Chapter 13
Helicopter Transportation Fatality Risk Assessment

13.1 Overview

When offshore operations started in the North Sea, there were three severe accidents within a few years (1973, 1977 and 1978) in the Norwegian sector, with 34 fatalities. This created a high awareness level in the Norwegian offshore industry, as well as in unions and among employees. The UK sector had a series of fatal accidents in the early 1980s, which culminated with an accident with 45 fatalities when a Chinook crashed just before landing in Sumburgh on Shetland in November 1986. This accident caused the complete abandonment of the Chinook helicopter in offshore operations in UK the and Norway.

The high attention in Norway on the risk during helicopter transportation to offshore fields has led to several initiatives over time. The first initiative was the initiation of a series of Helicopter Safety Studies (HSSs), of which the latest is HSS3 (SINTEF 2010). These studies are conducted once every 10 years.

Helicopter transportation safety in offshore flying was also the topic of an official Norwegian White Paper in 2002 (Norwegian official report 2002), which proposed ambitions and actions for a significant reduction in risk levels. A safety advisory group for helicopter safety on the NCS has also been formed (CAA 2007) with representatives from supervisory and air traffic control authorities, helicopter operators, oil companies and unions for offshore employees.

Helicopter operators in Norway have been quick to replace old helicopters with new models as soon as they have become available. This is believed to be to some extent because of the high attention on these issues, but also the fact that some of the largest oil companies have requested modern helicopters in bidding for their transportation contracts. Norwegian companies have also employed more sophisticated preventive maintenance schemes.

There has only been one helicopter accident in Norway associated with the offshore transportation of personnel since 1978, when a Super Puma crashed into the Norwegian Sea in September 1997. It should be noted that the accident in August 1991 when a helicopter crashed into the sea in the Ekofisk field is not counted as a transportation accident, as the helicopter was used in the maintenance

J.-E. Vinnem, *Offshore Risk Assessment vol 1*, Springer Series in Reliability Engineering, DOI: 10.1007/978-1-4471-5207-1_13,

of a flare tip on one of the Ekofisk installations, with fatal outcome for the three persons on board.

The accident in 1997 involved people being shuttled daily between accommodation onshore and the FPSO installation during the commissioning phase, because of insufficient accommodation capacity in this phase. This accident put considerable focus on the significant risk increase employees were being exposed to, if shuttled between offshore installations or between an offshore installation and onshore on a daily basis. The volume of shuttling has been reduced significantly since then.

Safety standards have not improved correspondingly in UK offshore helicopter operations, and there are significant statistical differences between the UK and Norway when it comes to FAR.

Fatal accidents have continued to occur outside Norway during the past 15 years, and there have been recent fatal accidents during the transportation of personnel offshore in both the UK and Canada. We therefore propose different fatality rates for the UK and Norway in this chapter.

However, it should be emphasised that helicopter transportation is not risk free in the Norwegian sector either. There have been several near-misses the past 10 years, for instance when one of the main blades was almost 75 % fractured from a foreign object in 2002 and the helicopter was lucky enough to find a nearby tanker onto which it could make emergency landing. The values in Chap. 17 also demonstrate that helicopter transportation risk is still the highest contributor to offshore employees' risk levels in Norway.

This chapter builds on previous work, such as Vinnem and Vinnem (1998) and Vinnem (2008), in addition to the following studies: HSE (2004), SINTEF (2010) and Heide (2012).

13.2 Accidents and Incidents—Offshore Northwest Europe

This section provides a brief overview of the helicopter accidents and incidents in the UK and Norwegian sectors since 1990. Table 13.1 presents the accidents and incidents that have occurred, mainly based on HSS3 (SINTEF 2010). There is one difference with respect to the HSS3 study, namely precursor events; i.e. when flights could return to land or the installation, which are not included. Experience from the Risk Level project (PSA 2012) has demonstrated that the list of precursor events included in HSS3 is not complete. The two occurrences in Holland were found on company webpages.

An accident offshore Newfoundland, Canada in 2009 can be added to the incidents and accidents in Table 13.1. A warning light for main gearbox lubrication failure came on 13 min after levelling off at a cruising altitude of 9,000 ft. The crew declared an emergency, started to return and descend to 800 ft, believing they had 30 min of emergency lubrication available. 10 min later they crashed with high force in the sea. Two pilots and 15 passengers died of drowning, and one

Table 13.1 Overview of helicopter accidents and incidents, UK, Holland and Norway, 1990–2012

