Helicopter Safety Study 3

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Main report

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ABSTRACT

The overall objective of the Helicopter Safety Study 3 (HSS-3) is to contribute to improved safety in helicopter transport of personnel to, and from, fixed and floating oil- and gas installations on the Norwegian Continental Shelf (NCS). The study is a follow-up of the previous studies Helicopter Safety Study (HSS-1) and Helicopter Safety Study 2 (HSS-2).

The HSS-3 main report describes a method for risk quantification, development for the periods 1999–2009 and trends 2010–2019, plus statistical/historical data and the estimation of risk levels. In addition, the study includes an analysis of passengers' risk perception regarding offshore helicopter transport, and a proposal on how the safety can be followed by a set of lagging and leading indicators to monitor safety. Finally, recommendations are given for a number of measures about how safety can be improved or, as minimum, be maintained at the present level. A separate appendix report contains background material for the study.

KEYWORDS	ENGLISH	NORWEGIAN
GROUP 1	Safety	Sikkerhet
GROUP 2	Helicopter	Helikopter
SELECTED BY AUTHOR	Helicopter safety	Helikoptersikkerhet
	Flight safety	Flysikkerhet
	Risk level	Risikonivå
	Resilience	Resiliens

PREFACE

This report is the result of very good cooperation between the petroleum industry, the helicopter industry, labour unions, the authorities and research in a joint effort to improve the safety of helicopter transport on the Norwegian Continental Shelf. We hope our recommendations will be of use to the community, and that the industry and the aviation authorities follow up our suggestions for concrete measures.

We thank all contributors for their openness and valuable input.

Trondheim, March 2010

Ivonne Andrade Herrera

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EXECUTIVE SUMMARY

Introduction

The overall objective of the Helicopter Safety Study 3 (HSS-3) is to contribute to improved safety in helicopter transport of personnel to, and from, fixed and floating oil- and gas installations on the Norwegian Continental Shelf (NCS). The project is named Helicopter Safety Study 3 (HSS-3) and is a follow-up of the previous HSS-1 and HSS-2 studies. HSS-1 and HSS-2 cover the periods 1966–1990 and 1990–1998 respectively and are available in English. HSS-3 covers the period 1999–2019. The HSS-3 report is so far only in Norwegian language with an English executive summary. The main report describes a method for risk quantification, development for the periods 1999–2009 and trends 2010–2019, plus statistical/historical data and the estimation of risk levels. In addition, the study includes an analysis of passengers' risk perception regarding offshore helicopter transport, and a proposal on how the safety can be followed by a set of lagging and leading indicators to monitor safety. Finally, recommendations are given for a number of measures about how safety can be improved or, as minimum, be maintained at the present level.

Main conclusions

The main conclusions from the Helicopter Safety Study 3 (HSS-3) are as follows:

1. There has been only one helicopter accident, with no fatalities, on the NCS during the period 1999–2009. This represents a significant reduction compared with the previous period 1990–1998 where there were 2.3 fatalities per one million passenger flight hours. For the whole 20 year period of 1990–2009, five accidents with 12 fatalities are recorded. These data result in a risk estimate of 0.9 fatalities per one million person flight hours and an accident rate of 0.4 accidents per million person flight hours.

2. The risk reduction on the NCS in the period 1999–2009 compared with 1990–1998 is estimated to be 16 % according to expert judgements. The most important contributing factors are as follows:
   - Gradual introduction of new helicopter types and the implementation of the latest generation helicopter technology
   - Improved use of systems for vibration monitoring in helicopters (Health and Usage Monitoring System (HUMS) / Vibration Health Monitoring (VHM))
   - Increased pilot skill by added requirements regarding competence, experience and simulator training on NCS operations.
   - Improved flight operational procedures
   - Improved helideck design and operations through requirements and active use of the Norwegian Oil Industry Association's (OLF) helideck manual and guidelines
   - Improved emergency preparedness (such as improved emergency personal locator beacons, impact absorption and rescue suits, more rescue helicopters)
   - Introduction of Safety Management System (SMS)
   - The establishment of the Committee for Helicopter Safety on the Norwegian Continental Shelf has contributed to cooperation and promoted specific offshore safety related rules and recommendations specified in the Helicopter Safety on the Norwegian Continental Shelf. Part 1: Organizing of the public authorities’ involvement (NOU

2001: 21) and Part 2: Trends, objectives, risk influencing factors and recommended measures (NOU 2002: 17).

3. In the forthcoming period (2010–2019) the possible risk reduction is estimated at 23 % compared with the period 1999–2009. It is expected that the following planned improvements will be the most significant contributing factors to this reduction:
   - Continued introduction of new helicopter designs and implementation of a new generation of helicopter technology
   - Increased technical and operational experience with the new helicopter types (in particular Sikorsky S-92 and Eurocopter EC225)
   - Further development, updates and increased use of HUMS/VHM
   - Further development of Flight Data Monitoring (FDM) and SMS
   - Increase in engine performance compared to helicopter weight (introduction of *Performance Class 2 enhanced*; PC2e)
   - Improved safety standard of helidecks (procedures, size, lighting equipment, marking, monitoring of helideck motions, weather reports, turbulence knowledge)
   - Improved meteorological services.

Figure 0.1 shows the risk reduction in the three 10-year periods that have been analysed. In HSS-2 the risk reduction between the two first periods was estimated to be 45 %. In HSS-3 a risk reduction of 16 % is estimated for the period 1999–2009 compared to the previous period (1990–1998), and an additional 23 % risk reduction is predicted for the coming 10 year period: 2010–2019. The reduction of 23 % in this period is given under the assumption that already planned improvements will be implemented, ref. above list. In addition, a further reduction of risk is expected if additional safety measures are implemented, see below.

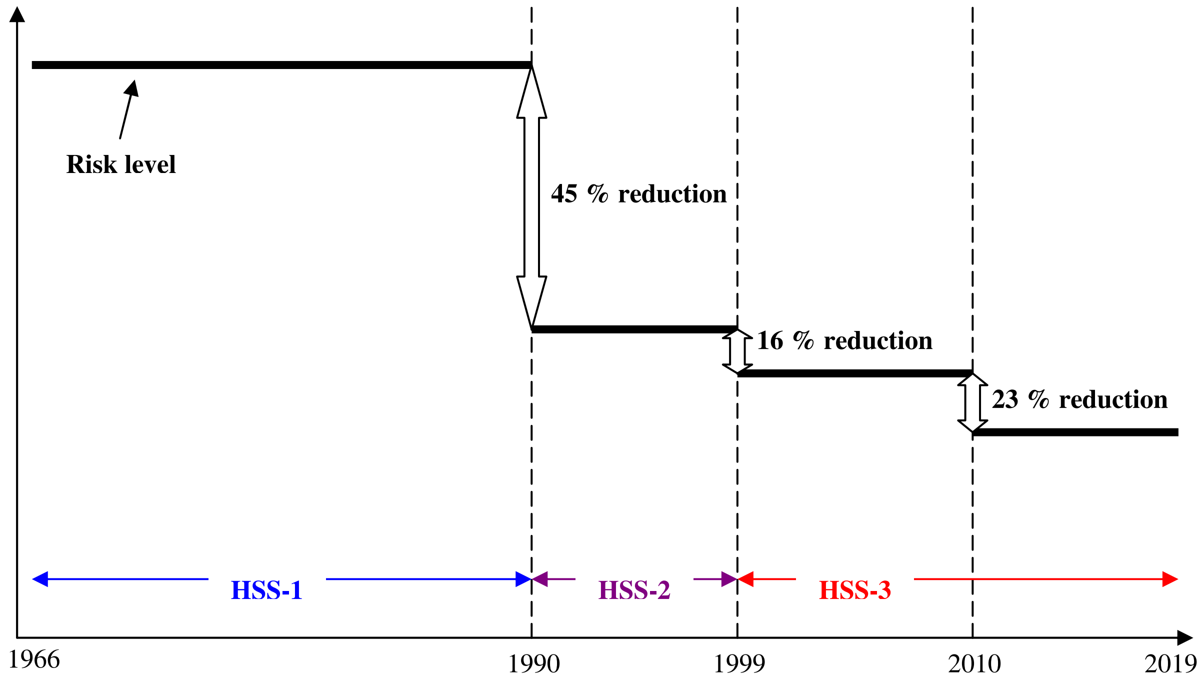


Figure 0.1. Estimated change in risk levels 1966–2019.

4. The most important potential *threats* for helicopter safety in the coming period are considered to be the following:
   - Lack of the possibility to maintain established Norwegian additional requirements for offshore flights, or that it will not be possible to introduce new requirements adapted to the conditions on the Norwegian Continental Shelf
   - Exemption from offshore special requirements and deviation from recommended guidelines
   - Unwanted consequences from changes implemented by the helicopter operators and other players in this area
   - Reduced competence among technicians and pilots in the helicopter companies due to the retirement of existing personnel
   - Lack of competence and resources regarding offshore helicopters in the Civil Aviation Authority – Norway (CAA-N)
   - Too much focus on cost and revenues by the different players on the NCS.

5. There have been significant changes in the internal framework conditions in the two major Norwegian helicopter operator companies in the period 1999–2009. The operator companies constitute parts of larger international corporations, and have access to more capital and larger helicopter fleets. The meeting between different management cultures has required demanding learning- and integration processes. The current study has revealed a set of organizational development characteristics that may have contributed to reduced focus on the primary operational tasks. In the long run such effects represent a safety threat if they are not properly managed.

6. *Perceived risk* is context- and situation dependent. The interviews with the offshore workers illustrate that there exist several situations and what we have termed "small omens" which have great influence on perceived risk. The passengers own stories fulfil several objectives; they are an important source for the ability to control a situation, organizational learning through the sharing of knowledge; at the same time giving input to what can be done to reduce the perception of risk and improve safety.

7. Resilience engineering represents a new safety perspective. Use of the *resilience* concept in the project has given room for analysing successful operations and the organization's ability to maintain safe operations. In this study we consider flight safety to be a dynamic characteristic, and the result of an interaction between several players and functions. Helicopter safety is something the system *does* and is not a property of the system. As far as it is possible this study has applied resilience principles to identify leading safety indicators.

