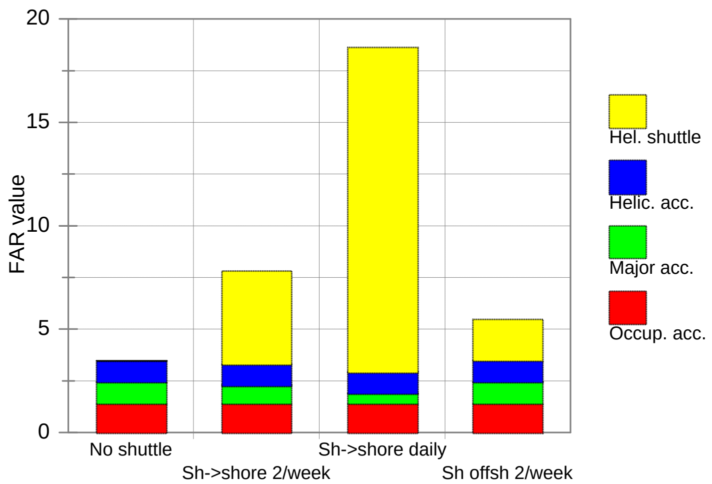
Two activities are not covered in the presentations of future risk levels, diving and barges used for crane operations and pipe-laying (see Appendix E for details). These may be characterised as follows:

- No diver fatalities occurred in the past ten years, whereas 0.8 fatalities are predicted for the future ten years, in spite of the future activity level being about half of the level during the past ten years.
- One fatality occurred on pipe-laying vessels in the past ten years, corresponding to the same value predicted for the future ten years.

3.3 Sensitivity Studies

There are two types sensitivity studies that have been carried out:

- Overall findings have been substantiated by sensitivity studies, which are carried out in order to illustrate the importance of the most critical assumptions made.
- Sensitivity studies are also used in order to illustrate the effect of certain changes to operations or emergency preparedness that could be considered for the future.



The presentation in this section is limited to the second category of sensitivity studies. Appendix H presents more extensive sensitivity studies.

The study has demonstrated the critical effects on the risk levels for

Figure 12 Comparison average FAR values for an offshore worker according to extent of shuttling performed the persons involved, when extensive shuttling to shore is performed, during for instance installation and commissioning of new facilities. The diagram considers the average annual FAR level for an offshore employee, according to the extent of offshore shuttling that the person is exposed to:

i. No shuttling.

ii. Shuttling to shore twice per week (75 minutes per trip).

iii. Shuttling to shore daily.

iv. Shuttling to a nearby installation offshore twice per week (20 minutes per trip).

It may be noted that all estimates include risk due to helicopter transport to shore. It may thus be observed from the levels demonstrated here, that helicopter associated risk is important for the overall risk level for offshore employees.

The diagram shows the considerable increase of risk to an employee who is shuttled either to shore or to another installation regularly. Even for shuttling twice per week the increase is significant, the total risk is doubled if the shuttling is twice per week to shore. If the shuttling is daily, the total risk increases by nearly a factor of 5.

It should be noted that the risk estimates that are considered here include the transport from shore to the installation, which is often excluded when concept or operational alternatives are compared. The influence of shuttling would obviously have been even more extensive if this approach had been chosen.

Finally, it could be noted that another aspect of shuttling has been shown to be favourable with respect to reduction of risk, when an installation is demanned and permanent manning is replaced by visits paid by personnel who are shuttled from a nearby installation. This reflects the fact that a significant reduction in exposure to offshore risk, offsets by far the increase due to more helicopter flight risk. The differences are illustrated by a numerical example in Appendix H, Section H4.

4 Summary of Trends - Risk to Environment

The details of the assessment of risk to the environment are presented in Appendix F (in the second volume) and (for sensitivity studies) Appendix I.

4.1 Blowout Risk

There has been no oil spill in the Norwegian sector in the period 1988 - 97exceeding 1000 m^3, and no blowouts involving surface release of other fluids than gas from shallow gas pockets. The overall estimated frequency of oil blowouts in the period 1988 - 97 was 0.30 which corresponds to a probability equal to:

0.26

that there should be an oil blowout in the period.

