Evaluation of offshore emergency preparedness in view of rare accidents

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Abstract

The offshore industry in the North Sea has gone from a very high risk level for employees some 30– 40 years ago, to a low level. The paper reviews the statistics briefly and discusses the implications of the low level. There has from the beginning of the operations been strong focus on emergency preparedness, due to the remoteness of the operations mostly far from shore. But there will always have to be a balance between the focus on preventative safety efforts and the extent of emergency preparedness provisions. This is discussed in detail, based on an extensive evaluation of the adequacy of emergency preparedness provisions recently performed. The main findings are presented, and the robustness and validity of the approach is discussed, together with implications of the rare major accidents.

Keywords:
Major hazards, emergency preparedness, preventative safety, tolerability of risk

1. Introduction

1.1. Background

The North Sea[1] offshore industry is almost 50 years, from its modest start around 1960. During the first two decenniums there were many fatal accidents and the industry had a bad reputation. In Norway at least, Norwegians after some time gained experience to the extent that they could take over the responsibility gradually for the operations, and from around 1980 national control philosophies, attitudes and cultures started to take precedence over US inspired cultures, values and organisations.

During the first 20 years, there were several major accidents on installations and during helicopter transportation of personnel to/ from shore, in addition to numerous occupational accidents, including a number of fatal diver accidents. Disasters were certainly not too few in those days. Norway had several large helicopter accidents during the 1970s, in most cases without survivors at all. Not so many occurred in the UK sector in the 1970s, but here on the other hand, there were several fatal accidents during the 1980s.

Abbreviations: ALARP, as low as reasonably practicable; FAR, fatal accident rate; HES, health, environment and safety; MMS, Minerals Management Service; MTO, Man, Technology and Organisation; OGP, oil and gas producers; ONGC, Oil & Natural Gas Company [of India]; Pemex, Petróleos Mexicanos; PRA, probabilistic risk assessment; PSA, The Petroleum Safety Authority [Norway]; QRA, quantitative risk assessment; RNNP, risk level in Norwegian petroleum [activity]; SAR, search and rescue; TLP, tension leg platform.

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[1] ‘North Sea’ is in this paper used as the short expression for all North European waters north of the English Channel with offshore activity, including Norwegian Sea, Barents Sea, North Atlantic and West of Shetland, but not northern Russian waters.

’Major accident’ in the offshore industry is often understood to be an accident sequence that is out of control and that has the potential to cause five fatalities or more. This may be for instance gas leaks where ignition has occurred or, in the case of structural failure, where at least local structural failure has occurred. This interpretation is in accordance with HSE’s definition (HSE, 2005), but is not straightforward to use, due to the reference to ‘potential to cause five fatalities or more’. This is discussed to some extent in Vinnem et al. (2010).

With respect to major accidents on installations, the last multi fatality major accident in the North Sea occurred in July 1988, with loss of 167 lives on Piper Alpha, due to fire and explosions, following an uncontrolled gas release (Cullen, 1990). This was the worst loss of lives in the offshore industry, exceeding quite distinctly the loss of 123 lives in the Norwegian sector some 8 years earlier, with the capsize of the flotel Alexander L. Kielland in March 1980 (NOU, 1981).

After 1988 however, no major accidents have occurred on installations in the North Sea, but some multi fatality helicopter accidents have occurred. The last time emergency evacuation of an installation was performed in the Norwegian sector was in 1985, following an ignited shallow gas[2] blowout, which resulted in a severe explosion and a long lasting fire (NOU, 1986). A reservoir gas blowout occurred on the Norwegian installation ‘Snorre Alpha’ in 2004 without fatalities. It is not obvious whether this event shall be classified as ‘major accident’ or not, se further discussion in Section 5.

Following some of the major accidents in the Norwegian sector up until 1980, it became apparent that evacuation means had to be improved in relation to what had been inherited from the marine industry, lifeboats and life rafts. The covered lifeboats were launched by two wire falls, with two hooks that needed to be load free simultaneously in order to be able to release the hooks and move the boat away from the installation. Such release failed in many cases, and many boats ended up being crushed against the structure, such as in the case of Alexander L. Kielland accident.

Several improvements were developed in order to improve this situation. But none of these improvements have been tested in real cases since developed. Based on experience data, it is therefore impossible to establish whether the emergency preparedness is adequate or not, or whether the trend is positive or negative. This was the background to the study presented in the following, a need to establish as far as possible the status and the trends.

The scope of the paper is limited to conditions in the North Sea. It is nevertheless instructive to make reference to the reservoir blowout on the ‘Deepwater Horison’ (Department of the Interior, 2010a), with the resulting explosion, long lasting fire and subsequent sinking of the installation. Eleven fatalities occurred prior to evacuation by conventional lifeboats, and a massive subsea oil spill which at the time of writing has not been stopped, make this the worst major accident in the Gulf of Mexico for a very long time.

1.2. Particularities of offshore emergency preparedness

In the southern North Sea the installations are small, often not normally manned, several installations are often interconnected through a set of bridges, water depth is shallow and the installations are sometimes quite near to shore. These descriptions are typical for southern UK sector, Danish and Dutch sectors.

The installations in the northern North Sea, Norwegian Sea, Barents Sea, West of Shetland and North Atlantic are not like this at all, they are large, some with populations in the several hundreds, semi-deep or deep water depth and typically more than 100 km distance from shore to the installation. This remoteness implies that in the case of an emergency, the installation has to be self sufficient with respect to resources as well as on-scene emergency management.

The remoteness and the need to be fully self sufficient is the most particular aspect with respect to emergency preparedness. But there are also offshore operations in other sectors worldwide that are similarly remote. The harsh environmental conditions in combination with the remoteness are probably the unique aspect of the northern European operations. The remoteness also implies that helicopters cannot be relied upon in an emergency, onshore helicopter will typically have a response time of at least 60 min after scrambling. Helicopters may also be prevented from being used, due to the accident scenario. Offshore operations may in the future expend into offshore arctic regions. The experience in the North Sea will also be useful in order to formulate requirements for emergency preparedness in offshore arctic regions.

1.3. Objectives of the paper

The objectives of the paper are to describe the methodology that was chosen in a recent study in order to evaluate the adequacy of the emergency preparedness arrangements for the Norwegian offshore sector, and to evaluate whether recent improvements have had an effect or not. The challenges for the methodology are outlined above, the lack of experience data on which the study could be based.

The objectives are further to discuss the findings of the study and the robustness and validity of the conclusions from the study.

Finally, the objective is to discuss the balance between preventative safety efforts and emergency preparedness, should these two be considered independently, or is there a basis for a balanced consideration. This is particularly relevant in relation to authority requirements.

2 Shallow gas implies small gas pockets usually few hundred meters below seafloor, where drilling operations are performed without pressure control devices.

1.4. Scope and limitations of the emergency preparedness study

The purpose of the study was to give an overview of the strengths and weaknesses in the emergency preparedness offshore in an MTO (Man, Technology and Organisation) perspective, and to assess the effects of those improvements that have been implemented over the last 10 years (Vinnem, 2008b).

Oil spill emergency preparedness was not to be covered by the study. The significance of this aspect has been emphasized strongly by the 'Deepwater Horizon' oil spill (Department of the Interior, 2010a), but the study was completed some 15 months before this accident occurred in April 2010.

Another limitation was concerned with movement of large personnel groups on severe weather warning. Traditionally this has not been done in the North Sea, but has been the rule in the Gulf of Mexico for many years. Recently however, it has been concluded that some old installations in the Norwegian sector are vulnerable to wave impact, due to subsidence of the formation and the structure, thus resulting in insufficient air gap between the lowest deck and the sea level in extreme storm conditions. These installations are demanned on severe weather warning. During the last few years, some installations have further been found to have lifeboat deficiencies to the extent that safe evacuation in severe weather could not be ensured. Both these scenarios have caused a need for movement of large personnel groups if certain wind and weather conditions are forecasted. These large scale movements of personnel were also outside the scope of the study.

The main focus areas of the study were the following topics:

- Primary evacuation means for emergency evacuation.
- Operational limitations for rescue of personnel in the sea.
- Capabilities and qualifications of offshore emergency organisation.
- Capacity utilisation of offshore emergency resources.
- Perceived emergency preparedness level by the offshore population.

The methodology adopted in the study is presented in Section 3.1, followed by an overview of input data in Section 3.2, and the main findings in Section 3.3. A discussion of preventative safety versus emergency preparedness is presented in Section 4, followed by a more general discussion in Section 5. Risk levels for offshore installations in the North Sea provide an important background to the discussion, especially with respect to the discussion of accident prevention versus mitigation in Section 4. The risk levels are presented in Section 2 below.