Recommendations

Provided that the already planned improvements are implemented, the study concludes with the following recommendations for further improvement of safety. The following items are not prioritized:

1. Improve safety regarding approach helideck operations
2. Reduce the possibility of technical failures
3. Improve the management of organizational changes and changes in the internal framework conditions
4. Increase the use of proactive safety indicators

5. Improve interaction between the operators involved in offshore helicopter transport
6. Develop and maintain technical and operational competence
7. Reduce the risk of lightning strikes and their possible consequences on helicopters
8. Minimize exemptions from requirements and the OLF recommended guidelines
9. Evaluate measures to reduce perceived risk
10. Follow up and implement the recommendations presented in this report.

The recommendations listed here are explained in more detail in the following. Note: The items listed are not given in prioritized order:

1. Improvement of safety regarding approach helideck operations

Proposed measures:

- 1.1. Implement automatic flight approach procedures up to a specific distance to the installation, thereafter a safe visual approach in the last part of the approach and landing
- 1.2. Improve education, training and interaction for the pilots, plus the requirements for use of simulators such that the pilots can train on realistic operations regarding approach to the offshore platforms in non-optimal conditions
- 1.3. Minimize flights during night conditions and in reduced visibility, particularly flights to ships.

2. Reduce the possibility of technical failures

Proposed measures:

- 2.1. Complete thorough criticality analyses (Failure Modes, Effects and Criticality Analysis (FMECA) or similar) before new helicopters are put in service and before the implementation of major modifications
- 2.2. Focus on the use of the latest generation proven helicopter technology
- 2.3. Maintain the Norwegian offshore helicopter requirements, among others, the use of the Health and Usage Monitoring System (HUMS) and systems for position indication of the helicopter all the way down to sea level (Modified Automatic Dependent Surveillance (M-ADS) or similar)
- 2.4. Consistently apply the OLF's recommended guidelines for this type of helicopter operations
- 2.5. Improve the routines for reporting failures in critical safety equipment on helidecks.

3. Improve the management of organizational changes and changes in the internal framework conditions

Proposed measures:

- 3.1. Active use of risk analyses prior to implementing changes, and utilize the experience after changes have been implemented
- 3.2. Improve CAA-N’s mandatory inspection and surveillance programmes, notably with focus on routine follow up of the helicopter operators after major organizational changes
- 3.3. Ensure that Norwegian additional requirements are kept.

4. Increased use of proactive safety indicators

Proposed measures:

4.1. Improve safety management by extended use of leading indicators

4.2. Develop indicators based on observations of normal operations and better comprehension of what seems to work well (e.g. observations of landing on a moving helideck or base/heavy maintenance)

4.3. Further develop the Petroleum Safety Authority's project on "Risk level in Norwegian petroleum industry" (RNNP) to also include:
- reported incidents from the air traffic control and the helideck function
- a set of leading and lagging indicators as proposed
- monitor changes in risk levels through an update of the HSS-3 model based on the risk influencing factors (RIF).

5. Improve interaction between the operators involved in offshore helicopter transport

Proposed measures:

5.1. Increase the involvement of the air traffic service for offshore operations

5.2. Improve the communication and exchange of information internally and between the players in this sector. This to elucidate reporting routines, lines of responsibility and organization, and to learn from experience

5.3. Increase feedback from the Civil Aviation Authority to the helicopter operators in order to improve organizational learning across organizations

5.4. Improve the communication within and between the helicopter manufacturers and the helicopter operators. There is a special need to increase the availability of spare parts.

6. Develop and maintain technical and operational competence

Proposed measures:

6.1. Change the training of the technical personnel in order to increase system comprehension and more time to train on equipment that is specific for the operation of helicopters on the NCS

6.2. Extend and adapt the training of the pilots to realistic and critical situations

6.3. Initiate a project to look at the possibilities and possible safety gain of the paperless cockpit (Electronic Flight Bag or similar).

7. Reduce the risk of lightning strikes and their possible consequences on helicopters

Proposed measures:

7.1. Initiate a research project on the risk of lightning strikes on helicopters taking weather conditions and operations on the NCS into consideration.

8. Minimize exemptions from requirements and recommended guidelines

Proposed measures:

8.1. Minimize exemptions in overturn evacuation training in the requirements for refresher emergency training courses

8.2. Exempt possibilities to interpret the mandatory requirements that may lead to the lack of independent inspections of critical maintenance tasks offshore

8.3. Minimize exemptions from the Norwegian additional requirements and the special practice established for helicopter transport on the NCS (ref. item 2.3 on the use of HUMS and M-ADS).

9. Evaluate measures to reduce perceived risk

9.1. Measures to be further assessed:

- Make the safety videos less ‘serious’ (scaring) and stimulate the passengers to support each other socially, in particular those travelling for the first time and feeling uneasy
- Consider choice of seat in relation to specific needs as perceived risk varies with seating location
- Consider a possible weight limit for offshore workers in order to facilitate evacuation in emergency situations
- Improve the communication equipment in the helicopters and train the pilots to give clear and evident information (Passenger Announcement; PA)
- Fasten loose equipment in the cockpit (pilot’s suitcase, manuals etc.)
- Increase awareness of the heliguards as to their behaviour; notably to pay specific attention to those travelling for the first time, plus assisting passengers embarking/
  disembarking in bad weather condition (wind, helideck movements)
- Minimize exemptions from recurrent training for helicopter ditching
- Improve communication of credible information after incidents. (Correct information will reduce insecurity among the passengers.)
- Extend the project “Risk level in Norwegian petroleum industry” (RNNP) with new questions related to quantitative mapping (see the proposal in Chapter 8.2.5)
- Expand the next editions of RNNP with a specific qualitative part on helicopters.

10. Follow up and implement the recommendations presented in this report

Proposed measure:

10.1. OLF and the Civil Aviation Authority - Norway must in cooperation take an initiative to form a ‘body’ that can ensure that the proposed measures in this report will be evaluated and followed up by concrete actions. It is recommended that the cost/benefit analyses carried out (Chapter 10.6-10.7) are used as basis for this process.

Prioritizing measures

Prioritizing of the suggested recommendations and corresponding measures must be based on an overall assessment, taken into consideration cost/benefit, estimated risk reduction, feasibility, time, correlation with other measures, etc. It is also important to consider the effect of implementing more than one measure within a recommendation. Considering each measure separately with their estimated cost/benefit and risk reduction results, the following measures are considered as particularly favourable:

1. Complete thorough technical criticality analyses (FMECA)
2. Focus on the use of the latest generation proven helicopter technology
3. Implementation of automated approach
4. Improve CAA-N’s inspection and surveillance programmes
5. Consistently apply the OLF's recommended guidelines
6. Minimize flights in night conditions and in reduced visibility, particularly flights to ships

Based on a total judgement the following measures are considered of particular importance as well:

- Extend and adapt the training of the pilots to realistic and critical situations, and improve simulator requirements
- Extend the training of the technicians
- Continuance/replacement of M-ADS
- Focus on communication in order to learn from experience.

Method approach

An important part of the mandate for HSS-3 is to utilize the experience from previous studies, notably the two helicopter studies HSS-1 (1966–1990), HSS-2 (1990–2008) and the two public reports:

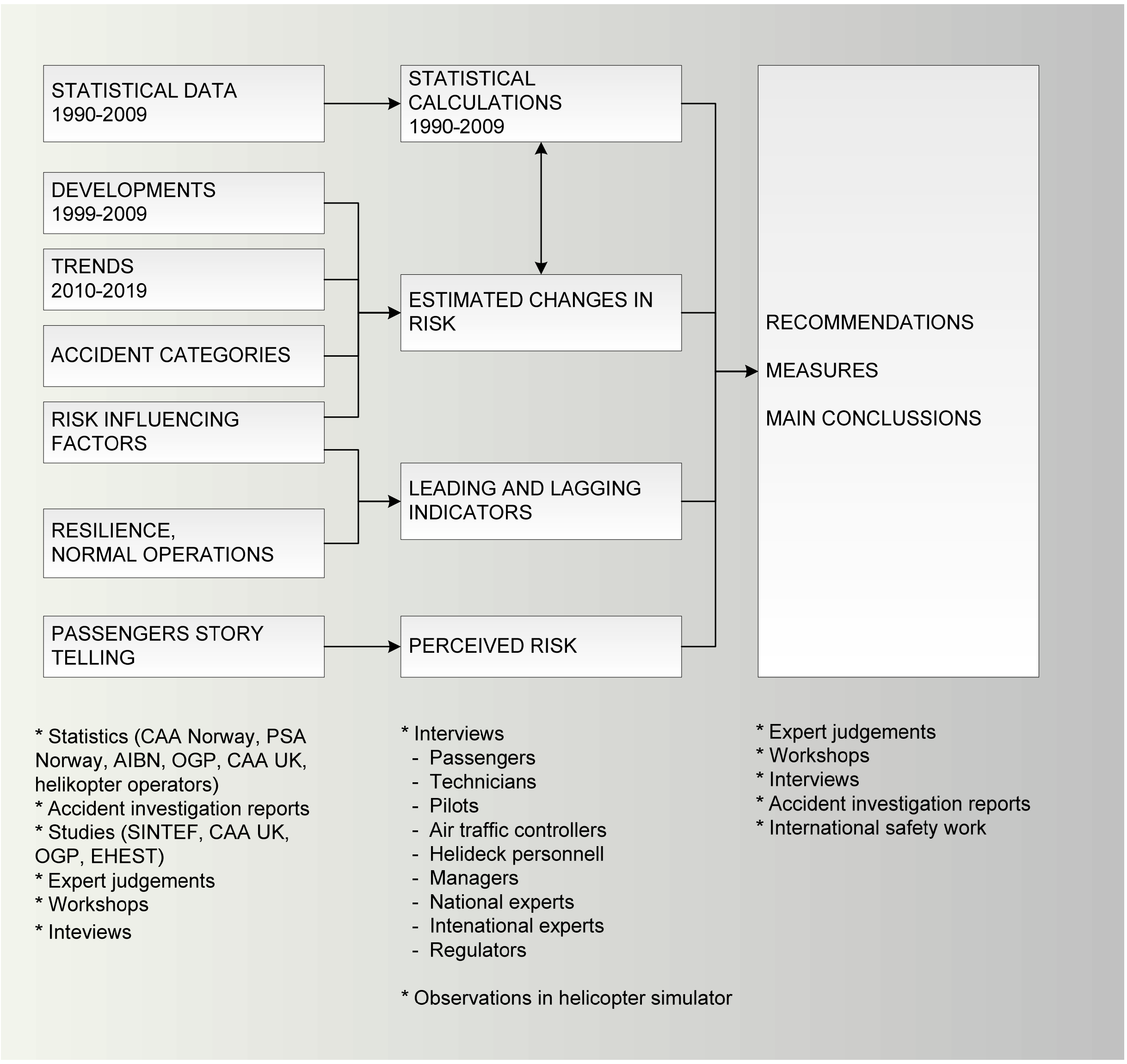
- Helicopter Safety on the Norwegian Continental Shelf. Part 1: Organizing of the public authorities' involvement (NOU 2001: 21)
- Helicopter Safety on the Norwegian Continental Shelf. Part 2: Trends, objectives, risk influencing factors and recommended measures (NOU 2002: 17).