Years	Country	Helicopter type	Fatalities/injuries/survivors	Location	Short description	Primary cause	Flight phase
1990	UK	S-61 N	6/0/7	Brent Spar	While manoeuvring to land on the helideck, the tail rotor struck a crane. Aircraft descended onto the helideck and fell into the sea where it sank rapidly	HOF	Landing
1992	UK	AS332 L1	11/1/5	Near Cormorant A	Aircraft taking pax from platform to flotel 200 m away. Access Bridge had been lifted because of adverse weather. Aircraft departed and then turned downwind with insufficient airspeed and descended rapidly into the sea and sank	HOF	Take-off
1995	UK	AS332/L2	0/0/18	Cruising to Brae A	Controlled emergency landing caused by lightening damaged the tail rotor	Environmental	Cruising
1996	Norway	S-61 N	0/0/16	Crusing to Ula/Gyda	Controlled emergency landing caused by strong vibrations when main rotor blade failed	Fatigue cracks	Cruising
1997	Norway		12/0/0	Cruising to Norne	Failure of shaft to MGB caused helicopter to disintegrate	Technical	Cruising
1997	Holland	AS332/L2	0/0/8	Cruising from L7 to Dan Helder	Controlled emergency landing (20 Dec 1997)	Unknown	Cruising
2002	UK	S-76	11/0/0	Leman field	Rotor blade failure during approach to platform. Aircraft went out of control and crashed into the sea	Main rotor blade failure	Approach
2002	Norway	AS332/L2	0/0/16	Crusing from Sleipner to Sola	Strong vibrations because of severe damage to main rotor blade, caused emergency landing on nearby tanker	Main rotor blade damage	Cruising
2006	Holland	AS332/L2	0/0/17	SAR flight from Den Helder Apt	Controlled emergency landing because of abnormal engine indications	Technical	Cruising
2006	UK	SA365 N	7/0/0	Close to North Morecambe platform	When preparing to land on the North Morecambe platform in the dark, the helicopter flew past the platform and struck the surface of the sea. The fuselage disintegrated on impact and the majority of the structure sank	HOF	Landing

(continued)

Table 13.1 (continued)

Years	Country	Helicopter type	Fatalities/ injuries/ survivors	Location	Short description	Primary cause	Flight phase
2008	UK	SA365 N	0/0/7	During landing on helideck	Aircraft tail hits crane during landing on helideck	HOF	Landing
2009	UK	EC-225	0/0/18	ETAP field	Controlled ditching close to installation. All onboard escaped safely, rescued by a SAR helicopter and a 'Daughter craft'	HOF	Approach
2009	UK	AS 332L2	16/0/0	Cruising from Miller to Aberdeen	Catastrophic failure of the MGB because of fatigue	MGB technical failure	Cruising
2012	Norway	EC-225	0/0/21	Cruising from Halten bank to Kristiansund	Controlled emergency landing when a warning light for low hydraulic pressure came on	Unknown technical	Cruising
2012	UK	EC-225	0/0/14	30 miles east of Aberdeen	Controlled emergency landing when a warning light for low hydraulic pressure came on	Unknown technical	Cruising
2012	UK	EC-225	0/0/19	32 nm south of Shetland	Controlled emergency landing when several alarms started to indicate low hydraulic pressure	MGB technical failure	Cruising

passenger survived 80 min in the sea before being rescued with severe injuries. None of the emergency locator beacons in the helicopter, on the rafts and personal locator beacons worn by crew and passengers had activated in this accident. There was also a problem with the personal locator beacons in the 2009 controlled ditching in the UK sector, but this was a different problem, involving interference. The personal locator beacons were therefore withdrawn for some months, while these problems were solved.

An important observation from Table 13.1 is that all the accidents during cruising seem to have technical failures as their main causes. During take-off, landing and approach there are six occurrences, of which five are associated HOFs and one is technical.

All the accidents and incidents during take-off, landing and approach in Table 13.1 have occurred in the UK sector. In fact, even if the helicopter accidents in the 1970s and 1980s are included, no accident has occurred during take-off, landing and approach in the Norwegian sector. This difference is not statistically significant, because of the low number of accidents and incidents, but it is still noteworthy.

Accidents that occur on the helideck while the helicopter is parked are not included in Table 13.1 or in the discussion in this chapter.

HOFs dominate for accidents and incidents during take-off, landing and approach. This implies that accidents and incidents because of HOFs have a major contribution to the occurrences in the UK sector, but not in the Norwegian sector. This is somewhat surprising, as the qualification and training requirements are based on international standards, and thus should be the same. However, the differences are not statistically different, as noted above. Actually, if the accidents in the Norwegian sector in the 1970s were included, this would have changed somewhat, as HOFs played strong roles in at least two of these accidents.

Figure 13.1 presents an overview of non-fatal as well as fatal accidents. Fatal accidents are marked with a star below the year in question. Five such fatal accidents are in the UK sector and only one in the Norwegian sector.