2. Overview of risk levels

2.1 Historic perspective

2.1.1. Offshore installations

An extensive analysis of risk levels has been made in Vinnem (2008b), based on data from Norway and UK, from which Fig. 1 is taken. Fig. 1 presents the long term trends of fatalities per 100 million manhours (FAR values) over 40 years, limited to occupational accidents in the Norwegian offshore sector. Extensive reductions were achieved in the first 20 years. Obviously, the FAR levels in the last 20 years are more stable.

It is argued in Vinnem (2008b) that a 10 year average value should be used. The value presented in Vinnem (2008b) is based on the period 1987–2006. If the same approach is used with data

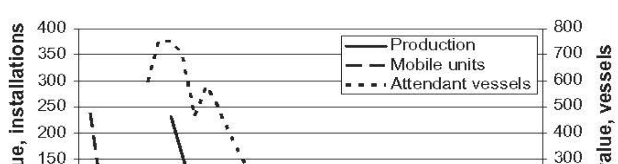

Fig. 1. Trend in Norwegian offshore occupational Fatal Accident Rate.

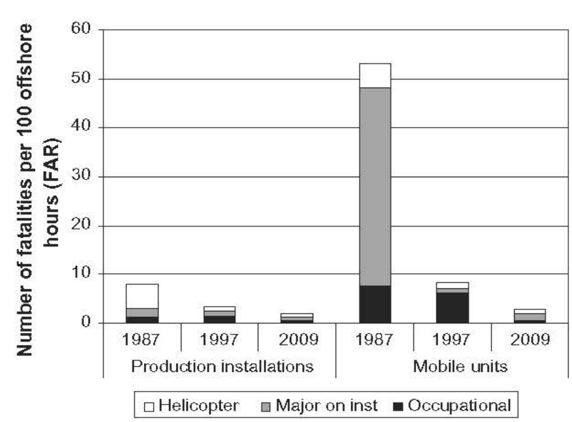

Fig. 2. Comparison of risk levels in 1997 and 2009 for production installations and mobile units, based on offshore exposure hours.

for the period 1999–2008, the values are slightly lower than for the previous period:

- Production installations: 0.58 fatalities per 100 million exposure hours.
- Mobile installations: 0.68 fatalities per 100 million exposure hours.

The mobile installations are mainly mobile drilling units in addition to flotels, which are mobile accommodation units. A comparison with UK sector is presented in PSA (2008), as average values for the entire Norwegian and UK sectors. The values presented in Department of the Interior (2010a) are per manhour, whereas the presentation in Vinnem (2008b) is based on exposure hours, i.e. the double value of the manhours.[3] The following values are presented:

- UK sector: 1.89 fatalities per 100 million exposure hours.
- Norwegian sector: 0.47 fatalities per 100 million exposure hours.

The values in Department of the Interior (2010a) also include vessels of different types, some of which have higher fatality risk levels than production and mobile drilling units. Further details are presented in Department of the Interior (2010a).

Various sources and considerations are reviewed and discussed in Vinnem (2008b) with respect to risk associated with major accidents, in spite of the fact that none have occurred during the last 20 years. The following values are calculated for the Norwegian sector:

- Production installations: 0.59 fatalities per 100 million exposure hours.
- Mobile installations: 1.40 fatalities per 100 million exposure hours.

Various sources are reviewed and discussed in Vinnem (2008b) also with respect to risk associated with major accidents during helicopter transportation. The following value is calculated for the future helicopter risk with new helicopter types taking over the majority of the transportation:

- Offshore installations: 90 fatalities per 100 million person flight hours.

The data sources reviewed and discussed in Vinnem (2008b) may be used in order to illustrate current risk levels as well as the risk levels some 12 years and 22 years ago. The same approach as in Vinnem (2008b) is used in order to illustrate the risk levels in 1987 and 1997 as opposed to 2009, where contributions from occupational accidents as well as major accidents on installations and during helicopter transportation.

Fig. 2 shows the extensive differences over a period of about 22 years. For the values in 1987, the risk levels have been calculated purely based on accident statistics for the period 1978– 1987, due to the significant number of fatal accidents in this period. The effect of the Alexander L. Kielland accident is also very obvious.

2.1.2. Helicopter accidents and ditching

One type of accidents and incidents that has been somewhat more frequent is helicopter accidents and ditching (see OLF, 2000). This type of accidents also has relevance for emergency assistance planning. Fig. 3 presents an overview of accidents and incidents in the North Sea, based on Vinnem (2008b) with addition of a recent incident. The majority of the data is from UK and Norway, with one accident in Dutch sector. The events 'G', 'I', 'J' and 'L' were of such nature that survival was not possible. The most notable events from a rescue point of view are the controlled emergency landings in July'88, November'88, January'95, January'96 and February'09. The helicopter capsized only in the November'88 incident, this occurred on short distance from an installation, and the rescue operations occurred within short time. In the other emergency landings on water, the helicopter remained upright for some time, and the rescue was much more delayed due to long distance, in the order of 1 h or slightly more.

Prior to the period shown in Fig. 3 there were several fatal helicopter accidents in the UK sector in the 1980s, whereas there were several fatal helicopter accidents in the Norwegian sector in the 1970s.

There has been a significant improvement in the occurrence of fatal helicopter accidents in the last 20 years; the resulting risk level was indicated in Section 2.1.1. Of those events in Fig. 3 where there were survivors, the following means of rescue were used:

[3] Offshore work rotation is 12 h on-duty and 12 h off-duty, thus total exposure hours (on-duty and off-duty) are the double of on-duty manhours.

- SAR helicopter: three incidents (of which two used both SAR and MOB boat).
- MOB boat: six incidents (of which two used both SAR and MOB boat).
- Lifeboat: one incident (in which SAR and a lifeboat were used).

With respect to helicopter accidents and incidents, there is actually some experience data with respect to successful rescue of personnel. The longest pickup times in Fig. 3 were somewhat in excess of 1 h, but less than 90 min.

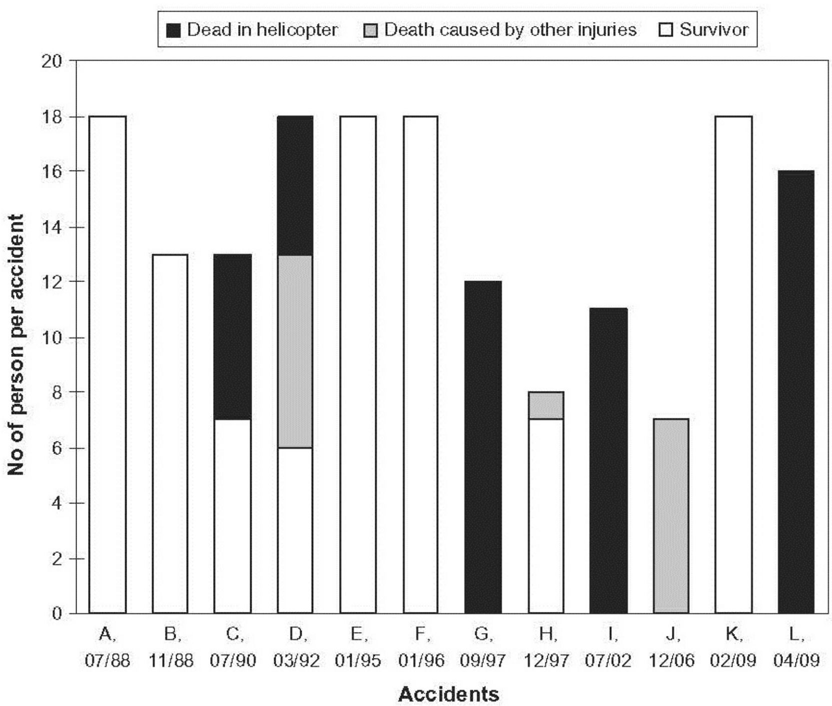

Fig. 3. Helicopter accidents and incidents in North Sea with personnel in the sea 1988–2009.

2.1.1. Summary: emergency evacuation

It has been demonstrated that in the Norwegian sector, no emergency evacuations have taken place after 1985, similarly none after 1988 in the UK sector. From helicopter accidents and incidents, there have been five fatal accidents in the last 20 years, and eight cases where rescue operations from the sea was required. Worldwide operations are therefore considered as a possible alternative source of information.

2.2. Significance of worldwide experience

It should first of all be noted that helicopter accidents are not included in the comparison with worldwide operations. This is because helicopter safety standards are considered to be significantly better in the North Sea operations, compared to worldwide operations (SINTEF, 2010).