This implies that HSS-3 is to build on and further develop the methodology applied in HSS-2. This includes a survey of the technical, operational and organizational changes which have taken place in the period 1999–2009, and the expected trends for 2010–2019 which may have influence on the safety for passengers and pilots in helicopter operations on the NCS. Emphasis has been placed on the use of the so-called risk influencing factors (RIF). Changes in the risk picture have been quantified by the use of expert judgments and a model that shows the overall impact of the risk influencing factors. In addition two innovative aspects have been included. One of these takes into account the passengers own experience with helicopter transport. The other incorporates development within safety thinking from a linear approach to consider safety as a dynamic interaction in continuous change using resilience engineering principles.

At the end of the project period the study was extended with three add-ons reflecting the latest developments in 2009:

- The significance of accidents and serious incidents experienced in 2009
- The challenges following changes in the internal framework conditions in the two largest Norwegian helicopter operating companies; CHC Norway and Bristow Norway
- The proposal for a new European decree which, if it comes into effect in its present form, will remove the possibility to maintain and possibly establish new Norwegian added requirements for helicopter operations on the NCS.

The above perspectives and the add-on activities form the basis for the recommendations and measures in this report with the aim of improving or maintaining the safety level for this type of personnel transport (ref. Figure 0.2).



Figur 0.2. Helicopter Safety Study 3 approach.

1. INTRODUCTION

1.1 Report structure

The overall objective of Helicopter Safety Study 3 is to contribute to improved safety in helicopter transport of personnel to and from fixed and floating oil and gas installations on the Norwegian Continental Shelf (NCS). Updating the risk models in the previous two studies is an important secondary goal in the project. In HSS-3, two new approaches have been utilized to provide a more nuanced understanding of risk and safety. One of the approaches takes the passengers' own perceived risk into consideration. The other implies a "resilient" approach which takes into account new safety philosophy theories. This is why the report has five main sections:

Part I: Introduction
Chapter 1 provides an introduction to the project's background and goals. Important terms and abbreviations used in the report are also explained in this chapter.

Part II: Quantification of risk
This section has six chapters and addresses risk level status. *Chapter 2* provides a general presentation of an updated risk model. This is a direct continuation of the model in HSS-2. *Chapter 3* provides an overview of the most important technical, operational, and organizational changes that have taken place in the time period 1999-2009, and which could be significant as regards safety. *Chapter 4* describes assumed trends in the forthcoming time period (2010-2019). *Chapter 5* presents statistics and provides an overview of incidents in Norway and the UK. In *Chapter 6,* the risk model for respective accident frequency and accident consequence is quantified based on statistics and expert judgments. Part II concludes with *Chapter 7*, which documents the arguments and provides estimates of the risk level.

Part III: Perceived risk
Chapter 8 presents a different perspective of risk, where the focus is based on passengers' own perceptions of risk during helicopter transport. The study is based on a qualitative approach and describes factors that are significant for perceived risk, based on passengers' own stories. The chapter concludes with a number of possible measures to reduce the level of insecurity some passengers experience.

Part IV: Suggested indicators
In *Chapter 9,* a third perspective on risk is presented. An introduction is given regarding the development of safety philosophy in general and the use of safety indicators. A short overview is provided about the "resilience" expression as a new perspective on safety, and an analysis method that is based on functional resonance (Functional Resonance Analysis Method, FRAM, Hollnagel, 2004), is described. Finally, a procedure to identify risk and safety indicators is presented, concluding with several suggestions for indicators.

Part V: Suggested and recommended measures
In *Chapter 10,* suggested measures are presented, along with a rough cost/benefit assessment as a basis for prioritization. In *Chapter 11,* an overview is provided of the most important conclusions and final recommendations from the project.

1.2 Background, financing, and project organisation

On assignment from the petroleum industry, SINTEF has previously conducted two comprehensive studies on the safety in helicopter operations in the North Sea.

- *Helicopter Safety Study* (HSS-1) covered the period 1966-1990 and was released in November 1990. A/S Norske Shell and Statoil took the initiative and commissioned the study. One of the main conclusions was that the biggest potential for improvement of safety in the next 10-15 years, was of a technical nature, for example through implementation of the technical surveillance system HUMS (Health and Usage Monitoring System).
- *Helicopter Safety Study 2* (HSS-2) covered the period 1990-2008, and was released in December 1999. Shell and Statoil were still initiators, but this time BP Amoco, Elf Petroleum Norge AS, Norsk Hydro ASA, Phillips Petroleum Company Norway, Saga Petroleum ASA, and the Civil Aviation Authority also contributed to finance the study. The study concluded, among other things, that despite a considerable risk reduction measured in the number of fatalities, there was still much room for improvement.

Helicopter Safety Study 3 (HSS-3) is a follow-up of the two previous studies, and covers the period 1999-2019. Figure 1.1 illustrates part of the problem in a historical perspective. The first study came to the conclusion that accident risk in the Norwegian sector in that time period was 4.1 fatalities per million person flight hours, based on statistics. The second study (HSS-2) concluded that risk in the Norwegian sector for the time period 1990-1998 had been reduced to 2.3 fatalities per million person flight hours, also based on statistics. The reason for the decline was in part due to implementation of the technical surveillance system HUMS (Health and Usage Monitoring System). One of the challenges in HSS-2 was to predict the further development of risk in the 1999-2009 time period. The estimate assumed that the risk under certain pre-conditions would decline by approximately 5 per cent in the North Sea (Norwegian and UK sector) during this time period. The third study (HSS-3) will, among other things, attempt to verify whether the estimated risk reduction has been reached in the Norwegian sector, as well as consider the development in risk for the forthcoming time period (2010-2019) (Figure 1.1). Furthermore, HSS-3 will map out possible trends and suggest measures to improve or maintain safety during personnel transport by helicopter on the Norwegian Continental Shelf.

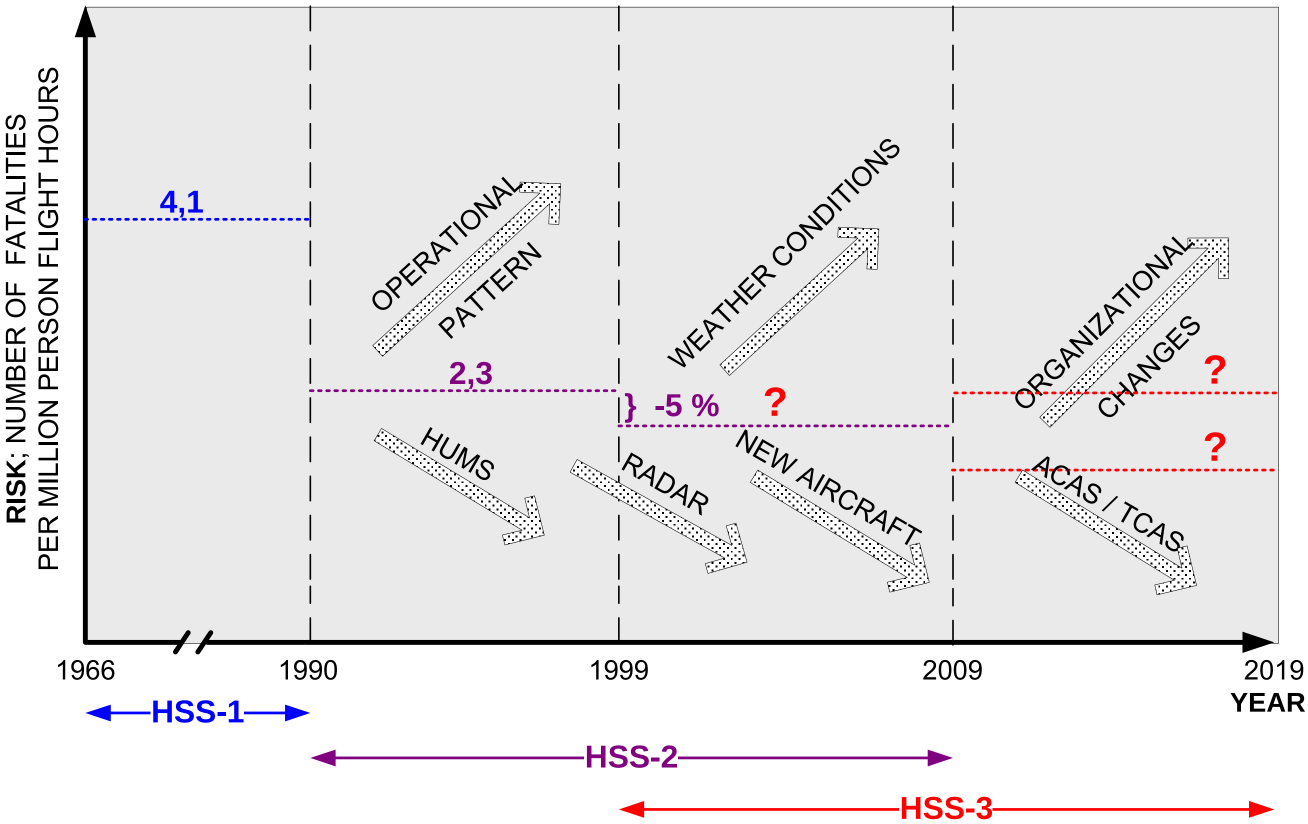


Figure 1.1: Schematic for the three SINTEF helicopter safety studies. The arrows are examples of (expected) changes in the respective time period. The direction of the arrows indicates whether the change is expected to contribute to increased or decreased risk.