It may be an obvious contention that this is a strong indication that the generic blowout frequency estimates that are used are overly pessimistic. This is however, not possible to ascertain. It follows from the values stated that the probability for no oil blowouts in the period has been estimated to 75%.

Blowouts from subsea wells are likely to play a more prominent role in the future, compared to what was the anticipated contribution in the period 1988 - 97. This is due to several factors, most importantly the considerable increase in the number of subsea wells and operations expected in the future. Secondly, the likelihood of blowout is to some extent higher for a subsea well, and the average duration of a subsea blowout is longer, due to the time needed to control the flow.

It is also shown that the frequency of blowouts increases quite significantly in the future, to an expected value of 0.58 for the period 1999 - 2008, corresponding to a probability that an oil blowout shall occur:

0.44

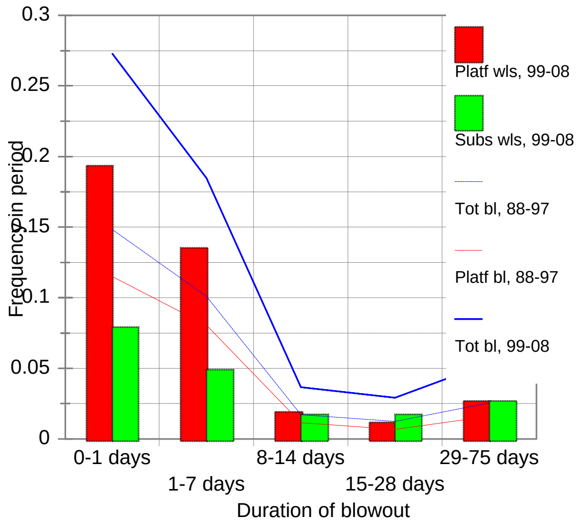


Figure 13 Contributions to oil blowout spill risk

For the assessment of environmental damage, the following categories of recovery is used:

- No damage: Recovery < 1 month
- Minor damage: Recovery 1 - 12 months
- Moderate damage: Recovery 1 - 10 years
- Serious damage: Recovery > 10 years

The diagram shows the distributions for recovery categories for the four regions that are considered separately, as well as the total value.

The regions “North Sea North” (“Tampen” area, blocks between 60th and 62nd parallel) and “Mid Norway” are the highest contributions to the environmental damage risk. The diagram indicates that the “Mid Norway” region is considered to be most vulnerable to severe environmental damage. This implied by considering that the [blue] curve for the Mid Norway region is the “flattest” in all intervals, most notably for recovery exceeding 10 years. Further details are presented in Tables 6-10 in Appendix F.

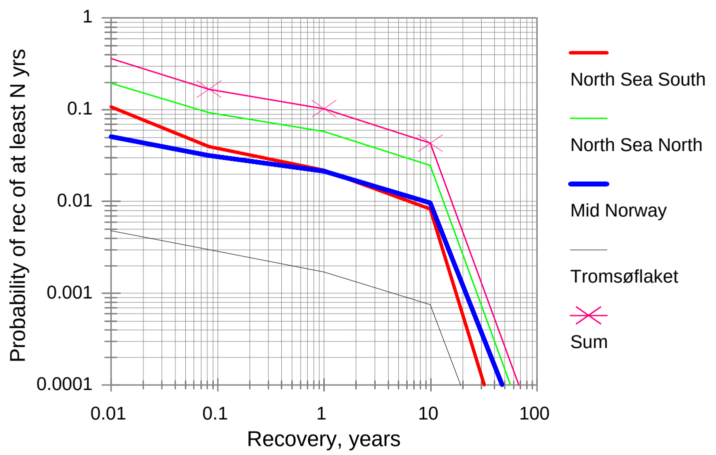


Figure 14 Recovery exceedance distribution for oil blowouts, 1999 - 2008

4.2 Contributions to Oil Spill Risk

The diagram shows the contributions to the spill damage categories from all different sources that have been analysed. The risk due to shuttle tankers is limited to the contributions from the 'non-refinery' shuttle tanker operations, as the supply to the refineries are not considered as 'offshore operations'.