The most extensive source on accidents in the worldwide offshore industry (as well as onshore operations) is the OGP annual statistical summaries, which have been published since 1998, the last report available refers to 2006 data (OGP, 2006). A summary of worldwide risk levels based on OGP data was presented in Vinnem (2008b). The report covers occupational accidents, major accidents and transportation accidents, for company personnel as well as contractors. The number of manhours included has increased by more than 150% during the period, and corresponds in 2007 to 650 million manhours, from 39 companies in 75 countries.

There is however, one critical limitation on the OGP data, which is clearly demonstrated by values in 2001, 2005 and 2007. The cap- size of P-36 offshore Brazil in 2001 following an explosion and fire which resulted in 11 fatalities is not included in the OGP values. If included, it would bring up the number of deaths from 19 to 30. In 2005 the total number of deaths in the OGP analysis is 10. There was on the other hand, one major fire and explosion on the Bombay High field, operated by ONGC in India. This accident resulted in 22 fatalities, which if included, would affect the value for 2005 considerably. The same applies to 2007, five fatalities are reported by OGP, excluding fatalities on attending vessels. The accident that Pemex had in October 2007 as a consequence of severe weather, with 22 fatalities, is not included. It is not known what other accidents that are not included in the OGP statistics, but that would not be major accidents.

Fig. 4 attempts to illustrate what the effect of inclusion of these additional major accidents in 2001, 2005 and 2007 would be, when fatalities and assumed manhours for the three companies in question are included in 2001, 2005 and 2007. The number of employees was found in the company web-pages, from which offshore manhours could be 'guestimated'. Fig. 4 is based on offshore exposure hours, including on-duty as well as off-duty hours.

It should be noted that the effect of additional companies is only considered in the years where the accidents occurred, 2001, 2005 and 2007. In fact we do not know if these operators had other fatal accidents in the years in question. If this is the case, the values in Fig. 4 represent under-prediction.

Fig. 4 presents the trend of offshore Fatal Accident Rates 1997– 2007, presented by OGP annual reports and the corrections given above. The generally falling trend in the period is obvious.

As noted above, the extra manhours from the companies with the additional accidents are only included in the years where they had the accidents. Fig. 5 presents an alternative evaluation, where manhours from these companies are added in all years, assuming 5% annual increase. In addition, the values are presented as rolling 3 year average values.

Fig. 5 demonstrated an overall falling trend, with levels that are comparable to those presented in Fig. 2. Helicopter fatalities are as noted above not included.

The values stated in this section indicate a return period of 30– 50 years for major accidents in the Norwegian sector. The absence of major accidents during the last 25 years is thus not at all sufficient to conclude what a typical frequency may be.

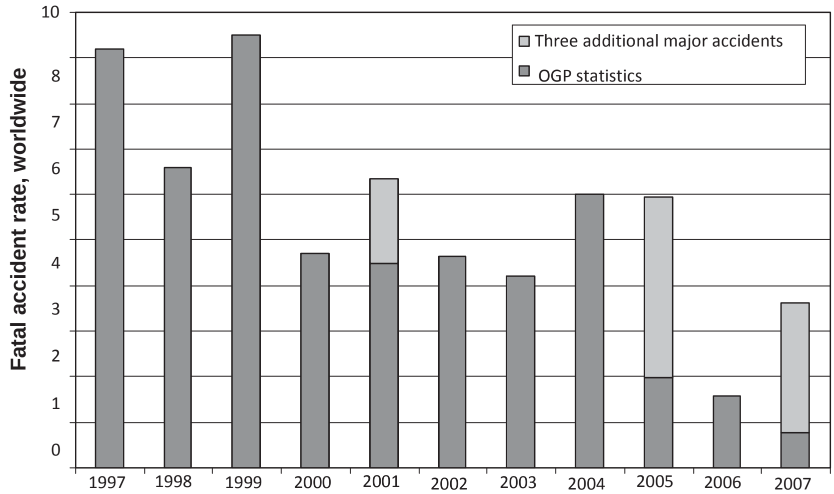

Fig. 4. Worldwide trend, offshore Fatal Accident Rate, based on OGP reporting.

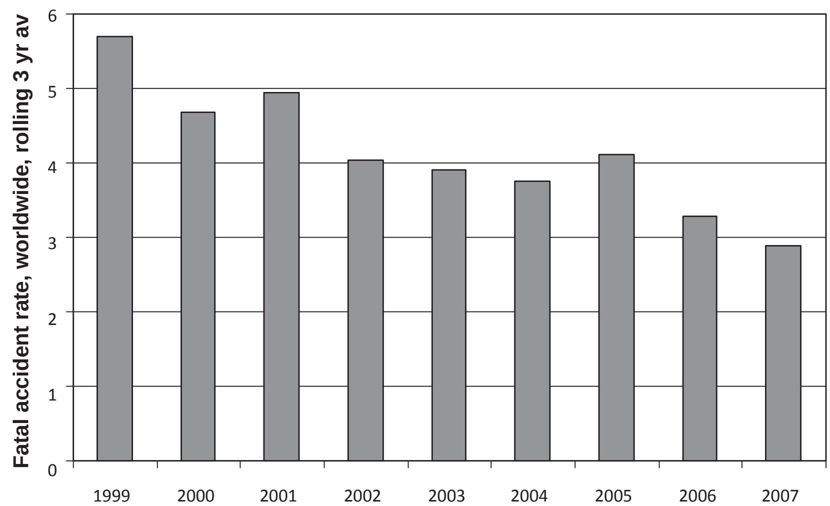

Fig. 5. Worldwide trend, offshore Fatal Accident Rate, 3 year rolling average, based on OGP reporting and additional companies.

3. Emergency preparedness study

3.1 Methodology used in the study

3.1.1. Challenges

There are several possible approaches that could be used for a study like the actual one. If there had been a lot of incidents and accidents where emergency evacuation and/or rescue had taken place, the study could have been based on analysis of experience from accidents and incidents. But as already pointed out, the cases where emergency preparedness solutions and arrangements have been tested in real life are virtually non existent during the last 25 years in the entire North Sea, except in the case of ditching of helicopters. And those solutions that are considered best practice currently have never been tested in real cases, only in training scenarios, simulation and model tests.

We may therefore 'complain' that disasters have become 'too rare' in the North Sea, at least for an event based analysis of experience. Other aspects are also influenced by the lack of actual experience data, such as the ability to have feedback on the performance of the emergency arrangements in real life usage. There has been little or no further development for many years of essential emergency equipment, such as freefall lifeboats, until the problems were discovered on some North Sea boats in 2005, see further discussion in Section 3.3.1.

In any case, it needs to be stated clearly that the lack of experience data is certainly very good news, it confirms that the accident prevention efforts have been successful for many years.

If we turn to worldwide operations there are also quite recent accidents and incidents where emergency arrangements have been used, but the equipment and training standards are so different, that there would be little or no point in using these cases to evaluate current standards in the North Sea.

Another possible approach could imply the use of Probabilistic Risk Assessment studies which are in fact carried out for all offshore installations under current legislation, especially in the UK and Norway. But these PRA studies (or QRA studies as they are often called) are often not very detailed, especially not for the consequences relating to how emergency preparedness arrangements affect the risk picture. The lack of experience data also comes into play here, because the lack of data implies that the results of the QRA studies with respect to emergency preparedness are quite coarse and rather uncertain.

At the same time, it was considered important to have as much as possible factual basis for observations and conclusions, this was considered essential as much of the discussion of emergency preparedness is rather emotions based, with little or no basis in facts. A considerable effort was made in order to collect relevant data, and to supplement this with qualitative information from seminars, interviews, questionnaire surveys, etc. Data from exercises and training may also be valuable data, and some actual experience data from use of emergency resources are available.

It is essential to recognize that the use of data will be limited by uncertainty, unrepresentativeness, as well as interpretation challenges. It is therefore essential to supplement data with qualitative evaluations and assessments, as well as findings from audits and investigations.

3.1.2. Adopted approach

The main thrust of the approach was to employ a social science inspired triangulation principle whereby the findings and conclusions could be based on preferably at least two different types of sources and inputs. In the study report it was considered as essential to present the factual data separately from the evaluations that were performed based on the available input. This is also to some extent implemented in the paper, where an extract of the data basis is presented in Section 3.2, and the main evaluations are presented in Section 3.3.