After the work on HSS-2 was finished and released in December 1999, the helicopter operators and the authorities took several initiatives to follow-up the recommendations in the report. Some of the important *official* initiatives are as follows:

In July of 2000, the Ministry of Transport and Communications appointed the *Committee for the Review of Helicopter Safety on the Norwegian Continental Shelf.* The mandate was to review the organising of the public authorities' involvement in this field. Results of the committee's work were released in June 2001, in the form of a public report *NOU 2001: 21 Helicopter safety on the Norwegian Continental Shelf. Part 1: Organising the public authorities' involvement).* A month later the Ministry appointed another committee under the same leadership. This time the mandate was (quote): "To suggest concrete and realistic helicopter safety objectives, consider whether today's helicopter safety level is acceptable compared to the mentioned objectives, and also consider the need for specific measures to promote helicopter safety." The work was released in September 2002, in the form of another public report (*NOU 2002: 17 Helicopter safety on Norwegian Continental Shelf. Part 2: Trends, objectives, risk influencing factors and prioritized measures).*

Both studies came with several recommendations. Among other things, they recommended the establishment of the *Committee for Helicopter Safety on the Norwegian Continental Shelf (SF).* The recommendation was adopted by the Director General of Civil Aviation, who established the committee in June 2003, with the following mandate:

> The Committee for Helicopter Safety on the Norwegian Continental Shelf shall work towards a significant improvement of helicopter safety on the Norwegian continental shelf. The overall risk of fatalities during helicopter transport offshore shall, as a minimum, be reduced by at least half in the next decade, as compared with the time period 1990-2000 (cf. NOU 2001: 17, Chapter 1.2).
>
> The Committee shall be a driving force in regards to the accountable authorities and players, so that suggested recommendations in NOU 2001:21 and NOU 2002:17 are conducted. The Committee will also address issues that are of significance to helicopter safety and follow up with recommendations for concrete measures.

This committee is still in activity. The mandate's goal of reducing the risk of fatality by half during this type of transport is further discussed in Chapter 7.

The necessary information exchange between SF and the HSS-3 project is secured in part by SINTEF (Ivonne A. Herrera) having participated as an observer in the meetings at SF.

The HSS-3 project has been carried out at the request of the petroleum industry, coordinated by the Norwegian Oil Industry Association (OLF). The project was financed as a multiple client assignment with the following parts ("owner group"):

- BP
- Civil Aviation Authority – Norway
- ConocoPhillips
- Eni
- GDF SUEZ
- Marathon
- Nexen
- Shell
- Statoil
- Total

The project's highest authority has been a steering committee consisting of representatives from the owner group, employee organisations, authorities, and SINTEF, and has consisted of the following members:

- Sverre Austrheim, ConocoPhillips (CoP), Chair
- Lars Bodsberg, SINTEF (observer)
- Roy Erling Furre, SAFE
- Geir Hamre, Civil Aviation Authority – Norway (CAA-N)
- Erik Hamremoen, Statoil
- Steinar Hviding-Olsen, Total
- Bryn Arild Kalberg, Petroleum Safety Authority Norway (PSA, observer)
- Ketil Karlsen, LO Industri/Energi
- Rune Meinich-Bache, BP
- Liv Nielsen, Eni
- Arnt Olsen, Shell
- Geir Pettersen, GDF SUEZ
- Leif Sandberg, Nexen
- Per Otto Selnes, Norwegian Oil Industry Association (OLF), formal commissioner of study on behalf of the owner group
- Steinar Tjøstheim, Marathon
- Tor Ulleberg, Statoil.

Several expert groups have been appointed on an ad hoc basis during the project period. All in all 50 people with special expertise have participated in these working meetings. In addition to the specially appointed members of the steering committee, the meetings have included helicopter pilots, maintenance personnel, helideck personnel, supervisory personnel, and others. Several international contacts have also been established. Among other things, Professor Erik Hollnagel, Mines ParisTech / ARMINES, has contributed in an activity concerning "Resilience Engineering". Professors Jan Hovden and Marvin Rausand at the Norwegian University of Science and Technology (NTNU) have provided comments on a draft of the main report.

1.3 Project goals

The overall objective of HSS-3 is to contribute to improved safety in helicopter transport of personnel to and from fixed and floating oil and gas installations on the Norwegian Continental Shelf (NCS).

Further quotation from the project description:

> ”The project is a follow-up of the two previous helicopter studies (HSS-1 and HSS-2). HSS-3's ambition is to be a leader in helicopter safety, and that the report will create a reference standard methodology for analysis of accident risk, as well as regards identification and assessment of risk reducing measures in this type of transport."

The overall objective will be reached by:

- Using experience from previous studies, in particular the helicopter safety studies HSS-1 and HSS-2, and the public reports NOU 2001: 21 and NOU 2002: 17.
- Obtain and analyze data material which has emerged after the last study (HSS-2) was completed. In practical terms this means from 1999 up to and including 2008, but also including any relevant incidents up to the conclusion of the project in the fall of 2009.[1]
- To further develop the analysis methodology by emphasizing new ideas, methods, and approaches. This will include any new Risk Influencing Factors (RIF), including safety promoting factors, and updating the weighting of the factors.
- Make suggestions for annual updating of risk indicators which reflect accident risk and are, to the least extent possible, influenced by the operators' willingness to report.
- Make suggestions that will help maintain or improve safety during this type of helicopter transport, as well as provide a foundation for prioritising the measures in relation to each other on the basis of rough cost/benefit assessments.

To reach the overall objective the following *secondary goals* have been established:

A. Verify that/whether the assumed reduction in risk during helicopter transport also includes perceived risk, that the reduction is genuine and is not generally due to random variations.

B. Explain any deviations (positive and negative) in relation to the goals in NOU 2002: 17. The goals in NOU 2002: 17 will also be assessed based on new developments in safety philosophy (e.g. *Resilience Engineering*).

C. Establish a "HSS-3 methodology" with risk influencing factors, safety promoting factors, and risk and safety indicators which provide a significant contribution to help explain risk development in helicopter transport, and which gains wide acceptance in the industry.

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[1] The Project period was subsequently extended to March 2010.

D. Identify all trends that will be important for the risk and safety level for offshore helicopter transport of personnel in the ten-year period 2010-2019, and map out relevant effects of these trends.
E. Identify all of the most important and most relevant measures to maintain or improve safety during this type of helicopter transport. With the aid of rough cost/benefit assessments, it will also provide a foundation for prioritizing the measures in relation to each other.

Towards the end of the project period, the study was expanded with three additional activities to include the latest developments in 2009:

- Significance of accidents and serious incidents occurring in 2009.
- Challenges as a consequence of changes in framework conditions internally on the part of the two largest Norwegian helicopter operators.
- Suggestion of a new European ordinance which, adopted in its current form, will remove the possibility to maintain and possibly establish new Norwegian supplementary requirements for helicopter operations on the Norwegian Continental Shelf.

1.4 Conditions and limitations

Use of the results from this study shall take place at the user's own risk, and neither SINTEF nor the commissioning party are responsible vis-à-vis other parties or third parties as regards consequential loss.

In addition to verifiable statistical data, the report builds upon SINTEF's analysis of information and viewpoints which have emerged from the petroleum industry, the helicopter environment in general, labour unions, and users of helicopter transport. These viewpoints have to a great extent been discussed in the report, but SINTEF is solely responsible for the report's recommendations and proposed measures.

SINTEF does not consider it to be its duty to determine which respective agencies should be responsible for carrying out the recommended measures. Generally this will be evident in the context of the report.

Certain other conditions and limitations are mentioned in Chapter 10.1.

1.5 Definitions

The following definitions are used in the main report and the appendices:

Floating helideck
A helideck mounted on an installation or vessel with motion characteristics such that pitch and roll movements exceed one degree in relation to the horizontal plane, or if the vertical movement exceeds two metres. (cf. BSL D 5-1).

Contribution (from a Risk Influencing Factor; RIF)
The product of the condition (status) of an RIF, and the weight of the RIF. The *contribution* is the amount an RIF contributes in relation to the total accident frequency and the associated accident consequence respectively.

"D"
The largest length or width of a helicopter including the rotors. (cf. BSL D 5-1).

Fatal Accident Rate (FAR)
(Expected) number of fatalities per million person flight hours.
Note: This report measures risk in the number of fatalities per million person flight hours, i.e. FAR/100.

Frequency/accident frequency
(Expected) number of accidents per million person flight hours.

Helicopter deck, Helideck
A deck on an installation or vessel which is designated for the start/take-off and landing of a helicopter. (cf. BSL D 5-1).

Influence
Influence of the condition (status) of an RIF on the condition (status) of another RIF, or on total accident frequency (or consequence). The influence from operational RIFs on the different types of accidents is called *weights/contribution*. The influence from organisational RIFs on operational RIFs is called *score.*

Influence Diagram
Visualisation of the relationship between RIFs and the risk related to different accident categories, and influences between RIFs.

Consequence
(Expected) number of fatalities in a helicopter accident.[2]

Customers
Oil and gas companies that purchase helicopter transport from the helicopter operators on the Norwegian Continental Shelf.

Authority and customer-related RIFs (Level 3 RIFs)
Risk influencing factors related to requirements from authorities (national and international) and customers, as well as the quality of activities they carry out (or potential deficiencies).

Operational RIFs (Level 1 RIFs)
Risk influencing factors related to the daily activities necessary to accomplish safe and efficient offshore helicopter transport. The daily activity encompasses *aircraft technical dependability, aircraft operations dependability,* necessary external *support functions* and other external conditions (for example weather conditions).

[2] In this project (as in HSS-2) the consequence of an accident is stated as the number of fatalities, because the risk is reported in the number of fatalities per million person flight hours. We therefore do not view consequences in the form of personal injuries, material damage, economic loss or loss of reputation.

Organisational RIFs (Level 2 RIFs)
Risk influencing factors related to organisations and their support functions and control of activities within helicopter transport. These factors are related to the helicopter manufactures and design organisations, helicopter operators and maintenance organisations, heliport/airport and helideck operators, and air traffic/air navigation service organisations.

Leading indicator shows the current condition of a system, where interpretations of some indicators can be used to predict future safety performance.

Perceived risk
A term expressing how people perceive risk. Perceived risk is important for personal assessments of whether risk is high or low. What one person perceives as a high risk does not necessarily pose the same level of risk to another person. (Rausand and Utne, 2009).

Framework conditions
A term for conditions that influence the practical possibilities an organisation, organisational unit, group, or individual has to control major accident risk and working environment risk. (Rosness, R. et al, 2009).