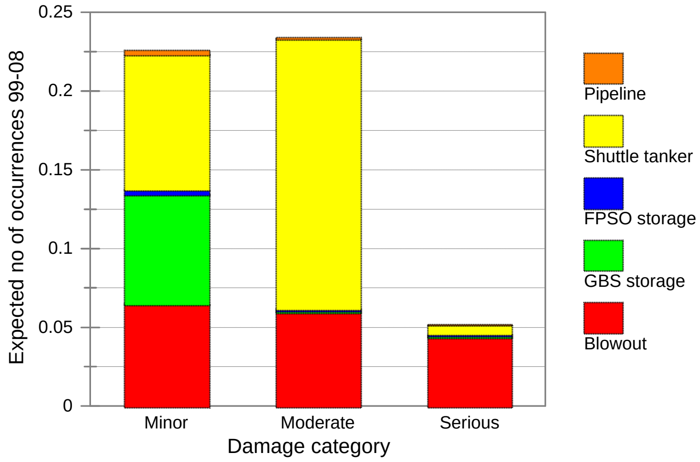


Figure 15 Contributions to oil spill risk

The main contributors are generally shuttle tankers, GBS storage and blowout. Blowout is the dominating contribution for the most serious environmental damages. For the contributions that are invisible in the diagram, the following expected number during the ten year period apply for minor, moderate and serious damage respectively:

- Pipeline: 3.6; 1.5 and 0.57, all · 10^{-3}
- FPSO storage: 2.1; 0.95 and 0.46, all ·10^{-3}

The risk contributions from shuttle tankers has been based on a risk assessment of tankers performed by Statoil. The scope of that study is slightly different from the present study in two respects:

- The study covers all shuttle tanker transport on behalf of Statoil, which is 95% of all activities from Norwegian fields.
- Also damage to areas outside the Norwegian sector from shuttle tankers that carry Norwegian cargo is included in the study, this has however been eliminated from the values used.

5 Summary of Trends - Risk to Assets

The details of the assessment of risk to assets are presented in Appendix G in the second volume.

The diagram shows the contributions to asset risk for the two most severe damage categories. The higher contribution from floating production installations in the future is quite obvious. This is mainly due to an extensive increase in the usage of floating production installations.

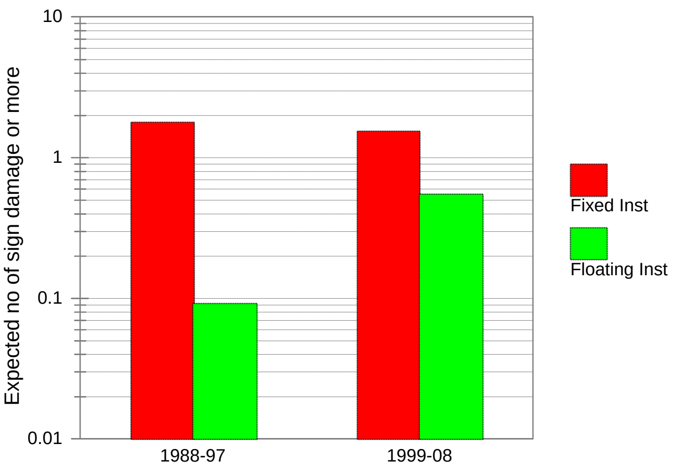


Figure 16 Asset damage frequencies for fixed and floating production facilities

The expected frequency of severe asset damage is expected to be virtually unchanged (around 2 during the ten year interval) also in the future, the increase for floating production systems is actually not as significant in absolute terms as it might appear, due to the logarithmic scale.

The contributions to the number of significant and severe damages as well as total loss, are shown in Figure 17 for production installations.

The characterization of asset risk is made by means of four broad categories according to the physical extent of damage (corresponding to 'WOAD categories') where only the three most severe categories have been addressed. As expected, the "significant" category (one module damage) is the highest contribution. With the uncertainty involved in this classification, it could be argued that the expected frequency has been around one event per year.