The following is a brief definition of the main steps of the methodology which was used in the study:

1. The scope of the study was structured into main topics and sub- topics as presented in Section 3.1.3 below.
2. For each topic it was attempted to provide at least two different data sources, either quantitative or qualitative data, with emphasis on consideration of topics in an MTO perspective, as discussed below in Section 3.1.4.
3. Qualitative evaluations were performed based on the available information, in relation to regulatory requirements, applicable standards, as well as recognized industry practice.
4. Where necessary, trade-offs were considered with a view to the As Low As Reasonably Practicable (ALARP) principle.
5. All topics were considered in parallel in order to draw the final conclusion about the overall status of the emergency preparedness for personnel in the Norwegian sector.

3.1.3. Main topics

The main topics were structured in three main focus areas. The main and the detailed topics are the following:

- Accidents originating on the installation:
  - 0 Combatment on the installations.
  - 0 Emergency evacuation by lifeboats.
  - 0 Secondary escape to sea level.
- Accidents due to external events:
  - 0 Helicopter ditching within safety zone.
  - 0 Emergency evacuation by lifeboats.
- Emergency resources:
  - 0 Area based emergency preparedness.
  - 0 Traffic surveillance by radar.
  - 0 Survival, localization and rescue from the sea.
  - 0 Medical evacuation to shore.

3.1.4. Focus on MTO aspects

The mandate for the study emphasized that the evaluation should be taking an MTO perspective. As a starting point, it is required to consider what are the implications of such a perspective. The most obvious is to consider how emergency operations may fail due to for instance human errors. The example cited below from Mexico in October 2007, see Table 1, is an illustration of such effects.

But often human operators provide the last option for rectification. In the Snorre Alpha subsea gas blowout, see Section 5, it was observed that the emergency management onboard the installation took decisions and implemented combatment actions that were not part of the emergency instructions. Their skills and experience were the basis for these actions, which were claimed to be significantly contributing to the avoidance of loss of life in that particular accident. This event provides a clear demonstration of the positive potential that is implied in the MTO approach, this is often overlooked.

The relevance of the negative effects of the MTO approach is demonstrated clearly over and over again, if major disasters are considered. If for instance the last major accident involving failure of evacuation facilities is considered, this may be illustrated clearly. The blowout from the Mexican mobile drilling unit Usumacinta 23. October 2007, resulted in 22 fatalities during emergency evacuation (Batelle, 2008). The following are found as the main causes of the high loss of lives:

- All crew members (about 80 persons) were evacuated by means of one covered lifeboat and one lifesaving capsule. None were wearing survival suits, and several people did not wear lifewest.
- The launching of both evacuation means was successful.
- After some time, both the lifeboat and the capsule capsized, probably because hatches were opened to get fresh air and to be able to see. Lack of command structure, training and competence appear to have been contributing factors.
- Vessels in the area and Mexican navy attempted to rescue people in the sea and in evacuation facilities, but 22 persons drowned, of which two crew members from one of the vessels involved in the rescue attempts. The weather conditions were severe, 22 m/s wind and 8–9 m waves.
- The investigation (PSA, 2008) concluded with several weaknesses in procedures, competence and cultural aspects.

A brief overview of some well known major accidents and the influence of human and organisational errors is presented in Table 1, based on Vinnem (2007). A general evaluation of MTO aspects involved in emergency evacuation is given in Skogdalen and Vinnem (2008). The table has been supplemented by the Deep- water Horizon accident for the purpose of completeness.

The following observations may be made from Table 1:

- Many of the investigations were performed at a time when MTO aspects were not focused upon, hence some information is unknown. Investigation reports are not available for all accidents implying also some unknown information. Organizational errors sometimes have to be inferred from the descriptions.
- In all of these cases, either human errors or organizational errors or both types of failures contributed to the severe consequences.
- Organizational errors found in all cases, except in two cases where the information is unavailable, either due to no survivors or due to lack of formal investigation report.
- Most of the fatalities have occurred during evacuation and rescue operations, but many of the organizational errors occurred in the phases prior to initiating the evacuation operations. The most common errors are those occurring in the management and supervision.

With respect to observations from these accidents and identification of lessons learned for risk reduction actions, the following may be noted:

- The first six accidents in Table 1 contributed to the requirement for an improved lifeboat concept, the freefall lifeboat. This has been compulsory on production installations in the Norwegian sector for more than 20 years. But no other country has adopted the same approach, which is very surprising, especially in areas with severe environmental conditions.

Table 1
Overview of human and organizational errors and technical faults in some well known offshore major accidents.

Accident	Description	Human errors	Organizational errors	Technical faults
Ekofisk Alpha (Norway, 1975)	Riser rupture, explosion, fire three fatalities during evacuation	Error in operation of lifesaving capsule	Substandard corrosion protection not detected and discovered	Failure of riser due to external corrosion
Deep Sea Driller (Norway, 1976)	Grounding during transit to shore six fatalities during evacuation	Investigation claims errors by captain, this is doubtful	Errors in onshore operational planning of transit movement, and in emergency management	Engine failure, lifeboat
Alexander L. Kielland (Norway, 1980)	Structural failure, capsizing 123 fatalities during evacuation and rescue	Unknown	Failures during emergency management	Launching systems and lifeboat engine failures
Ocean Ranger (Canada, 1982)	Capsizing on location 84 fatalities during evacuation and rescue	Errors when trying to close ballast valves	Failure to provide adequate competence relating to manual ballast operations	Failure of ballast control systems due to short circuits caused by sea water ingress
Glomar Java Sea (China, 1983)	Capsizing on location 81 fatalities during evacuation and rescue	Error in deciding when to carry out precautionary evacuation of personnel	Unknown	Unknown due to no survivors
Enchova (Brazil, 1984)	Blowout 36 fatalities during evacuation	Error in operation of lifeboat	Unknown	None known
Piper Alpha (UK, 1988)	Explosion, fire 167 fatalities during evacuation and rescue	Failure to follow procedures	Several failures during administration of major hazard activities, and emergency management	Fire walls failed when exposed to blast loading
Ocean Odessey (UK, 1988)	Burning blowout one fatality during evacuation	Unknown	Failures during emergency management	None known
West Gamma Norway, 1990)	Capsizing during transit between locations No fatalities	Unknown	Management errors in planning of transit operations not observing weather impact and avoiding exposure of many crew members to extreme weather	Equipment torn loose due to wave impact
Bombay High (India, 2005)	Collision, explosion, fire 22 fatalities during evacuation and rescue	Unknown	Management errors when deciding to bring supply vessel close to jacket platform in heavy swell to transfer injured person as well as in emergency management	Inadequate protection of risers below deck
Usumacinta (Mexico, 2007)	Structural failure, blowout 22 fatalities during evacuation and rescue	Failures by lifeboat captains likely in allowing hatches to be opened in bad weather	Errors in emergency management allowing unsafe behaviour in lifeboat and capsule	Foundation failure of jack-up due to weather leading to damage to wellhead platform
Deepwater Horizon (US GoM, 2010	Gas/oil blowout, causing explosion and subsequent fire, 11 fatalities on installation, remaining 115 persons evacuated	Ongoing investigations, but anecdotal information suggests several human errors made by drilling personnel causing the blowout	Anecdotal information suggests multiple organizational factors involved, involving BP as operator and several of subcontractors companies	Blowout preventer apparently failed in shitting in the well for so far unknown reasons

- The remaining accidents in Table 1, with the exception of Usumacinta accident in 2007 may be considered together. In these cases the conditions of the accident were so severe that it could not be expected that any evacuation system would be capable of assuring safety of personnel during emergency evacuation. The risk reduction actions for these scenarios should be focused on prevention of such scenarios through a combination of technical, human and organisational actions. For instance, the Piper Alpha accident was influenced by a bad platform layout, lack of blast walls and a safety management system with severe faults, according to HSE (2005).
- The Usumacinta accident has demonstrated the importance of emergency management in order to prevent unsafe behaviour inside lifeboat and capsule after they were water born (SINTEF, 2010). Similar faults have also been observed in other accidents, such as Ekofisk Alpha, Deep Sea Driller, Ocean Ranger, Piper Alpha and Bombay High.

3.2. Input data

3.2.1. Demographic data

The Risk Level project has amongst other activities conducted large questionnaire surveys four times, with 2 year intervals

(PSA, 2008; Tharaldsen et al., 2008; Vinnem et al., 2006). These surveys have collected large volumes of demographic data that was useful for the present study. A brief excerpt of some of the analyses of demographic data is presented in the following, the full presentation is available in Vinnem (2008a). Fig. 6 presents an overview of the average number of employees on offshore production installations in Norway, in the period 1996–2007. The following observations could be made from the diagram:

- The average number of company personnel on the installations has decreased virtually continuously in the entire period.
- The total number of average offshore employees decreased from 1996 until 2000, and has been increasing in the period after year 2000, the variations have been taken by the contractor personnel.