Lagging indicator measures the result of undesirable incidents in the form of fatalities, personal injuries, or losses.

Resilience
A term which widens the safety perspective. A system or organisation's ability to deal with risk is the focus in this perspective. It considers the system's ability to maintain operations before, during and after changes and disturbances, in relation to expected and unexpected conditions. Hollnagel et al., 2006: "*The intrinsic ability of a system to adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required operations under both expected and unexpected conditions*".

Risk
A term expressing the danger that helicopter transport on the Norwegian Continental Shelf represents for passengers and pilots onboard, stated as a combination of (accident) frequency and consequence (of a helicopter accident). A common measurement of risk within aviation is the number of fatalities in accidents per million person flight hours (based on incident data/statistics) and *expected* number of fatalities in accidents per million person flight hours based on risk analysis.
Note: There are several definitions of risk; for further understanding Rausand and Utne (2009) and Aven (2010) are recommended. Note that in this report risk is quantified in the number of fatalities per million person flight hours, unless otherwise specified. "Statistical risk" is risk figures based solely on statistical data. The terms "estimated risk" (or "risk estimate") are used for risk figures based on assessments, and or in combination with statistics.

Risk analysis
Systematic procedure to describe and/or calculate risk. Risk analysis is executed by mapping undesirable incidents and the causes and consequences of these. (cf. NS 5814, 2008).

Risk Influencing Factors (RIF)
A delimited group of factors or conditions that influence risk associated with offshore helicopter transport. An RIF can be stable or vary over time as a function variable or a random variable. An RIF has a condition (status) which is either acceptable or poor/unacceptable, and

which can change by introducing risk reducing measures, or as a result of other changes within the helicopter industry.

Safety
A term expressing a condition where the probability of injury to persons or damage to property has been reduced to an acceptable level, or lower, and is maintained at this level, through a continuous process of identification of hazards and risk/safety management. (cf. ICAO SMS 2008; "*The state in which the possibility of harm to persons or of property is reduced to, and maintained at or below, an acceptable level through a continuing process of hazard identification and risk management*.")

Safety indicator is an observable characteristic of an operational system that can be presumed to have a strong connection to the system safety. Safety indicators can be quantitative or qualitative.

Socio-technical system
A technical system where people who operate and maintain the system to a great extent influence the effectiveness of the system. The technology's efficiency is therefore largely dependent on the people who operate and maintain it, and there is a complex interaction between people and technology. (cf. HSE, 2002).

Accident
An incident which results in fatalities, severe personal injuries, and/or considerable material damage to the aircraft. (cf. ICAO Annex 13.)

Accident category (A1–A8)
The project defines eight accident categories, listed below. Shorter names for the accident categories for use in figures and such have been included in braces.

A1: Accident during take-off or landing at heliport/airport [Heliport]
Accident which occurs after passengers have boarded the helicopter and before TPD (*Take-off Decision Point*) or after LDP (*Landing Decision Point*) and before passengers have left the heliport/airport.

A2: Accident during take-off or landing on helideck [Helideck]
Accident which occurs after passengers have boarded the helicopter and before TDP (*Take-off Decision Point*) or after LDP (*Landing Decision Point*) and before passengers have left the helideck.

A3: Accident caused by critical failure in helicopter during flight [System failure]
Accident caused by critical system failure in the helicopter after TDP (*Take-off Decision Point*) and before LDP (*Landing Decision Point*), for example in the main rotor, tail rotor, engine, gearbox, etc. When a critical system failure occurs, the craft (pilots/passengers) can only be saved through a successful emergency landing.

A4: Collision with another aircraft [Mid-air collision]
Collision with another aircraft during flight, without any critical failure occurring. (*Mid-Air Collision*; MAC)

A5: Controlled flight into terrain, sea or building [Terrain collision]
Accident caused by collision into terrain, sea, or building after TDP (*Take-off Decision Point*) and before LDP (*Landing Decision Point*), with no critical failure occurring. (*Controlled Flight Into Terrain, sea or building*; CFIT)

A6: Accident with risk for persons in the helicopter [Person inside]
Accident involving danger to persons (pilots/passengers) located in the helicopter, for example caused by toxic gases due to a baggage or cargo fire.

A7: Accident with danger for persons outside helicopter [Person outside]
Accident involving danger to persons (pilot/passengers) located outside the helicopter, for example, the tail rotor strikes a person.
(Note that danger to other persons than helicopter pilots and passengers, for example helideck personnel, is not included.)

A8: Accident caused by weather conditions, surrounding environment, or other [Other/unknown]
Accident caused by weather conditions (for example lightning strike), surrounding environment (for example collision with a vehicle at the heliport/airport), or other (for example an act of terror), in addition to accidents with unknown causes.

1.6 Abbreviations

The following abbreviations are used:

AAIB	Air Accident Investigation Branch (UK)
ACARS	Aircraft Communications Addressing and Reporting System (system which transmits the status of safety-critical systems in the helicopter to the air traffic control via radio or satellite)
ACAS	Airborne Collision Avoidance Systems (warning system in helicopter when there is danger of collision with another aircraft)
ADS	Automatic Dependent Surveillance (system for surveillance of the aircraft's position)
ADS-B	ADS-Broadcast (system for surveillance of the aircraft's position)
ADS-C	ADS-Contract (system for surveillance of the aircraft's position)
AIBN	Accident Investigation Board Norway
AML	Working Environment Act
AOC	Air Operative Certificate
ARA	Airborne Radar Approach (radar assisted approach)
ARC	Airworthiness Review Certificate
ASR	Air Safety Report (report/warning of aviation safety conditions)
BSL	Regulations for civil aviation issued by the Norwegian CAA
CA	Canada
CAA-N	Civil Aviation Authority - Norway
CAA-UK	Civil Aviation Authority - UK
CAP	Civil Aviation Publication (publications released by the CAA – UK)
CFIT	Controlled Flight Into Terrain (controlled flight into terrain, sea, or other obstacles)
CHC	Canadian Helicopter Corporation (parent company of CHC Norway, formerly Helikopter Service AS)
CHC Norway	The Norwegian registered subsidiary of CHC
CRM	Crew Resource Management (interaction between crew members)
DGPS	Differential Global Positioning System
EASA	European Aviation Safety Agency
EBS	Emergency Breathing System
ECCAIRS	European Co-ordination Centre for Aviation Incident Reporting Systems
EHEST	European Helicopter Safety Team

ELT	Emergency Locator Transmitter
EØS /EEA	European Economic Area
F	Frequency
FAR	Fatal Accident Rate (measure of frequency for number of fatalities, here stated as number of fatalities per 100 million person flight hours
FDM	Flight Data Monitoring (system for registration/surveillance of important operative parameters during flight)
FMECA	Failure Modes, Effects and Criticality Analysis
FoU / R&D	Research and Development
FPSO	Floating Production Storage and Offloading
FRAM	Functional Resonance Analysis Method
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
HFIS	Helicopter Flight Information Service
HLO	Helicopter Landing Officer (person responsible for preparing the helideck for landing)
HMI	Human Machine Interface
HMS	Helideck Monitoring System
HOMP	Helicopter Operations Monitoring Programme
HSLB	Accident Investigation Board for civil aviation and railroad (now AIBN/SHT)
HSS	Helicopter Safety Study
HSRMC	Helicopter Safety Research Management Committee
HUMS	Health and Usage Monitoring System
ICAO	International Civil Aviation Organisation
IHST	International Helicopter Safety Team
JAA	Joint Aviation Authorities (European aviation authority)
JAR-OPS	Joint Aviation Requirements – Operations (European regulations for flight operations)
C	Consequence (of an accident)
LDP	Landing Decision Point
LOFT	Line Oriented Flight Training (pilot training during flight)
LOSA	Line Operations Safety Audit (observation of pilots during flight)
LT / CAA-N	Civil Aviation Authority - Norway
LV	Norwegian Air Traffic and Airport Management (now: Avinor)
MAC	Mid-Air Collision
M-ADS	Modified Automatic Dependent Surveillance (system for surveillance of the aircraft's position)
MEL	Minimum Equipment List
MESYS	Avinor's system for reporting incidents
MSG	Maintenance Steering Group
MSI	Motion Severity Index (index for helideck movement)
NO	Norwegian Shelf
NOSS	Normal Operation Safety Survey (check of air traffic controller routines)
NOU	Norway's public report(s)
NPD	Norwegian Petroleum Directorate
NTNU	Norwegian University of Science and Technology
NVG	Night Vision Goggles
OD / NPD	Norwegian Petroleum Directorate
OGP	International Association of Oil & Gas Producers
OLF	The Norwegian Oil Industry Association
PC2e	Performance Class 2 enhanced (classification of engine power in relation to weight)

PSA	Petroleum Safety Authority Norway
R	Risk
RIF	Risk Influencing Factor
RIPS	Rotor Icing Protection System
RNNP	Risk level in the Norwegian petroleum industry (2008–)
RNNS	Risk level on the Norwegian Shelf (–2007)
SAR	Search and Rescue
SAS	Scandinavian Airlines System
Sdir	Norwegian Maritime Directorate
SF	Committee for Helicopter Safety on the Norwegian Continental Shelf
SMS	Safety Management System
SOP	Standard Operating Procedures
TCAS	Traffic-alert and Collision Avoidance System
TDP	Take-off Decision Point
TRF	Tail Rotor Failure
U	Accident category (U1–U8)
UAV	Unmanned Aerial Vehicle
UK	United Kingdom
VHM	Vibration Health Monitoring

2. METHOLOGY FOR QUANTIFICATION OF RISK

In this chapter, the general qualitative risk model in HSS-3 is described, based on accident categories and risk influencing factors (RIF). This is a direct continuation of the model used in HSS-2. The RIF-model can be split into a model for frequency and a model for consequence. These models are further discussed in Chapters 2.1.1 and 2.1.2. Quantification and use of the model for estimation of risk and risk change is described in Chapter 6 and in the appendices.

2.1 Risk model and influence diagram

Risk influencing factors (RIF) are defined as a separate group of conditions which influence the risk associated with offshore helicopter transport. An RIF could either be relatively stable, show long-term variation over time, or vary more randomly. The individual RIFs are in more detail defined and described in the appendices.

The risk is quantified as the number of fatalities (passengers and pilots) per million person flight hours. The risk is a combination of accident frequency and the consequence of different types of accidents.