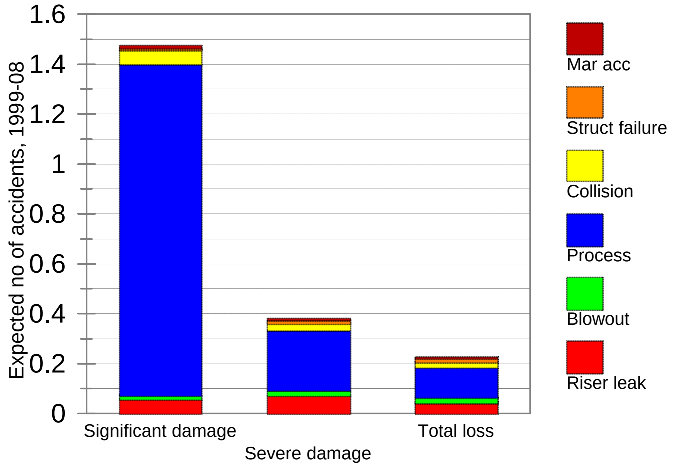


Figure 17 Contributions to asset risk for production installations, 1999 - 2008

Fire and explosion incidents caused by hydrocarbon leaks from process systems dominate for significant damage cases. Blowouts are shown to be more important for the higher damage cases.

Figure 18 shows a summary of the expected number of accidents with significant material damage to mobile drilling units in the period 1999 - 2008. It is demonstrated very clearly that the overall risk level is dominated strongly by the blowout risk.

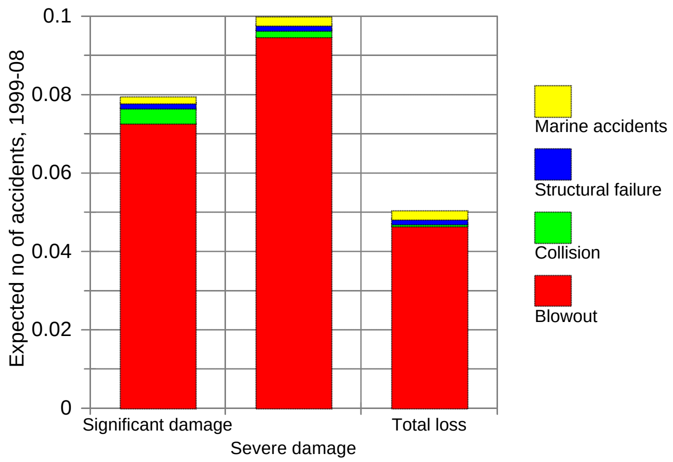


Figure 18 Contributions to asset risk for MODUs, 1999-2008

6 Overall Conclusions

6.1 Risk to Personnel

6.1.1 Implications of Assumptions

The consideration of how past trends are applied to future estimates was discussed in Section 2.3, where it was concluded that the average for the last ten years periods is appropriate to use for production and mobile drilling installations, whereas the average for the last five years periods is appropriate for attendant vessels.

A focussed effort by all involved parties is required, in order to discontinue the trends that have been observed from the last ten years. This is the important implication of the assumption in Section 2.3.

6.1.2 Important Conclusions

The study has shown that the overall risk level on the Norwegian Continental Shelf appears to be slowly increasing during the last ten years. The risk levels referred to here, are all related to occupational accidents. The only other accident is the helicopter accident in 1997. Such accidents are obviously so rare that trends can not be determined unless a very long period is considered.

When production installations are considered alone, some reduction of the risk level may be observed over the last five years. The average risk level for these installations is the lowest, and has been shown to be considerably lower than corresponding onshore activity.

For mobile drilling units the risk level is stable over the last ten years. However, the average FAR value on mobile drilling units is 4.6 times higher than that of production installations.

With respect to attendant vessels, when considered over the last ten years, a clear increase in the overall risk level has been experienced. Further, the average FAR value for attendant vessels is about 9.3 times higher than that of production installations.

The higher fatality levels on mobile units and vessels is important for future activities in the Norwegian sector, in relation to development of deep water and marginal fields. Use of floating production systems implies in addition to the floating production unit, also increased use of mobile drilling units and associated vessels.

When it comes to the floating production installations, there are indications that occupational hazards due to movements etc. are not very important for the overall risk levels.