It should be noted that relatively few new installations have been commissioned in the period, virtually all of them with a lower manning level compared to the average level shown in Fig. 6. This implies that on old installations, the variations have been even more distinct.

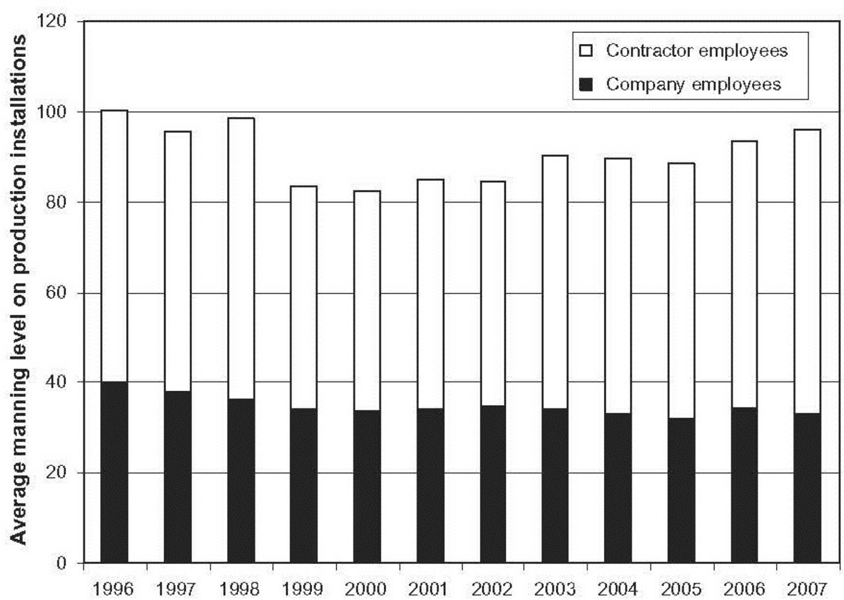

Fig. 6. Average manning level on Norwegian offshore production installations.

Fig. 7 presents an overview of the trends in average employee age in the period 2001–2007, split in three groups according to petroleum company, contractor company and rig owner employment.

Fig. 7 indicates an increasing trend, whilst the survey in 2005 represents a deviation from the general trend. It may be observed

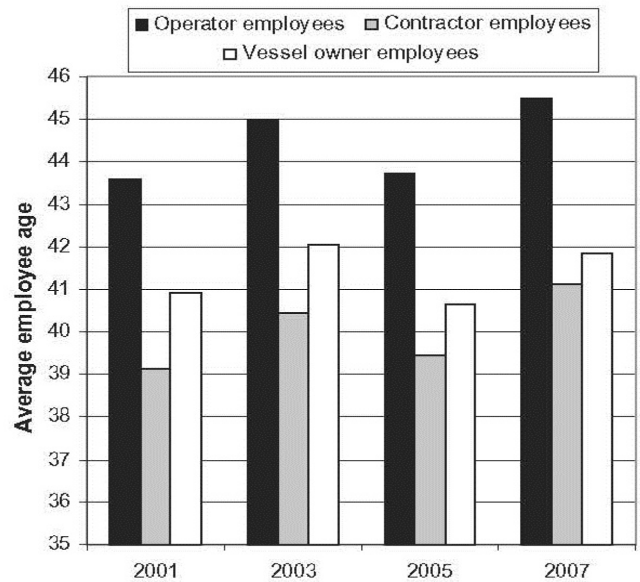

Fig. 7. Average employee age for different employee groups in the period 2001–2007.

that the results in 2005 are untypical in several respects, but no obvious explanation has been found. It could be noted that the year 2005 has the highest number of participants of all the four surveys, nearly 10,000 participants.

Fig. 8 presents an overview of what percentage of employees in the different age groups that have membership in the emergency preparedness organisation. Two types of membership in the off- shore emergency preparedness organisation are considered, those with demanding physical requirements to the members (smoke diving, fire fighting, rescue from sea, stretcher transportation, etc.) and those with management roles and no physical requirements. Fig. 8 is limited to those with demanding physical requirements.

It is worth noting that the highest percentage of all employees that have physically demanding requirements are found in the age group 51–60 years. It was expected that the highest percentage would be in one of the groups with younger personnel. One possible explanation is that often such positions are defined for supervisory personnel, which tend to be the oldest personnel. Another possible factor is that membership in the emergency organizations carries quite high fixed payment (i.e. independently of whether emergencies occur or not), which implies that personnel tend to hang onto such positions even if their physical fitness may have been reduced such that younger personnel should have taken their place.

3.2.2. Perceived emergency preparedness level

One of the most remarkable findings from the analyses of questionnaire survey data, was the significant improvement of the experienced level of emergency preparedness. The question in the survey was; 'The emergency preparedness on the installation is good', with a five point scale ranging from 'Agree completely' to 'Disagree completely'. The five reply categories are given numerical values 1–5 in the calculation of average scores. This implies that the lower the average score is, the closer is the average reply to 'Agree completely'. Fig. 9 presents the clear positive trend in the four surveys on this question.[4] The diagram shows that personnel with emergency preparedness functions and those without such functions all have the same extent of improvement of their view of goodness of the emergency preparedness arrangements. But those with emergency functions are in average somewhat more positive to the emergency capabilities. It could be noted that the improvement shown in Fig. 9 is one of the strongest effects seen in this survey over the 7 years.

Fig. 10 presents the same data, but split in another manner. Three areas in the Norwegian sector have an extensive cooperation scheme for emergency preparedness, called 'area based emergency preparedness' (Vinnem, 2008a). This involves cooperation between all installations in the area and common marine resources, typically an offshore based fully equipped All Weather SAR helicopter, an advanced, high speed standby vessel, and common traffic center for surveillance against passing vessels on collision course. These three area are referred to in Fig. 10 as 'Area 1'; 'Area 2' and 'Area 3', as opposed to those installations in areas where no cooperation has been formed.

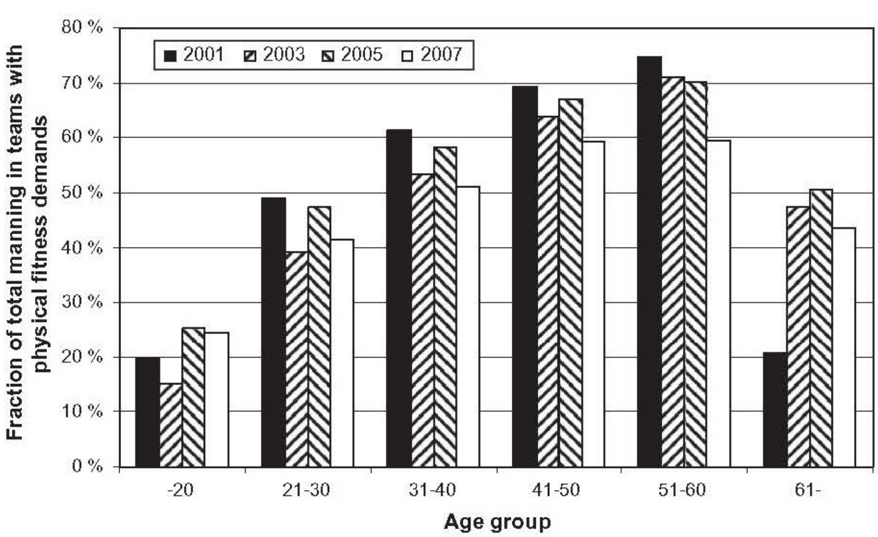

Fig. 8. Percentage of age groups that have emergency preparedness roles with physical requirements.

[4] The survey data from 2009 were not available for the study.

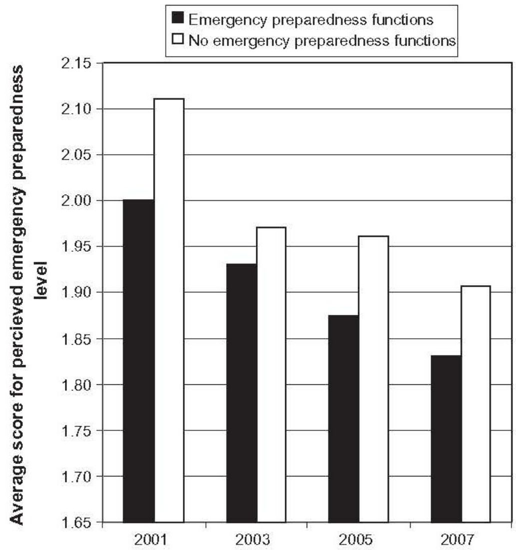

Fig. 9. Trend in 'emergency preparedness offshore is good' question for all employees in two groups.