It is noteworthy that only four out of the 14 accidents and incidents shown in Fig. 13.1 are from the Norwegian sector. The number of person flight hours was in 2011 41 % higher in the UK compared with in Norway (see also Sect. 13.3). The difference is even more significant since 2000, but this is not statistically significant because of the low number of events.

The number of accidents and incidents associated with MGB has been increasing; in fact, all the accidents in 2012 and one in 2009 as well as a fatal accident in Canada in 2009 were all caused by MGB problems.

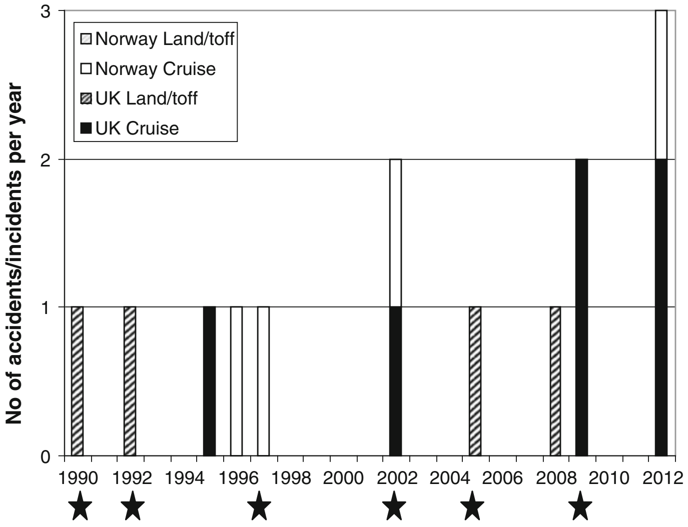


Fig. 13.1 Fatal (marked with *star*) and non-fatal helicopter accidents in the UK and Norwegian sectors, 1990–2012

13.3 Risk Modelling

13.3.1 Assumptions and Premises

When the risk of the helicopter transportation of personnel was initially assessed, it was assumed that the main factors would be the same as in fixed wing flying, namely that non-technical causes would contribute 70–80 % and that the majority of accidents would be associated with take-off, approach and landing. However, the majority of accidents initially occurred during transit (cruising), and therefore these two key assumptions had to be reconsidered.

Another aspect is also different. If engine or gear box failure occurs during cruising altitude, the helicopter is supposed to be able to make a controlled emergency landing, because of main rotor autorotation. The crew and passengers should be unhurt in such circumstances, especially as they are provided with survival suits, personal emergency beacon, and liferafts in the helicopter. Experience has shown that the helicopter often disintegrates in the air, thus making controlled emergency landing impossible. There have also been three cases of controlled emergency landing without fatalities in 2012.

A further aspect to consider is shuttling between two installations, which often has a short duration, and thus an entirely different relationship between take-off, approach and landing, compared with the cruising phase.

The UK and Norwegian sectors have traditionally been considered together, without any difference, when calculating accident and incident statistics. The risk levels presented in this chapter are predicted separately for the UK and Norwegian sectors, as the experience during the past 20 years has been quite different.

Finally, with respect to helicopter operations in the Norwegian sector, most helicopters in operation in the beginning of 2013 are new models, mainly Sikorsky S92 and Eurocopter Super Puma EC225. These new models have so far been involved in only one fatal accident (offshore Newfoundland, Canada, 2009), whereas all other fatal accidents are with older models. The Super Puma EC225 by contrast, has been involved in several incidents, as shown in Table 13.1. The improvement implied by these new models should be taken into account when calculating accident frequencies.

All these aspects need to be considered when developing the risk model. Many risk models in the literature fail to address some of these aspects.

13.3.2 Risk Model

The FAR values for personnel on an installation are usually expressed as the number of fatalities per 10^8 exposure hours (see Sect. 2.1.4). It is customary to express the FAR values for helicopter transport as the number of fatalities per 10^8 person flight hours.

The modelling is based on the same principles as those adopted by Heide (2012), namely that risk during helicopter transportation is function of the flight time during the cruise and approach phases as well as a function of the number of landings/take-off during landing and take-off. This can be expressed as follows:

$$\mathrm{FAR_{Hel}} = \mathrm{FAR_{Hel}^{cruise}} + \mathrm{FAR_{Hel}^{landing}} \tag{13.1}$$

where:

FAR_{Hel} = FAR value (per 10^8 person flight hour) for flying from onshore airport to the offshore helideck or back

$\mathrm{FAR_{Hel}^{cruise}}$ = FAR contribution from the cruising

$\mathrm{FAR_{Hel}^{landing}}$ phase = FAR contribution from the take-off and landing phases

The FAR for the helicopter transportation of personnel can be expressed as follows:

$$\mathrm{FAR_{Hel}^{cruise}} = \frac{\mathrm{Fat_{Hel}^{cruise}} \cdot 10^8}{\text{Person flight hours}} = \frac{\mathrm{Fat_{Hel}^{cruise}} \cdot 10^8}{\mathrm{Pass_{av}} \cdot \mathrm{Fl.hrs}} \tag{13.2}$$

where:

$\mathrm{Fat_{Hel}^{cruise}}$ = number of fatalities in helicopter accidents during cruising in the applicable period

$Pass_{av}$ = average number of passengers

$Fl.hrs$ = total number of flight hours in the applicable period.