The study has as noted in the introduction (see Page 2) taken a 'risk analysis approach' to estimation of risk levels associated with major hazards. These estimates show higher total loss frequencies for FPSO concepts, when compared to fixed installations. The operational experience is quite limited with FPSOs with the active turret concept as used in the Norwegian and UK sectors, implying that the total loss frequency for this concept is more uncertain than in the case of fixed installations, which has a considerable experience basis. Further details about the frequency estimates are presented in Appendix D. The higher estimate of the total loss frequency for the FPSO concept is mainly due to operational hazards, and to a lesser extent, the marine hazards. The sensitivity studies imply that such increased frequencies of total loss of FPSO systems have relatively high importance for the average risk level for personnel working on these production systems. Further details about the sensitivity studies are presented in Appendix H.

6.2 Environmental Risk

The study has shown that risk from tanker transport of crude oil is the dominant contributor to environmental risk, especially for environmental damage up to moderate levels. Considerable effort should therefore be devoted to risk control during tanker transportation to shore.

The second most important contributor is from blowouts. Blowouts may in fact be more important than tanker transportation in a risk perception context.

The overall findings with respect to the risk of environmental damage from blowouts is that the Mid Norway region (from the 62nd parallel up to Vesterålen, see Appendix D.) will be the most critical in the future. This is due the high vulnerability of resources along the coast, the fact that some of the future field developments will take place quite near the coast, and the extensive use of subsea production wells which are considered to increase the average duration of a blowout, due to more complex control being required.

It is also indicated that the possible use of multi bore wells may contribute significantly to increased environmental risk, especially North of the 62nd parallel. When it was assumed that half of the new wells were being completed as multi bore wells, the blowout risk in the two northern most regions increased by 45% and 64%, respectively. The underlying assumption was that the duration of the blowout would increase by six days, and a minor increase of the rate of the spill.

It has been shown that improvement of the oil spill contingency will be crucial in the future. This is especially true in the two northern most regions.

Annex: Definitions, Terms and Abbreviations

Term	Definition/Interpretation	Comments
AIR	Average Individual Risk	
Attendant vessels	Taken to include standby vessels, supply vessels and anchor handling vessels	
Environ-mental damage	Direct or indirect reduction of one or several resources resulting from an accidental spill, measured in terms of recovery	
FAR	Fatal Accident Rate Fatalities per 10^8 exposure hours	Exposure hours may be based on 'on-shift' hours (12 per day) or both 'on-' and 'off-shift' hours (24 per day). The exposure hours may also relate to the entire manning complement or groups within this total, such as all personnel in so-called 'hazardous areas'. The basis for the calculation should be stated when such values are used.
Floating production unit	Includes FPSOs (see below) and other floating production units of semi-submersible type, including TLPs.	The TLP units are in some respects considered as 'fixed' installations, this is noted separately where relevant.
FPSO	Floating Production, Storage and Offloading unit	Implies use of a monohull, i.e. tanker shaped vessel.
Intervention	Is taken to imply all activities conducted in production wells other than wireline and coiled tubing operations.	
MODU	Mobile Drilling Unit	
NPD	Norwegian Petroleum Directorate.	
Personnel risk	Risk to employees on offshore installations and vessels involved in offshore operations.	The study is mainly limited to fatality risk.
QRA	Quantitative Risk Assessment	
Recovery (duration)	Time required before a resource has recovered to the population level or condition prior to the spill, considerations given to natural variations.	The recovery time for at least one of the affected resources must be at least 1 month for the effect to be classified as environmental damage.
Risk	Expression of probability for and consequence of one or several accidental events.	

Risk analysis	Analysis which includes a systematic identification and description of risk to personnel, environment and assets.	
Risk to assets	Risk for damage to structures and/or equipment	Limited to effects of accidents, i.e. events which may cause injury to personnel or environmental damage
Risk to Environment	Risk for damage to environmental resources	Limited to accidental spills
Special vessels	Includes vessel types such as diving vessels	
TLP	Tension Leg Platform	
WOAD	Worldwide Offshore Accident Databank	Annual 1994 report used