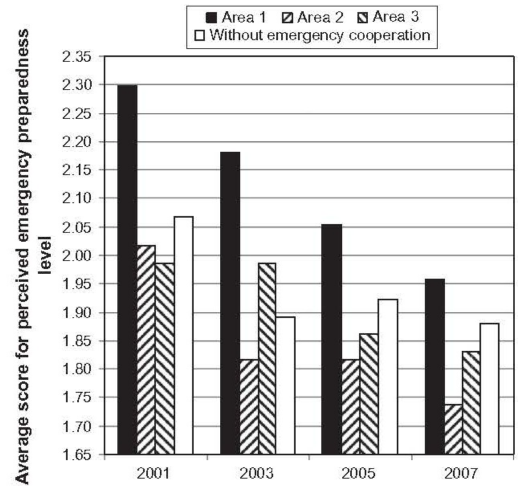

Fig. 10. Trend in 'emergency preparedness offshore is good' question for employees in areas with cooperation schemes and areas without cooperation schemes.

It has been an intense debate between groups of offshore employees as well as between some groups and management on whether the cooperation scheme for emergency preparedness is an improvement or the opposite. Based on the values in Fig. 10, it appears that the offshore work force in these areas have the same appraisal of the positive development of the emergency preparedness as in those areas where no cooperation exists. It could even be argued that the score reduction is the highest in those areas with emergency preparedness cooperation, based on visual observations from the diagram.

3.2.3. Use of SAR facilities

There are five offshore based SAR helicopters in the Norwegian sector. The fleet of offshore based SAR helicopters was increased significantly due to the introduction of area based emergency preparedness. There are two helicopters in the southern part, two helicopters in the north part of the North Sea (in the actual sense of the word) and one helicopter in the Norwegian Sea (see also Fig. 10). One of the helicopters in the northern North Sea is not part of an area with emergency preparedness cooperation. Fig. 11 presents the annual distribution of missions and hours spent on these missions, for one of the helicopters in the northern North Sea, as average values in the period 2003–2007. The annual values are:

- Annual number of missions: 496.
- Annual number of operational hours: 472.

There is also information about the ambulance missions, which are categorized into red, yellow and green criticality. The 'red' missions, typically 25% of all ambulance missions, are those cases where lack of rapid transfer to onshore hospital may be life threatening. The 'green' missions are those without criticality, to the extent that the personnel could wait for the next scheduled flight,

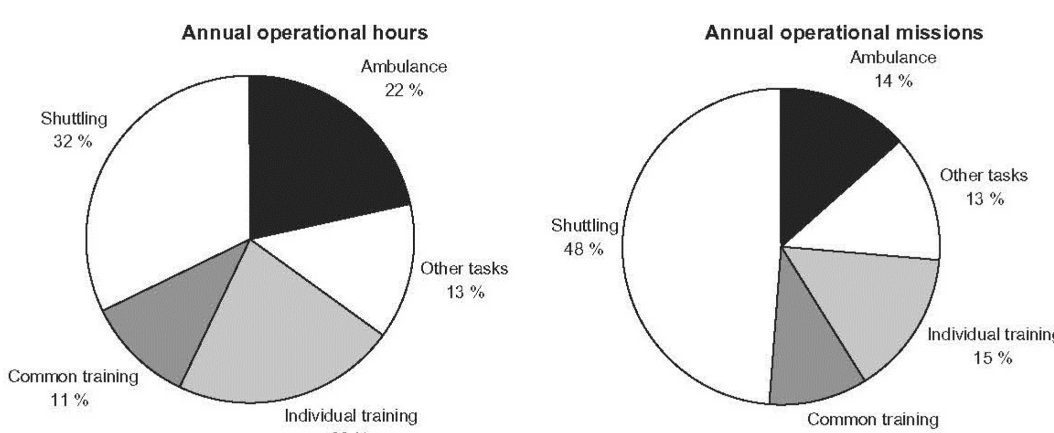

Fig. 11. Distribution of operational missions and hours for one SAR helicopter.

whereas the ‘yellow’ are the remaining missions. Based upon the values given, the number of red missions is typically one mission per helicopter per week. This implies that there is significant reserve capacity in the system.

3.2. Main findings

3.2.1. Overall status of emergency preparedness

Several sources of information were interpreted in combination, in order to reach the overall conclusion, that the overall status of emergency preparedness for personnel in the Norwegian sector is good, as outlined in the methodology description in Section 3.1.2. The main factors are the following:

- The clear improvement of the perceived goodness of emergency preparedness in the period 2001–2007 as outlined in Section 3.2.2.
- The clearly positive effects of the changes in the last 10 years; see Section 3.3.2.
- Few negative findings in external audits and investigations of accidents and incidents.

The significance of the clear improvement of the perceived goodness of emergency preparedness has already been commented upon, in relation to the effect of introduction of area based emergency preparedness, around 2002–2003. Some union representatives have been very negative towards the area based emergency preparedness, claiming that the reduction of the number of standby vessels for individual installation to have a significantly negative effect. The opposite view is that these often slow moving standby vessels are replaced by SAR helicopters and modern, high speed standby vessels as common resources. The data from the questionnaire survey as presented in Section 3.2.2 above has such a strong positive trend in the period with introduction of the area based emergency preparedness, that there is no basis to confirm the negative attitude by some workforce representatives.

The period 2001–2007 also covers the period in which a number of design weaknesses in freefall lifeboats have been discovered during testing of such lifeboats on the installations, starting in 2005. Still, the trend in the data in Section 3.2.2 is positive also after 2005.

3.2.2. Effect of changes the last 10 years

The changes that have been introduced the last 10 years are concerned with the following:

- Area based emergency preparedness:
    - o Rapid medevac capabilities for critical medical cases.
    - o Surveillance of external ship traffic.
    - o Rescue of personnel in the sea after helicopter ditching.
    - o Operational constraints on the basis of emergency preparedness restrictions.
- Man-over-board emergency preparedness.
- Lifeboats.
- Survival suits.
- Qualifications of personnel in emergency teams.

3.2.3.

The most significant change over the last 10 years, possibly the last 20 years, is the introduction of area based emergency preparedness. There are many experts and workforce representatives that agree on the significance of this improvement. And there are clear indications from the questionnaire survey that the offshore employees also value the increased professionalism implied by this concept, see Section 3.2.2.

In addition to those arguments that have already been mentioned, there has also been increased focus on operational limitations that reflect the capability limits of the available emergency resources. This implies for instance that helicopter transportation may have to be halted temporarily as long as the weather conditions are so severe that rescue of personnel from helicopter ditching would not be possible with the resources that are available.

The most important limitation of the area based emergency preparedness is the extent of the area, which determines the maximum response times to the most distant installations. The requirement is to be able to rescue 21 persons in the sea within 120 min, independently of the environmental conditions. Some of the areas have an extension which is just on the borderline of meeting the requirement, without any extra margins.

SAR helicopters have very few limitations with respect to rescue of personnel from the sea in all weather conditions, although evaluation by pilots suggests that a lower pick-up rate may be expected in severe weather conditions. The starting up of the rotor on the installation in strong wind may be a limiting factor. The SAR helicopters may also be used to rescue personnel outside the safety zone, but the regulatory requirement is limited to the safety zone.

When helicopters are not available, man-over-board boats is the only other option, but with severe operational limitations with respect to sea states.

There has been increased focus on rescue of personnel who fall in the sea, including a requirement for two independent systems, focus on qualifications and motivation for use of preventative measures.

The detection of weaknesses in freefall type of lifeboats in 2005 has led to extensive studies of necessary improvements of freefall as well as conventional lifeboats. When these studies have been completed, it may be presumed that the boats will be at least as good as what was presumed at the time of installation.

New survival suits have been developed the last 3 years as a response to weaknesses detected in association with tests in the area based emergency preparedness development program. These improvements are essential in order to allow response times up to 120 min.

There has been increased focus on and attention to qualifications of personnel in emergency teams, including physical fitness of personnel with demanding physical requirements, as well as competence of personnel in the emergency management teams. Some companies have the rule that no contractor employees shall participate in the emergency teams. It has been shown that the number of company personnel is reduced continuously, and that the average age is increasing, see Section 3.2.1, such that it be- comes more and more difficult to recruit company personnel with necessary physical capabilities to the emergency teams.