The general risk model is shown in Figure 2.1. Only generalized RIFs (boxes) and influences (arrows) have been illustrated here. Details of the model are described in the coming chapters.

The risk model in HSS-3 is a continuation of the model which was developed in the previous helicopter study HSS-2, which in turn is a continuation of the model used in HSS-1. Some changes have been made compared with the previous model from HSS-2:

- Some new RIFs have been included, some have been merged, and most have been restructured in the influence diagram
- The quantitative model, and the use/significance of expert opinions have been made clear
- Status/condition, weighting and contribution based on incident reports, incident data and expert opinions have been updated

The goals of the risk model in HSS-3 are to:

- Establish the relationship between the risk influencing factors and the risk for passengers and pilots in helicopter transport on the Norwegian Continental Shelf, to qualitatively describe all factors which influence risk connected to this type of transport.
- Establish quantitative figures for the degree of influence of each of the accident categories from the respective RIFs, to predict risk.
- Quantify changes in the condition of the RIFs, to (be able to) estimate the effects of the changes on the risk level.
- Demonstrate which risk influencing factors contribute the most to overall risk, and thereafter discuss which measures are profitable in terms of safety.
- Predict (change in) risk in the next ten-year period by assessing changes within each RIF.

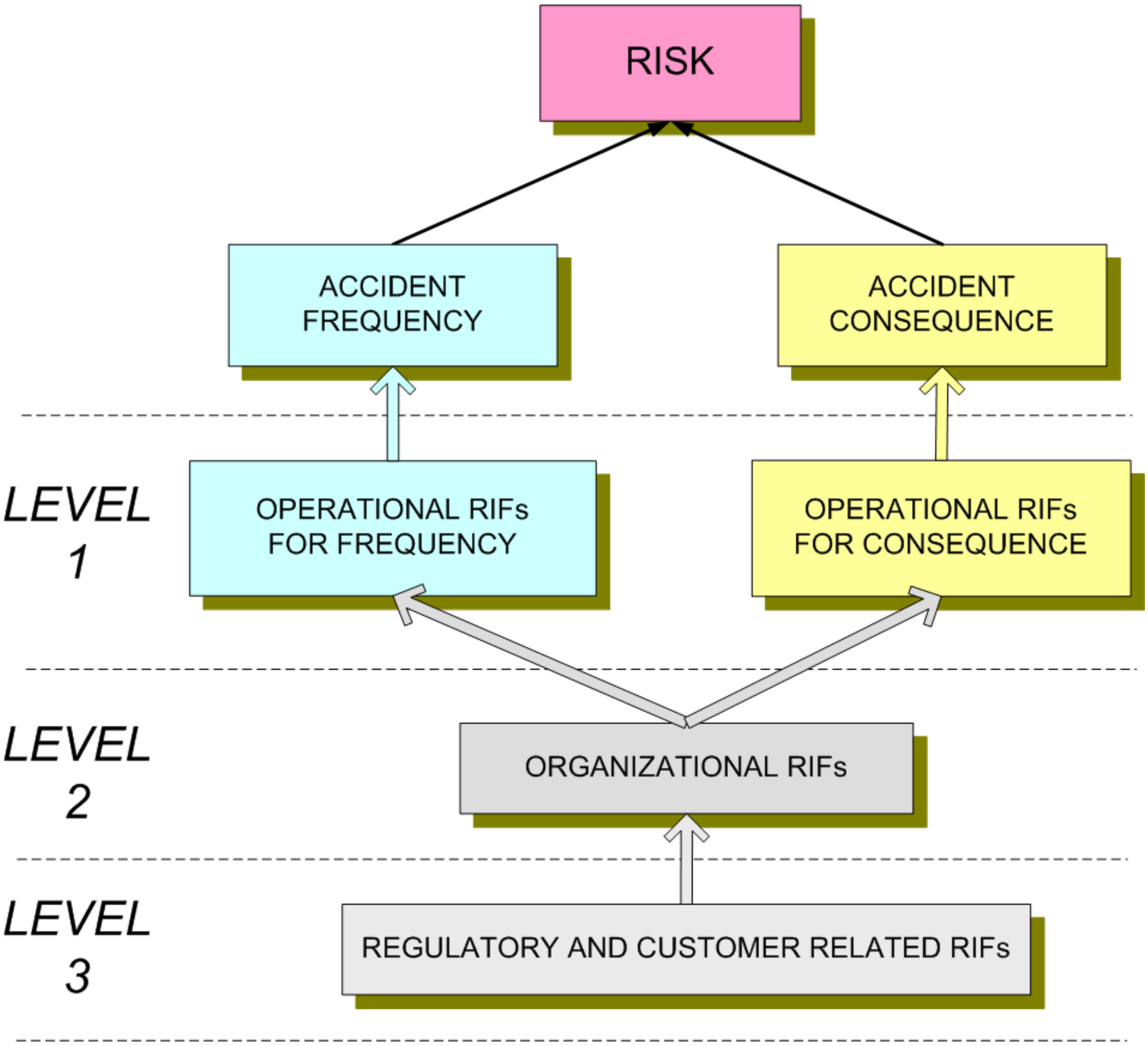

Figure 2.1. General risk model.

The RIFs are organised in three levels based on their direct effect, and the levels are defined as follows:

1. **Operational RIFs (Level 1):** Risk influencing factors/conditions related to the necessary daily activity to achieve safe and efficient offshore helicopter transport. The daily activity encompasses aircraft technical dependability, aircraft operations dependability, necessary external support functions and other external conditions (for example weather conditions).

2. **Organisational RIFs (Level 2):** Risk influencing factors/conditions related to organisations and their support and control of activities within helicopter transport. These factors are related to the helicopter manufactures and design organisations, helicopter operators and maintenance organisations, heliport/airport and helideck operators, and air traffic / air navigation service organisations.

3. **Authority and customer-related RIFs (Level 3):** Risk influencing conditions related to requirements from, and activities of authorities (national and international) and customers (oil companies)

2.1.1 RIF frequency model

The frequency model is illustrated in Figure 2.2, where each box represents an RIF. The RIFs are organized in a hierarchy with three levels. The operational RIFs on Level 1 have been split into four main causes which can be regarded as general "super-RIFs". The individual RIFs have been defined in more detail and described in the appendices.

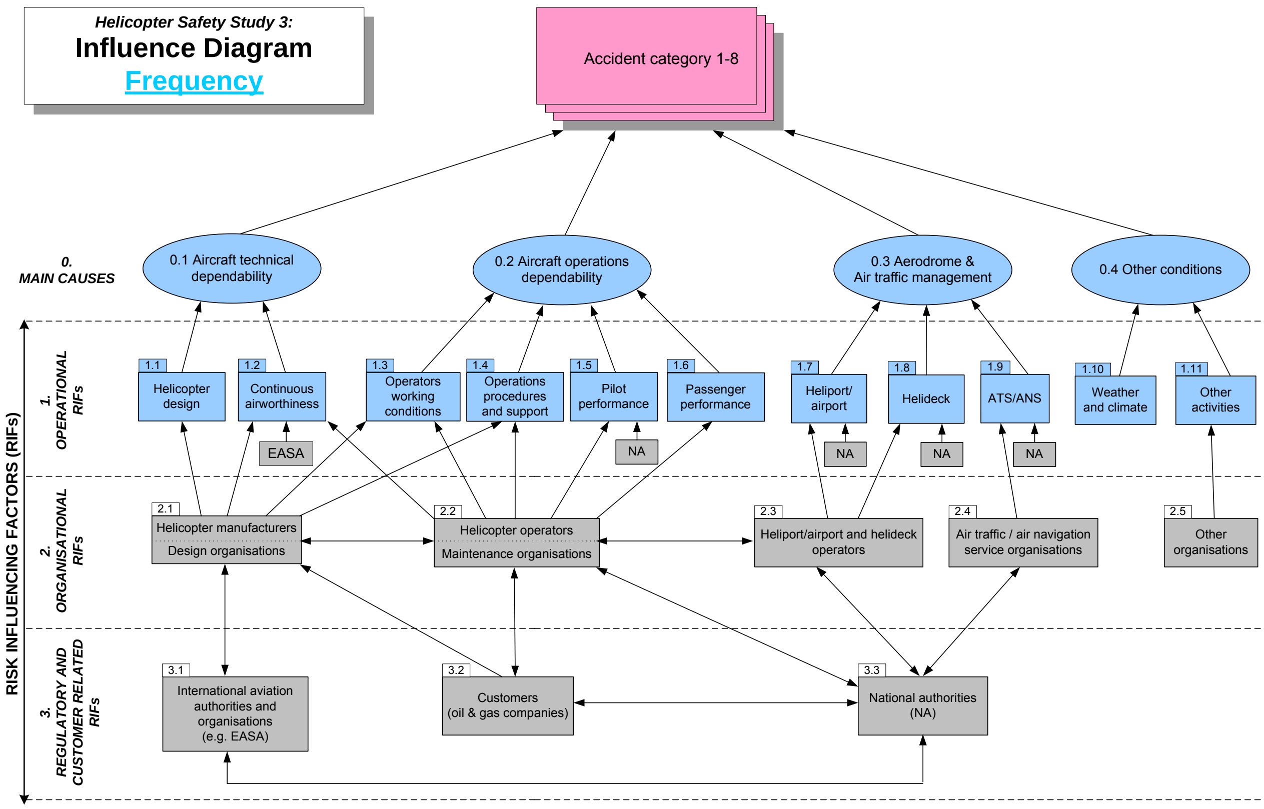

Figure 2.2. Frequency influence diagram

The arrows between the boxes (RIFs) illustrate the influence between the RIFs, or which RIFs are being influenced by other RIFs. For example, the status of national authorities (RIF 3.3 NA) influences the status of the helicopter operators, heliport/airport and helideck operators and the Air Traffic Service (ATS/ANS) on Level 2, in addition to several operational RIFs on Level 1. Note that the diagram is simplified by there not being any direct arrows between National Authorities (NA) on Level 3 and the RIFs on Level 1. This influence has instead been illustrated by means of small boxes marked NA on Level 1. Most of the arrows in the diagram go from one level to the level alone, but this is not a requirement. For example, the arrows between National Authorities on Level 3 and the Air Traffic Service (ATS/ANS) on Level 2, go both ways.