It is further usual to include pilots in the calculation of fatalities, although separate FAR values can be expressed for them.

The accident rate for helicopters, $\mathrm{AR}_{\mathrm{Hel}}^{\mathrm{cruise}}$, can be expressed as follows:

$$\mathrm{AR}_{\mathrm{Hel}}^{\mathrm{cruise}} = \frac{\mathrm{N}_{\mathrm{acc,\,Hel}}^{\mathrm{cruise}}}{\text{Flight hours}} \tag{13.3}$$

where:

$\mathrm{N}_{\mathrm{acc,\,Hel}}^{\mathrm{cruise}}$ = number of accidents during cruising the in applicable period

The FAR for helicopters, $\mathrm{FLAR}_{\mathrm{Hel}}^{\mathrm{cruise}}$, can be expressed as follows:

$$\mathrm{FLAR}_{\mathrm{Hel}}^{\mathrm{cruise}} = \frac{\mathrm{N}_{\mathrm{acc,\,Hel}}}{\text{Flight hours}} \cdot \frac{\mathrm{N}_{\mathrm{F,acc,Hel}}}{\mathrm{N}_{\mathrm{acc,Hel}}} \tag{13.4}$$

where:

$N_{F,acc,Hel}$ = number of fatal accidents during cruising in the applicable period

Equations 13.2, 13.3 and 13.4 should also be repeated for the take-off and landing phases:

$$\mathrm{FAR}\frac{\text{landing}}{\text{Hel}} = \frac{\mathrm{Fat}\frac{\text{landing}}{\text{Hel}} \cdot 10^{8}}{\text{Number of landings}} \tag{13.5}$$

where:

$\mathrm{Fat}_{\mathrm{Hel}}^{\mathrm{landing}}$ = number of fatalities in helicopter accidents during take-off or landing in the applicable period

$$\mathrm{AR}\frac{\text{landing}}{\text{Hel}} = \frac{\mathrm{N}_{\mathrm{acc,\,Hel}}^{\mathrm{landing}}}{\text{Number of landings}} \tag{13.6}$$

where:

$\mathrm{N}_{\mathrm{acc,\,Hel}}^{\mathrm{landing}}$ = number of accidents during take-off or landing in applicable period

The FAR for helicopters, $\mathrm{FLAR}_{\mathrm{Hel}}^{\mathrm{landing}}$, can be expressed as follows:

$$\mathrm{FLAR}_{\mathrm{Hel}}^{\mathrm{landing}} = \frac{\mathrm{N}_{\mathrm{acc,\,Hel}}^{\mathrm{landing}}}{\text{Number of landings}} \cdot \frac{\mathrm{N}_{\mathrm{F,acc,\,Hel}}^{\mathrm{landing}}}{\mathrm{N}_{\mathrm{acc,\,Hel}}^{\mathrm{landing}}} \tag{13.7}$$

where:

$\mathrm{N}_{\mathrm{F,acc,\,Hel}}^{\mathrm{landing}}$ = number of fatal accidents during take-off or landing in applicable period

13.4 Previous Predictions

HSS1 (SINTEF 1990) was carried out immediately after the period with many fatalities in UK operations, and this study calculated a high fata-lity rate of:

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

The study conducted in 1998 (Vinnem and Vinnem 1998) divided accident frequency into separate values for cruising and landing/take-off. A comparable value would, however, be:

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

The HSS was updated in 1999 (HSS2, SINTEF 1999), and the statistics from SINTEF were compiled in a white paper (Norwegian official report 2002) on helicopter safety in 2002. This study documented the following value:

$$1.4 \times 10^{-6} \text{per\ \ person flight hours}$$

The white paper also proposed the objective of reducing the risk level by 50 % over a 10-year period compared with the average for the period 1990–2000.

The HSS was updated in 2010 (HSS3, SINTEF 2010). This study documented the following value for the period 1999-2009:

$$\begin{aligned} 2.4 \times 10^{-6} \text{per person flighthours(average\ \ for\ \ North Sea)} \\ 5.6 \times 10^{-6} \text{per person flighthours(UK sector)} \end{aligned}$$

The exposure hours in the UK sector in the period 1999–2009 seems to be too low value in HSS3 (see also Sect. 13.5), and therefore the FAR value is too high. Past reductions in FAR and future objectives may seem to be very significant reductions in the fatality rate, but several factors need to be considered:

- The original SINTEF study (HSS1) covered the period 1969–1989 and during the period 1975–1986 there were more than 125 fatalities in helicopter accidents in the North Sea. Since 1986, only three fatal accidents with 39 fatalities have occurred.
- The period 1975–1986 was considered in the HSS, but the study did not attempt to consider if any trends could be identified or whether there was any basis for making distinctions between Norwegian and UK operations.
- It is an established fact that improvements were introduced in helicopter operations in the 1980s because of the high number of accidents and thus a reduction in the frequency of accidents would be expected.