3.2.4. Other significant findings

The development of emergency preparedness during the last 10 years is mainly a story of improvements and success, but there are some aspects that could be further improved. These aspects mainly reflect the fact that several of the recent improvement are not based on regulatory requirements, but are voluntary improvements adopted by most of the companies in the industry, but not all. The aspects where further implementation would be preferable are the following:

- Traffic surveillance in order to prevent passing vessel traffic on collision course being undetected.
- Modern, high speed standby vessels.
- Offshore located SAR helicopters.

There are two traffic surveillance centres for ship traffic monitoring based on electronic transfer of radar signals, these cover 90% of the installations (Vinnem, 2008a). It has been observed that the surveillance performed by these centres is reliable, efficient and imply a long warning time with ample opportunity to contact the ships in order to make them change course before the installation has to start preparations for shutdown and evacuation. The experience is that where the installation itself or its standby vessel has the responsibility for detection of vessels on collision course, vessels are rarely detected on collision course. As there is no reason to assume that there are fewer vessels on collision course in these areas, the implication is that such surveillance is less reliable. It would be highly preferable if all installations had traffic centres to take care of the ship traffic monitoring.

The new generation, high speed standby vessels which includes an internal docking facility for lifeboats has so far only been com- missioned for areas with cooperation agreements, which implies that only a small fraction of all standby vessels are of this standard. It would be a clear advantage if more vessels of this generation were contracted by the installations which are not part of cooperation areas.

The offshore located SAR helicopters represent a significant improvement of the emergency preparedness, not the least due to the ability to carry out medevac in cases where it is essential for the patient's chance of survival to arrive at an onshore hospital within 2–3 h. In a study (OLF, 2000) prior to introducing the area based emergency preparedness it was assumed that there would be about 15 cases with such critical emergency patient transfer for the entire Norwegian sector per year. The experience with five helicopters is that each helicopter carries out about one such transfer per week ('red' missions), i.e. about 250 cases per year. It could be added that the five helicopters cover installations with about 80% of the offshore population as far as production installations are concerned (see Vinnem, 2008a). It is assumed that the fraction is lower for mobile drilling units, but there are no available data in order to substantiate this assumption. There is most probably about 25–30% of the offshore workforce who does not have access to such helicopters and would therefore have somewhat lower survival chances in case of very serious injury or illness. This could be improved if more areas had access to offshore located SAR helicopters.

3.3. Robustness and validity

Robustness and validity are essential aspects of study like the present, and is a challenge due to the lack of actual experience data. The robustness is further a challenge, due to the fact that at least one of the findings of the study is quite controversial. As al- ready discussed, the data relating to the perceived goodness of the emergency preparedness are quite clear with respect to the improvement of perceived goodness as reported in Figs. 9 and 10 and discussed in Section 3.2.2. But a few of the unions who organize offshore employees have been strongly against the area based emergency preparedness cooperation, claiming that the loss of individual standby vessels for each installation is a significant reduction of emergency preparedness. The arguments focus mainly on the perceived assurance implied by a vessel that may be observed continuously by the offshore workforce, rather than actual achievements that the vessels are expected to be able to perform.

This argument is on the other hand somewhat difficult to accept, as the data reported in Figs. 9 and 10 are essentially demonstrating that the perceived quality of the emergency preparedness has improved continuously in the period, in spite of introduction of area based emergency preparedness and detection of weaknesses in lifeboats. The data further shows that the perceived quality has improved actually also on installations which are part of the area based emergency cooperation. The effect is quite strong, and is in direct contradiction to what has been claimed by these unions.

Some HES experts have remarked that those unions that are the strongest opposition to the area based cooperation are those that also have members onboard the standby vessels, i.e. those that may be negatively affected by the reduction in the number of standby vessels. The implication of this is a possible hint that the opposition is influenced by arguments relating to job security of standby vessel crew members, rather than feeling of assurance of the employees on offshore installations.

It is noteworthy that there are other unions, of which two are large unions with a high membership of offshore employees that are in favour of the area based cooperation. One of these unions has been a very clear supporter of the area based cooperation and has taken actively part in the development of for instance the new generation of standby vessels. Also employer representatives clearly support the improvement and increased professional- ism that are implied by the area based emergency preparedness.

This implies that one of the main findings of the study is sup- ported by the data from the questionnaire as well as observations from interviews with a number of persons, representing employees as well as employers. This finding should therefore be robust.

With a study like the present, one of the main principles to increase the robustness of conclusions is to ensure that there is at least two, preferably independent, sources for each main conclusion.

Another principle that may be used in order to increase the robustness is to allow independent review and discussion of findings before finalisation of the conclusions. This has also been carried out in the present case. A separate internal reference group from PSA has reviewed the draft findings and conclusions, in addition to several presentations and discussions to internal groups in PSA. Also a forum with employee, employer, authorities and government representation has discussed the results of analysis and findings on two occasions.

4. Preventative safety versus emergency preparedness

The relationship between accident prevention and emergency preparedness is one interesting aspect from a philosophical point of view that is implicitly focused upon as a result of the present study. It is emphasized that this aspect was not part of the study (Vinnem, 2008a). The oil companies have for some time expressed the view that improved accident prevention is not given any credit by the authorities. As a general viewpoint, this applies to prevention of injury to personnel as well as prevention of environmental damage. Norway has had for some time a fundamental discussion about possible permission to start exploration and production activity in some environmentally sensitive areas near the coast in northern Norway (not full arctic conditions, but close to arctic conditions). The relationship between accident prevention and emergency preparedness is one of the elements in that very politically sensitive discussion relating to environmental effects. The discussion in this paper will however, be limited to personnel safety, and not particularly focused on northern Norway.

4.1. Regulatory requirements

Norwegian as well as UK regulations for offshore facilities and operations have important requirements that affect the balance between preventative safety and emergency preparedness, but not with explicit requirements that may be used to determine what this balance should be.

Norwegian regulations have requirements that call for continuous risk reduction, irrespective of the risk level. There should be efforts made to reduce risk through preventative or mitigation measures, and good proposals shall be implemented unless the negative effects of such proposals (including costs) are in gross dis- proportion to the benefit, i.e. the risk reduction (ALARP; As Low As Reasonably Practicable). UK also has similar requirements for ALARP evaluations and risk reduction process.

Both sets of regulations also have in addition some minimum requirements for preventative safety as well as emergency preparedness. In Norwegian regulations there is for instance a requirement to use lifeboats of the freefall type, and two independent systems for rescue of personnel who fall into the sea. There is also the requirement that when the dimensioning of passive fire protection is performed, this shall be done without taking the effect of active fire protection (such as fire water) into account.

There are further requirements that personnel may be evacuated and rescued in what is termed ‘situations involving hazard and accident’, i.e. major hazard scenarios defined in QRA studies, accidental events of limited extent and situations implying temporary increase of risk (PSA, 2002).

In the UK, there is a requirement to provide arrangements that give a 'good prospect of escape, evacuation and recovery' for all foreseeable events (HSE, 1995).

In general there is a tendency in regulations to call for adequate emergency provisions for foreseeable circumstances, irrespective of what has been done in order to reduce the probability of these circumstances. Thus there is no right to reduce the extent of emergency preparedness provisions due to improved preventative safety.

It is further known that companies who have argued towards Norwegian and UK authorities along the lines of reduction of emergency preparedness due to improved preventative safety, have received replies to the effect that such an approach is not viable.

4.2. Industry viewpoints

Several international and national standards for the offshore industry (NORSOK, 2006; ISO, 1999, 2000) emphasize the general risk reduction principle that priority shall as far as possible be given to measures to reduce the probability of accidents rather than measures to reduce the consequences of accidents. These standards are all referenced in for instance Norwegian legislation. The implication of such a principle is that if probability of accidents may be reduced, there should not be any need to improve emergency preparedness. This is the viewpoint often adopted by the industry, based upon the wording of the standards.

But there may be other priorities and circumstances that will inspire the industry to improve the emergency preparedness arrangements. One such circumstance is the need to maintain a good reputation. Especially when it comes to emergency preparedness relating to environmental spill is this a significant factor. The Norwegian industry is as mentioned above very keen to open up new acreage for exploration in some near-shore areas in northern Norway (Norwegian Sea). The debate is focused on environmental spill and environmental risk, and the willingness to invest in improvement of preventative measures as well as emergency preparedness is certainly present. This is due to authority requirements and pressure from Non-Governmental Organisations, but is also influenced by the need to maintain a good reputation. This has also been demonstrated by the actions taken by industry in order to improve oil spill containment from deep subsea wells, following the severe oil spill from the Deepwater Horizon blowout.