The operational RIFs on Level 1 are sorted under the four main causes for accidents (0.1-0.4) on Level 0. This was done to make the diagram easier to read, and for the opportunity to indicate risk influence from each of the four main causes. The main causes are *not* RIFs, but a grouping of operational RIFs on Level 1. The influence of the operational RIFs runs directly to the accident categories U1-U8, and not via the main causes. The English version of the RIF diagram is available in the appendices.

2.1.2 RIF consequence model

The consequence model is illustrated in Figure 2.3. The individual RIFs are defined and described in more detail in the appendices. The interpretation of the boxes and arrows is the same as was described for the frequency model (Chapter 2.1.1.).

The English version of the RIF-diagram for consequence is also provided in the appendices.

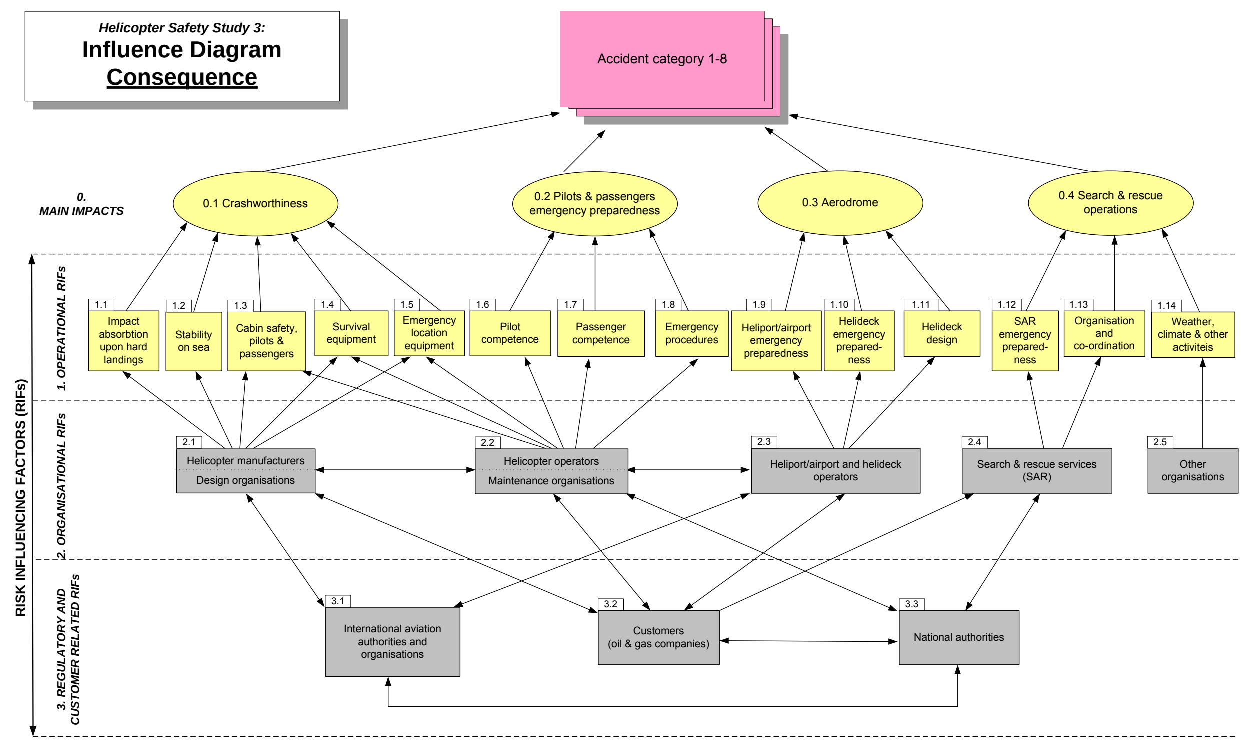

Figure 2.3. Consequence influence diagram

2.2 Quantification of risk using the risk model

The risk model described above is used in combination with accident statistics and expert opinions to quantify risk. The frequency model and consequence model are quantified separately, and the methodology for, and the results of the quantifications are presented in the attachment report. Since there are only a few accidents, and even fewer fatal accidents, the risk estimates based on statistics will be sensitive to both individual accidents and the selected period. Use of the RIF model will contribute to providing more stable risk estimates.

Risk (R) is quantified as the product of the frequency (f) of accidents and their average consequence (C):

$$R = f \times C$$

where:

f = accident frequency, i.e. (expected) number of accidents per million person flight hours
C = accident consequence, i.e. (expected) number of fatalities per accident

This kind of risk measurement is often expressed as FAR (*Fatal Accident Rate)*, which is the number of fatalities per 100 million person flight hours. Another common risk measurement for helicopter transport is the number of fatalities in accidents per million person flight hours. The latter measurement is used most often in this study.

2.2.1 Data sources and use of statistics

Statistics for the Norwegian Shelf are collected from CAA-N, AIBN, and PSA. For the UK Shelf and the North Sea, statistics are mainly collected from CAA UK and official reports from OGP. In addition, accidents are registered continuously and incorporated during the review of investigation reports.

The statistics are mainly used to look at the historical development of the number of fatalities per million person flight hours, both continuously (through a 5-year moving average) and for each period. Statistics are collected for the purpose of mapping the number of fatalities per million person flight hours for the period 1999-2009 for the Norwegian Shelf, the UK Shelf, and the North Sea in total.

Statistics in the form of registered accidents and incidents (and previous: occurrences) are also assessed and categorised in relation to the accident categories and the risk influencing factors in the RIF-model. Through this work, typical incidents have also been identified, in particular in the time period (1999-2009).

The findings from the statistics also provide input for:

- quantification of the current risk level (number of fatalities per million person flight hours)
- indicators for helicopter safety (typical incidents)
- identification of measures (typical areas where several incidents have occurred)

2.2.2 Expert judgment and use of identified trends

HSS-3 has to a great degree been based on expert judgments from a larger group of persons with interest in and knowledge of helicopter safety. Experts have been used to a varying degree within all of the topics covered in the report. Use of experts helps provide the most accurate description of the actual situation, and also provides a valuable foundation for the study's results on the part of the players that will be affected.

Expert judgments have been carried out in several sessions:
- Working meetings with a group of experts with different backgrounds
- Telephone meetings (where all participants had the opportunity to look at the same screen)
- Group interviews
- Individual interviews
- E-mail exchanges, in particular for quality assurance of the contents

When quantifying the risk model, there has been no weighting by the experts. In the working meetings the different answers from the experts were discussed in plenary where each individual could state the reason for their answer, and where the experts could to a certain degree, agree on a common answer.

During the expert sessions the RIF-model was used actively, both as illustration, and for the "break down" of risk contributions to clarify each players' role in the big picture.

Trends in the periods 1999-2009 and 2010-2019 are used to quantify changes in risk influencing factors, and to then quantify the total change in risk within the time periods. The effect of these trends is assessed through expert judgments for both frequency and consequence. The expert judgments to quantify the effects of the trends for frequency and consequence were primarily carried out in several work meetings with a wide composition of different professional groups.

The change in risk in the periods 1999-2009 is assessed on the basis of expert judgment alone, and this can contribute to more uncertainty factors. The largest contributors of uncertainty in connection to change in risk are considered to be:
- The quantification and assessment of the effect of trends is conducted within parts of the RIF-model, typical for a risk influencing factor. Interaction effects can therefore lead to uncertainty in the isolated contribution from each RIF.
- The experts have been asked about the per cent improvement/deterioration of the condition of an RIF they are assessing. The experts may have either over-estimated (too much improvement/deterioration) or under-estimated (too little improvement/deterioration). Compared to the statistics it would appear that the experts, in this case, overall have "underestimated".
- The expert opinion assessments were conducted over a long period of time (from the fall 2008 of to the fall of 2009). During the winter of 2009, three offshore helicopter accidents occurred abroad, which brought much attention in Norway as well. This has most likely affected the expert judgments. This could also have contributed to a larger variation in the experts' assessments of the effect of trends.
- The different experts come from very different backgrounds and viewpoints. Everyone's opinion has to the greatest extent possible been considered. However, when the experts attempt to agree on one answer, it is not always the most correct one.

2.2.3 Conditions, limitations and uncertainty in the estimation of risk

The following conditions and limitations have been made in the estimation of risk:

- An important precondition in HSS-3 is that, to the greatest degree possible, methods and results from the HSS-1 and the HSS-2 studies will be used, in particular the HSS-2. Emphasis has therefore been placed on the results from HSS-2 and HSS-3 being comparable. Therefore the risk level in HSS-1, HSS-2 and HSS-3 has been measured in number of fatalities per million person flight hours, (and for example not relative to number of person kilometres or helicopter flights, which are common alternatives). In HSS-3 however, there have been some changes made to the methodology regarding the risk influencing factors.

- Risk is only considered for ordinary passenger transport offshore. Accidents related to cargo missions, training flights, test flights, and SAR operations are therefore not included in our risk consideration. Generally, these types of operations have a higher accident frequency than ordinary passenger transport, but the consequence is usually lower because fewer people are involved.
- Risk is only considered for passengers and pilots in the helicopter. Incidents where risk is identified in relation to a third party, for example, heliport/helideck personnel and maintenance personnel/technicians, are disregarded.
- Due to a limited data basis in the form of few accidents (no fatal accidents) on the Norwegian Shelf in the last ten years, we have largely based our risk estimate on expert opinion and their assessment of the probability of hypothetical accidents.
- In the expert judgments the focus lies on quantifying *trends* from the previous period (1990-1998) to this period (1999-2009). The results from the quantification of trends are used as a basis to calculate the risk estimate in HSS-3. This means that the results from HSS-2 have been given significant emphasis.
- Any potential interaction effects between RIFs for frequency and RIFs for consequence have not been considered.
- The RIF model and the quantifications do not take into account the interaction effects between the various risk influencing factors. The total risk is calculated only from additive contributions from the risk influencing factors or from the eight identified accident categories.

3. DEVELOPMENTS IN THE PERIOD 1999–2009

This chapter provides an overview of identified changes and trends in the period 1999-2009 which could be of significance for safety. The changes are linked to the RIF hierarchy for frequency (F) and consequence (C) in the applicable risk model (see Chapter 2.1.1 and 2.1.2) and form the basis for expert judgments around the quantification of changes in risk level. Most of the changes primarily influence the *frequency* of incidents, and are to a lesser degree connected to the *consequence* if an incident occurs. The changes are sorted under the following groups:

- Technical helicopter development
- Operational helicopter development
- Development in helideck construction and helideck operations
- Development in Air Traffic Management
- Organisational development
- Developments in authority and customer relationships
- Developments in emergency preparedness

Note that many of the changes can relate to several RIFs, both on the frequency and consequence side. It is therefore not always obvious which heading the different changes should be placed under. In these cases, an assessment is made of where the change will have the biggest influence. Also note that many of the changes which have been implemented will also have an effect in the *next* period (2010-2019). Chapter 4 describes trends which are currently expected for the next period.