One of the deficiencies of the SINTEF studies is the lack of distinction between fatality risk during cruise and landing/take-off. This is an important distinction especially when shuttling is considered.

It might be argued that taking only the 10 year period following a period with high fatalities gives rise to an over-optimistic prediction. However, it would be impossible to define how much of the earlier period would need to be included to avoid such optimism.

Risk parameters were in the second edition of this book (2007) presented for the period 1996–2005. The data sources are presented in Tables 13.2 and 13.3.

The most up to date FAR value for helicopter transport in the North Sea was in 2007:

$$1.32 \times 10^{-6} \text{per person flight hours}$$

This implies a similar value to that stated in the Norwegian official report (2002), which was 1.4 per million person flight hours. If the corresponding value is calculated for the period 1987–2005, this becomes 1.35 per million person flight hours. In the Norwegian white paper, five year rolling averages were shown; these were naturally varying. Table 13.4 separately presents the derivation of FAR for cruising and landing on installations.

New predictions are made separately for the UK and Norwegian sectors in Sects. 13.6 and 13.7, because of the differences discussed above. These predictions are made for a 20-year period, owing to data limitations. When combined predictions are made (Sect. 13.5), they are limited to 10 years.

13.5 Combined Prediction of Risk Levels: UK and Norwegian Sectors

Risk parameters are presented for the period 1992–2011. The data sources are presented in Tables 13.5 and 13.6.

CAA statistics provides the number of passengers and air traffic movements from relevant airports. For 2000 and 2001, these values correlated with flight hours and person flight hours, and average conversion factors could thus be established. The values were also checked against the number of offshore employees in the period, and reasonable consistency was established. However, the person flight hours from HSS3 for the UK sector in the period 1999–2009 (6.1 million person flight hours) seem to be too low.

Table 13.2 Helicopter statistics for UK and Norway offshore operations, 1996–2005

Area	Person flight hours (million hours)	Sources
Norway	7.090	NOU2002:17 and RNNS report 2005
UK	10.320	NOU2002:17 extended to 2005
Total	17.410	Corresponding number of flight hours: 1.348 million hours

Table 13.3 Helicopter accident statistics for UK and Norway offshore operations, 1996–2005

Aspect	Number of persons	Sources
Accidents, cruise	3	):
Accidents, take-off/landing	0	):
Fatal accidents	2	): NOU2002:17 and HSE 2004
Fatalities	23	):
Survivors	0	):

Table 13.4 Helicopter risk parameters for the cruising and landing phases

Factor	Cruising	Landing on platform	Comments
Basis in period	1996–2005	1987–2005	
Accident rate	2.22×10^{-6}	2.0×10^{-7}	
Fraction of fatalities to total number of persons exposed	1.0	0.46	
Fatal accident rate	1.48×10^{-6}	2.01×10^{-7}	
Average number of fatalities	11.3	6.0	Both values based on period 1987–2005

Table 13.5 Helicopter statistics for UK and Norway offshore operations, 1992–2011 and 2002–2011 (in parenthesis)

Area	Person flight hours (million hours)	Sources
Norway	14.670 (7.673)	NOU2002:17 and RNNP (PSA 2012)
UK	21.021 (10.525)	NOU2002:17, CAA statistics
Total	35.692 (18.199)	Corresponding number of flight hours: 2.733 million hours

Table 13.6 Helicopter accident statistics for UK and Norway offshore operations, 1992–2011 and 2002–2011 (in parenthesis)

Aspect	Number of persons	Sources
Accidents, cruise	7 (4)	):
Accidents, take-off/landing	3 (2)	):
Fatal accidents, cruise	3 (2)	):
Fatal accidents, take-off/landing	2 (1)	): NOU2002:17 and HSS3
Fatalities, cruise	39 (27)	):
Fatalities, take-off/landing	18 (7)	):
Survivors, cruise	18 (18)	):
Survivors, take-off/landing	13 (7)	):

The FAR value for helicopter transport in the North Sea can be calculated as an average for the two periods:

Table 13.7 Helicopter risk parameters for the cruising and landing phases, 2002–2011

Factor	Cruising	Landing on platform	Comments
Accident rate	1.46×10^{-6}	3.8×10^{-7}	
FAR	7.3×10^{-7}	1.89×10^{-7}	
Fraction of fatalities to total number of persons exposed	0.60	0.50	
Average number of fatalities (in fatal accidents)	13.0	9.0	Values based on period 1992–2011

$$1992 - 2011 : 1.60 \times 10^{-6} \text{per person flight hours}$$

$$2002 - 2011 : 1.87 \times 10^{-6} \text{per person flight hours}$$

This implies values that are somewhat above that stated in the Norwegian official report (2002), which was 1.4 per million person flight hours. Table 13.7 separately presents the derivation of FAR for cruising and landing on installations.