4.3. Proposed principles for balance between preventative safety and emergency preparedness

The balance between accident prevention and emergency preparedness is not straightforward to conclude on. The findings of the present study will to some extent strengthen the focus on this controversy. The question then becomes is there a way out of the dilemma, a way that may provide a compromise between the regulatory and the industry viewpoints. We will try to outline such a compromise here, through a process with four steps. This process is applicable under Norwegian and UK legislation, both being risk based legislation, based on the ALARP principle. It will not be applicable under more prescriptive legislation, such as for the US Outer Continental Shelf. It may be applicable in other legislations which are based on the same principles as the UK and Norwegian legislation, subject to evaluation in each case. This approach also fulfils the industry viewpoints as outlined in Section 4.2, in the sense that preventative measures should be given priority. The following steps are recommended:

1. The frame conditions must always be satisfied, according to regulations (UK as well as Norwegian):
   - Minimum requirements for preventative safety.
   - Minimum requirements for emergency preparedness.
   - Minimum requirements with respect to acceptable risk levels (upper tolerability limits).
2. ALARP process shall be conducted according to regulations.
3. When making decisions about risk reducing measures:
   - Priority to be given to measures that may reduce probability over consequence reducing measures.
4. If not implementing a certain emergency preparedness measure, the preferred preventative measures which shall have to be implemented shall be specified.

5. Discussion of findings in the study

The implications of too rare accidents are probably most extensive for a study like the one reported in this paper. Except for res- cue of survivors from helicopter accidents and incidents there is very little relevant experience data on which such a study could be based. The discussion above has outlined how the lack of data could be compensated for.

Also the emergency preparedness associated with oil spill containment from deep subsea wells as demonstrated by the Deepwater Horizon blowout may be considered in this context. It was not until the blowout occurred that it was realised by BP and others (Department of the Interior, 2010b) that the technology for oil spill containment from such wells was far from satisfactory developed. Such events have been very rare for many decades even on a worldwide basis. The previous subsea well blowout with a large oil spill was the Ixtoc blowout in Mexican Gulf of Mexico in 1979/1980, which took almost 10 months to completely kill the blowout (Department of the Interior, 2010b).

Robustness and validity are on the one hand essential aspects of the present study, and is on the other hand a challenge due to the lack of actual experience data. The triangulation approach that was selected is probably the best approach to choose in these circumstances. The approach is parallel to that chosen in the Risk Level project (Batelle, 2008; Vinnem, 2007), which has to some extent been remarkable in the sense that it has been possible to gain trust and confidence by all parties, employees as well as employers, in spite of the severe mistrust when the project was initially launched.

The statement 'reasonably foreseeable' is a key concept in some of the regulations. The question may therefore be to what extent the lack of major accidents creates a situation where such occurrences are no longer 'reasonably foreseeable'.

It has been noted, see Sections 2.2 and 3.1, that major accidents have occurred on several occasions in other areas where offshore oil and gas operations take place. The last 10 years have seen accidents like P-36 (Brazil, 2001), Temsa (Egypt, 2004), Bombay North (India, 2005), Usumacinta (Mexico, 2007) and Deepwater Horizon (US, 2010), amongst which only the Temsa burning blowout did not result in major loss of lives.

It has also been noted that in some of the near-misses that have occurred in the Norwegian sector during the last few years, severe accidents with major loss of life could have occurred under slightly different circumstances. This applies at least to the following near-misses:

- Subsea gas blowout: The Snorre Alpha (Statoil, 2005) subsea gas blowout in November 2004 did not ignite, but could have ignited and thereby caused major loss of life. The foundation of one of the anchors for the TLP could also have failed, as an alternative cause of major loss of life. The official investigation report (PSA, 2005) did not classify event as a major accident, but this debatable.
- Major gas release: The Visund (PSA, 2006) major gas release in January 2006 with initial flowrate of some 900 kg/s did not ignite, but could have ignited and thereby caused major loss of life. A less extensive, but still major gas release in the UK sector in February the same year did actually ignited, but only minor injuries resulted.
- Gas cloud in concrete shaft: The Statfjord Alpha (PSA, 2008) gas release in the utility shaft in May 2008 did not ignite, but could have ignited and thereby caused major loss of life, due to the close proximity to the accommodation module.

It is thereby demonstrated that very good control over ignition sources and to some extent fortunate circumstances has contributed to the fact that no major accidents with significant loss of life have occurred for a long time. But these (and other) near-misses indicate that such accidents have to be classified as 'reasonably foreseeable'. It would not be correct to rule out the possibility of such major events.

As already noted, see Section 4.1, the regulations of most of the nations around the North Sea are risk based, implying that risk assessments are used in order to specify what safety prevention and mitigation solutions and actions that should be implemented. The lack of relevant experience data from emergency preparedness solutions and operations often imply that the risk assessments are relatively vague with respect to risk contributions from emergency preparedness scenarios. This is an aspect which preferably should be strengthened, and should have somewhat higher focus by the industry, its consultants and the authorities.

The final implication to be noted is that the lack of experience data may be taken as an additional indication that the emergency preparedness level should not be allowed to be reduced. It would probably take still a long period (say at least 20–30 years) with no major accidents before it could be considered relevant to take up such a discussion.

6. Conclusions

It has been demonstrated that major accidents have been rare in the North Sea waters for more than 25 years. But the lack of experience data for the offshore areas considered does not imply that such circumstances can be excluded as 'reasonably foreseeable', occurrences in other offshore areas show that such events are possible, and near-misses in the North Sea have demonstrated that the potential is still present.

In 2010 this may be further emphasized through the Deepwater Horizon disaster. Major accidents had not occurred in the US Gulf of Mexico water for more than 30 years, and it appears that for in- stance politicians virtually had ruled out the possibility of such major accidents.

For the worldwide offshore community it will be important to strive to prevent recurrence of major accidents. This is clearly demonstrated by experience associated with Deepwater Horizon blow-out, where US authorities have put a ban on all drilling activities from floating installations for 6 months, (Department of the Interior, 2010b). During this period it is up to the industry as well as authorities to demonstrate by the end of the period (or sooner) that drilling from floating installations is safe to reopen. In the case of the US Gulf of Mexico this is mainly based on the risk of environ- mental damage. Also major risk exposure to personnel would be expected to have the same effect, especially in other areas.

The role of authorities such as Petroleum Safety Authority [Nor- way] and UK Health and Safety Executive has been acknowledged as crucial for such purposes for many years, as these authorities have taken a leading role in pushing for continuous increase in safety levels. The US Minerals Management Service (MMS) has not had a similar prominent role (Norwegian Research Council, 2010). This was realised by US Department of Interior shortly after the Deepwater Horizon blowout, when the regulatory control was transferred from MMS to a new authority, Bureau of Ocean Energy Management, Regulation and Enforcement. This authority does not have responsibility for taxation and resource management, with the obvious possibility of conflict of interest. It has been demonstrated how it has been possible to conduct a robust study of the emergency preparedness arrangements and their status, in spite of the rare occurrences of major accidents the last 25 years in the North Sea and waters further north.

The lack of experience data from relevant major accidents implies severe restrictions on use of occurrence data, and alternative approaches had to be chosen for the emergency preparedness study. The lack of occurrence data also implies that the basis for analysis of major hazard risk becomes rather vague.

It is therefore recommended that the emergency preparedness level should not be reduced, but preference should still be on preventative measures. This applies to the entire North Sea area. Improvement of emergency preparedness standards is recommended in some other areas, such as the US Gulf of Mexico.

In Norway at least, the main focus with respect to emergency preparedness during the last 4–5 years has been on hardware,
i.e. freefall lifeboat modifications, new survival suits as well as modern, high speed standby vessels. But maintenance of a high emergency preparedness level is also strongly dependent on non- tangible aspects such as competence, training, attitudes, motivation and perception of the level of protection. The debate of the area based emergency preparedness in Norway in the early years of the new decennium has confirmed this importance beyond reasonable doubt.

The offshore operations in the Norwegian sector are being extended into more northern waters, and have already entered into the Barents Sea, although not yet with permanent operational presence. There may be a need to revisit the balance between pre- ventative safety and emergency preparedness for the extension of permanent operational presence into the Barents Sea areas.

Acknowledgements

The study was financed by the Petroleum Safety Authority, whose permission to publish this paper is gratefully acknowledged. The author is also acknowledging the assistance and comments provided by personnel in PSA and Safetec Nordic. The paper expresses the views solely of the author. The valuable comments made by the anonymous reviewer are gratefully acknowledged.

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