The trends are shown in Fig. 13.2 for the North Sea in total, as well as for the UK and Norwegian sectors separately. The values for the North Sea are rolling 10 year average values, whereas those for the sectors are rolling 15 year average values (except in the period 1996–2001, when they build up from 10-year average to 15-year average values.

It can be seen that the average for the North Sea is slightly increasing and the trend for the Norwegian sector is falling, whereas the trend for the UK sector is increasing.

13.6 Prediction of Risk Levels: UK Sector

There have been relatively frequent helicopter accidents in the UK sector for almost 30 years, and so there is a good statistical basis for predictions. It is nevertheless considered to be most appropriate to use an average over 20 years when considering one sector only. The FAR value for helicopter transport in the UK sector is:

$$1992 - 2011 : 2.1 \times 10^{-6} \text{per person flight hours}$$

This values is somewhat above the average value for the North Sea (i.e. UK and Norwegian sectors), see Sect. 13.5. Table 13.8 separately presents the derivation of FAR for cruising and landing on installations.The replacement of older helicopter models with new models (S92 and EC225) is much slower in the UK compared with in Norway. It is therefore considered to be relevant to predict fatality rates for the future in the UK sector as experienced in the recent years. It has also been documented that several accidents have been caused by HOFs, which would also suggest that significant change is unlikely in the future.

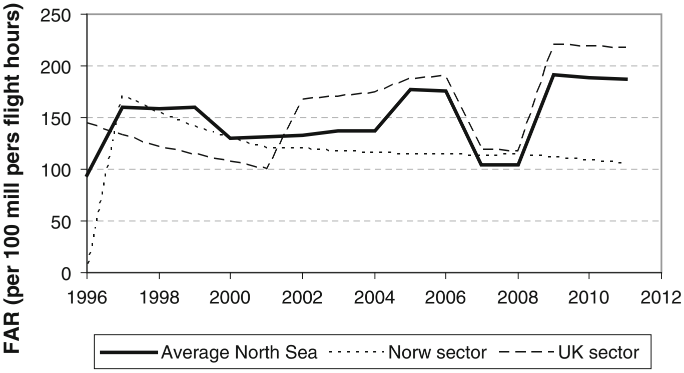


Fig. 13.2 Trends in average FAR values, North Sea and UK and Norwegian sectors, 1996–2011

Table 13.8 Helicopter risk parameters for the cruising and landing phases, UK, 1992–2011

Factor	Cruising	Landing on platform	Comments
Accident rate	2.1×10^{-6}	6.6×10^{-7}	
FAR	1.04×10^{-6}	4.4×10^{-7}	
Fraction of fatalities to total number of persons exposed	0.60	0.58	
Average number of fatalities (in fatal accidents)	13.5	9.0	

13.7 Prediction of Risk Levels: Norwegian Sector

There has only been one fatal helicopter accident in the Norwegian sector during a period of almost 30 years, and so the statistical basis for predictions is poor. It is thus considered to be most appropriate to use an average over 20 years when considering one sector only. The FAR value for helicopter transport in the Norwegian sector is:

$$1992 - 2011 : 0.82 \times 10^{-6} \text{per person flight hours}$$

This value is considerably lower than that for the North Sea as well as the UK sector value (see Sects. 13.5 and 13.6). Table 13.9 separately presents the derivation of FAR for cruising and landing on installations.

The replacement of older helicopter models is almost complete in the Norwegian sector, because oil companies have required the use of newer models when new contracts have been signed. It is claimed by experts that the S92 helicopter shows a lower incidence rate of major failure precursors. It is therefore considered to be relevant to predict lower fatality rates for the future, compared with what has been experienced in the past.

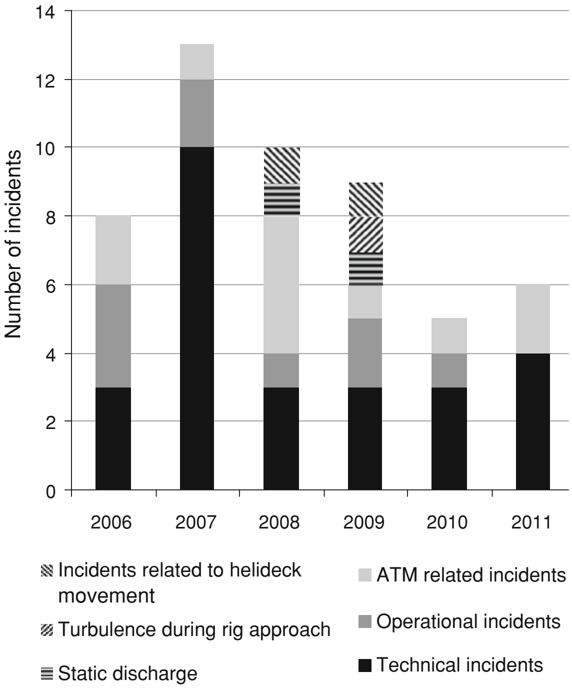
Table 13.9 Helicopter risk parameters for the cruising and landing phases, Norway, 1992–2011

Factor	Cruising	Landing on platform	Comments
Accident rate	3.7×10^{-6}	0	
FAR	1.22×10^{-6}	0	
Fraction of fatalities to total number of persons exposed	1.0	0	
Average number of fatalities (in fatal accidents)	12	0	

The Risk Level project suggests trends in potential major accidents with helicopters, based on precursor events with no (apart from 'luck') or only one remaining barrier. Figure 13.3 presents the trend for the past six years, suggesting a downward trend. However, the diagram also indicates that other causes may limit the reduction that is achievable, as operational (including pilot) errors and ATM errors are significant contributors, whereas helideck movement and turbulence have less importance.

The helicopter safety white paper (Norwegian official report 2002) suggested a long list of improvements that together were considered to imply a reduction by 50 % of the fatality frequency, according to the goal. Some of the main actions were (Hamremoen 2007):

Fig. 13.3 F Major hazard indicator 1 from the PSA Risk Level project, reflecting the major hazard potential of precursor events, Norwegian sector, 2006–2011



- Flight data monitoring
- New technology
- TCAS 1 collision avoidance system
- EGPWS, Enhanced Ground Proximity Warning System
- De icing (rotor)
- Survivability in Sea state 6.

A safety advisory group was also established (CAA 2007). Contact with two of the leading members (Karlsen 2007; Hamremoen 2007) of the group revealed that the majority of the actions have already been implemented for the majority of the helicopters in the Norwegian fleet (CAA 2007). There are two main features of improvement being sought through these actions:

- Reduction in the frequency of technical and operational faults that may lead to fatal accidents.
- Reduction in the consequences of such faults, i.e. reduce (or eliminate) the number of fatalities resulting from such faults.

This implies that an event that in the past could have led to serious consequences may in the future have less severe consequences. In theory this should be reflected in the criteria used to classify incidents, but it will probably take some time before a revision is made.

When all these factors are taken into account, we have attempted to consider what these qualitative factors may result in with respect to the prediction of fatalities in helicopter transportation in the future. The percentage completion of recommendations was 67 % at the end of 2007 and it is now considered to be 100 %. It should, however, be noted that what effect these actions will have on the future incident rate is based on subjective evaluations made by a large group representing different organisations and interests.

The final aspect to consider is that helicopter accidents are so rare that some margin must be allowed for what could be called ‘unexperienced events’ (or unknown threats), namely mechanisms that are unknown until they occur for the first time. This may, for instance, be related to the volume of traffic in ‘near arctic’ conditions in the Barents Sea. Allowance has been made for such occurrences in the future. On this basis, we have subjectively considered that a representative average value for the future may be the following:

- Helicopter transport: 70 fatalities per 100 million person flight hours

This corresponds to full compliance with the 50 % reduction target of the official white paper (Norwegian official report 2002).

Table 13.10 presents the predicted FAR for cruising and landing on installations separately for the Norwegian sector. For the landing and take-off values, 50 % of the UK values has been applied.

Table 13.10 Helicopter risk parameters for the cruising and landing phases, Norway, future predictions

Factor	Cruising	Landing on platform	Comments
Accident rate	3.1×10^{-6}	3.3×10^{-7}	
FAR	1.34×10^{-6}	2.2×10^{-7}	
Fraction of fatalities to total number of persons exposed	0.68	0.58	
Average number of fatalities (in fatal accidents)	12	4.5	

13.8 Other Risk Parameters

13.8.1 Fatality Distribution

A distribution of fatalities occurring in helicopter accidents may be required in cases where an f–N distribution is used to ex-press risk to personnel. This may be generated from accident statistics. Figure 13.4 presents the distribution of fatalities per fatal accident.

Most helicopters in use in the North Sea typically have 14–18 seats and therefore it is usually not necessary to distinguish between different helicopter types. The Chinook helicopter has 45 seats, but this helicopter has been out of use for North Sea activities following the accident in 1986.

Figure 13.4 shows an overview of the number of fatalities in helicopter accidents during cruising and landing. Accidents that occurred on the helideck are omitted from the presentation.

13.8.2 Comparison of Risk Associated with Shuttling

Vinnem and Vinnem (1998) demonstrated the critical effect of extensive shuttling between the shore and offshore facilities on the risk levels for the persons invol-

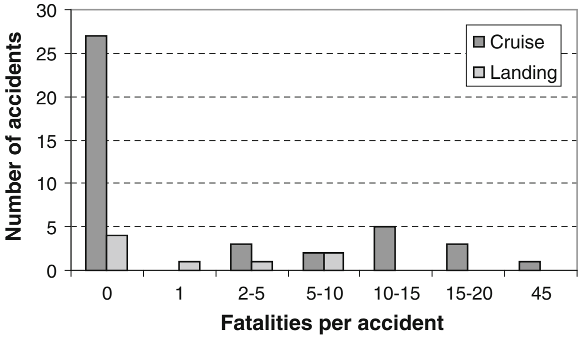
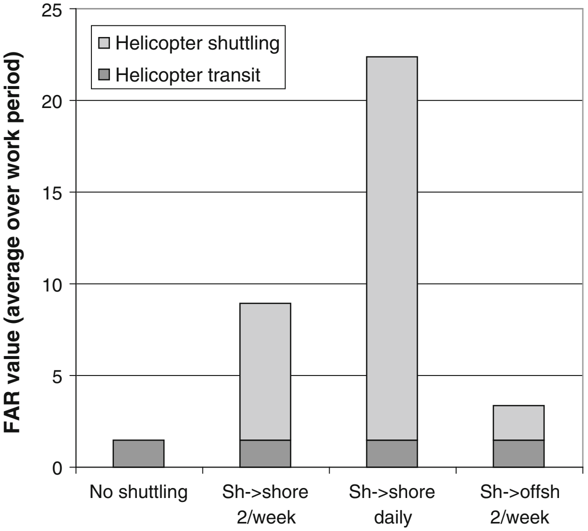


Fig. 13.4 Fatalities in North Sea offshore helicopter accidents

Fig. 13.5 Comparison of average FAR values for an offshore worker according to the extent of shuttling performed



ved. This is sometimes undertaken during offshore installation and/or the commissioning phase of new facilities. Figure 13.5 shows the ave-rage annual FAR value for an offshore employee, according to the extent of off–shore shuttling that the person is exposed to.

The following shuttling situations are shown (abbreviations used in the diagram are also included):

1. No shuttling (‘No shuttle’).
2. Shuttling to shore twice per week (‘Sh → shore 2/week’, 60 min each way).
3. Shuttling to shore daily (‘Sh → shore daily’).
4. Shuttling to a nearby installation offshore twice per week (‘Sh → offsh 2/week’, 15 min per one way trip).

All helicopter operations are included, while transport between the installation and shore at the outset and finish of a full working period (usually 2 weeks), as well as any shuttling during that working period are also included. It may thus be observed from the levels demonstrated here, that helicopter associated risk is important for the overall risk level imposed on offshore employees.

The diagram shows the considerable increase in risk to an employee who is shuttled either to shore or to another installation regularly during the offshore work period. Even for shuttling twice per week, the increase is significant, and the total risk experienced by offshore workers is doubled if being shuttled twice per week from shore. If shuttling is daily, total risk increases by a factor of almost five.

It should be noted that the total risk values presented here include transportation 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 the initial and final flights (to/from shore) were ignored.

13.9 Prediction of Risk Levels for an Individual Installation

Risk levels for an individual installation can be predicted using the Eq. (13.7) presented by Heide (2012):

$$\theta = (\mathrm{T} + \mathrm{T}_1\varphi) \cdot \alpha_1 \cdot \alpha_2 \cdot \alpha_3 + (1 + \varphi \cdot \mathrm{N}_1) \cdot \beta_1 \cdot \beta_2 \cdot \beta_3 \tag{13.8}$$

where:

θ = Proportion of flights where an average passenger perishes,

T = Flight time directly between the heliport and offshore helipad,

T_1 = Extra flight time for flights that have an intermediate landing,

φ = Proportion of flights that have an intermediate landing,

α_1 = Proportion of accidents per time unit for the accident rate that is dependent on flight time,

α_2 = Proportion of fatal accidents per accident for time dependent accidents,

α_3 = Proportion of passenger fatalities per fatal accident for time dependent accidents,

N_1 = Number of intermediate landings,

β_1 = Proportion of accidents per flight for the accident rate that is dependent on the number of flights,

β_2 = Proportion of fatal accidents per accident for flight-dependent accidents, and

β_3 = Proportion of passenger fatalities per fatal accident for flight-dependent accidents.

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