3.1 Technical helicopter development

New helicopter types

The helicopter operators on the Norwegian Shelf have in recent years put new helicopter types into use, in particular Sikorsky S-92A (in use since 2005) and Eurocopter EC225 (in use since 2008). These helicopters have become dominant on the Norwegian Shelf. This is the newest generation in helicopters and they have improved the operability on every level, also in relation to safety. There have however, been a few issues with getting the technical bugs out, e.g. with the Rotor Icing Protection System (RIPS). Nevertheless, the problems have not been any more substantial than what is common with the phase-in of new helicopter types. The run-in period problems have generated a few incident reports, but it is not clear whether this reflects an increase in the risk level during the phase-in.

Many of the older helicopter types currently used on the Norwegian Shelf have been undergone significant equipment upgrades through the years, and can almost be considered new, with improved performance and improved safety levels in relation to earlier versions.

With the new helicopters come improvements and requirements related to consequence and preparedness, in the form of improved stability at sea, improved impact absorption and improved cabin safety for passengers and pilots. (See Chapter 3.7 where trends related to emergency preparedness are described in more detail.)

HUMS on all machines
Systems for technical condition monitoring of helicopters – HUMS (*Health and Usage Monitoring System*) or VHM (*Vibration Health Monitoring*) – also existed before 1999. After the Norne accident in 1997, many argued that such systems should be made mandatory for helicopter transport on the Norwegian Shelf. In 2005, the use of vibration monitoring systems became a regulatory requirement through BSL D 1-16. In practical terms it has been a customer requirement for a while, and therefore is considered "mandatory" through contracts being made. HUMS is therefore a well incorporated system for both the helicopter operators and helicopter manufacturers. Currently it is a mature system, but is still undergoing continuous improvement. There still appear to be significant challenges in relation to interpretation and use of data from HUMS.

M-ADS – Requirements, replacement and exemption
M-ADS (*Modified Automatic Dependent Surveillance*) is a satellite-based system for surveillance of helicopters outside radar range. The system was developed and tested through the 90s, and made mandatory through a regulation from 1999 (BSL D 2-10).

The objective of M-ADS was originally to monitor helicopters all the way down to the sea surface and in other areas without radar coverage. The importance of surveillance all the way down to the sea level was made apparent in connection with the Norne accident, where a M-ADS system, or an equivalent system, was not in use, and the helicopter's location was not known. Today the M-ADS system is mandatory in helicopters for owners of a Norwegian licence or permission to conduct commercial flights with helicopters between Norway and installations on the Norwegian Continental Shelf, as well as flights between such installations (BSL D 2-10, 2004). This system is unique to Norway and has functioned very well, but serious delivery problems for new units and spare parts in the last few years has lead to the discussion of alternative solutions. As a result of the difficult delivery situations for these systems, there are currently situations where the CAA-N grants exemption from use of M-ADS in areas with radar coverage.

Anti-collision system
The international generic term for airborne anti-collision systems is *Airborne Collision Avoidance System* (ACAS). In the helicopters on the Norwegian Shelf there are two versions of ACAS, either *Skywatch* or *Traffic Alert and Collision Avoidance System* (TCAS). Skywatch is the simplest system and has been replaced by TCAS I in new helicopters in the last few years. TCAS is delivered in two variations. TCAS I provides information about traffic and warning (alarm) of possible conflicts with another aircraft (*Traffic Alert*, TA). TCAS II, in addition to an alarm, also provides advice (*Resolution Advisory,* RA) on what the crew should do in the vertical direction (height) to avoid collision. TCAS III is not yet developed, but is expected to provide an alarm and advice (RA) for changes in both height and direction. TCAS III is not expected to be developed in the near future for planes or helicopters.

The development has been that more and more helicopters, especially new helicopters, are equipped with TCAS I. TCAS was made a customer requirement through OLF during the previous period. The Committee for Helicopter Safety on the Norwegian Shelf has discussed whether the authorities should require TCAS I for all helicopter flights offshore (recommendation from SF's working group in 2005).

NOU 2002: 17 advised that TCAS II should also be a regulatory requirement for helicopters. This was not carried out in the previous period because the system had not been sufficiently tested and was not readily available. Successful tests with the TCAS II in helicopters have now been executed and the system will be in place in some new helicopters during the next period.

Airworthiness Review Certificate (ARC)
The ARC provisions went into effect in 2009. Previously CAA-N renewed ARC. Now ARC is renewed annually by certified inspectors with the helicopter operators.

Other Equipment
Rotor Icing Protection System (RIPS)
The icing problem is well known to helicopter operators in the North Sea, and will pose even more challenges when the petroleum activity moves further north (to the Norwegian Sea and Barents Sea). There were some initial difficulties in getting the RIPS system to be operative, but the problem has now been solved, and the system is considered to be nearly fully operational for both S-92 and EC225. De-icing systems became a customer requirement through OLF from Bergen and further north during the period (1999-2009).

Ground Proximity Warning System (GPWS)
Enhanced Ground Proximity Warning System (EGPWS)
EGPWS is a continuation of GPWS, and the system provides an alarm in relation to radio height and looks ahead in relation to terrain. Requirements mandate that the system is used in connection with fixed-wing transport of passengers. The system is standard equipment in the latest generation of helicopters, like S-92 and EC225.

3.2 Operational helicopter development

Presentation of data in cockpit
The method of presenting information to the pilots in the cockpit has changed radically from a few years back. The amount of information has increased considerably through increased digitalisation and processing power, and it is a challenge to present this information at a manageable level for the pilot.

Increased standardisation of procedure
In the last decade there has been a focus on standardisation of procedures and equipment. This is most likely a contributing cause to why there have been no serious operational incidents. JAR-OPS 3, which was issued in 1999, influenced the standardisation with a new manual for all helicopter types. Towards the end of the period, CHC Norway operated with a fleet of four different helicopter types, and the procedures were standardised to the greatest extent possible. Important regional and organisational differences make it difficult for universal procedures to be fully implemented without local adaptations.

Flight Data Monitoring (FDM)
Flight Data Monitoring (FDM) with subsequent analysis of FDM data is a useful tool to identify, quantify and assess risk (cf. CAP 739). FDM is a requirement for flying with passengers in large (fixed-wing) aircraft. ICAO Annex 6 also includes a recommendation for this in heavy helicopters (maximum starting weight 7 000 kg). Analysis of FDM data makes it possible to identify areas where practical work experience deviates from Standard Operation Procedures (SOP). By defining the limit values for normal/acceptable operation of the craft, you can register when and how the limits are exceeded, and use this information to locate weaknesses in procedures and training. Analysis of FDM data has among other things revealed

tendencies for too rapid descent during approach to helideck, and has also contributed to solve the “mystery” regarding helicopters that tipped over during taxiing.

FDM is not a regulatory requirement, but was made a customer requirement by the biggest oil companies in the previous period. OLF’s recommended guidelines 066 require FDM to be installed in all helicopters used for passenger transport, and both of the largest Norwegian helicopter operators have installed FDM. FDM has therefore been installed on all machines and is fully operational on all machines with the exception of the Super Puma L1 and L2 machines which are due to be phased out. FDM produces a large amount of data, but the use of the data material is currently limited. There is a huge potential for future utilisation here.

New approach patterns and landing procedures
Procedures for approach and landing are improved by small steps while gaining experience from concrete incidents or introduction of new equipment. An example of this is no longer retracting the wheels during shuttle-flight, a procedure instituted after a few near-landings on Ekofisk without the wheels down.

GPS approaches to the Oseberg platform have been approved for use. The development of new approach patterns is part of the GIANT project which is part of EUs sixth framework programme for R&D. CAA-N is part of the steering group in Work Package 3.4.1, together with the UK Civil Aviation Authorities. Using GPS as help during radar assisted approach (*Airborne Radar Approach;* ARA) is used by Norwegian operators.

Simulator training
Helicopter simulators have developed into being a priceless aid when training pilots. In recent years the simulators have become much more realistic and provide very good training. With the increase in logging flight data, it has become possible to recreate accidents, incidents and difficult situations from actual flights and to practice these in a simulator. Training in a simulator cannot fully replace actual flight when it comes to developing good “airmanship”, but it does constitute a significant supplement.

However, the amount of simulator training for pilots has been reduced from the previous period. Previously, pilots had 16 hours of simulator training per year. At the beginning of this period, the amount had been reduced to 14 hours per year, and in the middle of the period it was reduced to 12 hours per year.

Other flight experience requirements
The helicopter operators are about to hire a number of new pilots. The hiring process has gone through a development with increased focus on quality rather than quantity. Among other things, the required number of flight hours has been reduced through a cooperation between the helicopter operators and OLF/customers. Instead, there is increased focus on the quality and relevance of experience for each individual pilot. Much like in the rest of the oil industry, there is a generational shift among pilots and it has been more challenging to find pilots with satisfactory experience.

3.3 Development of helideck design and helideck operations[3]

Helideck operations and helideck design

The standard for design of and operations on helidecks is ICAO Annex 14 Part II. The British CAP 437 (CAA/SRG, most recently updated in 2005) continues and widens these standards and is used as a guide by many states. BSL D 5-1 is the equivalent Norwegian provision for design and operation of helidecks. In Norway OLF has also published a helideck manual, most recently revised in 2007. New requirements (BSL D 5-1) are along the lines of the changes in ICAO Annex 14, and some additional Norwegian requirements have been put into force from 2008.

Helideck operations are perceived by pilots to be the most risky part of a flight: wind, dark, turbulence, movement of helideck, and proximity of other constructions make landing and take-off from helidecks demanding. In recent years there has been a considerable emphasis on helideck safety, both nationally and internationally. Dedicated studies have been conducted and comprehensive manuals have been published.

Regarding the size of helidecks, the unique Norwegian requirement of 1.25 D is a clear improvement. This requirement will most likely not spread beyond the Norwegian Continental Shelf, and will be under pressure when adjusting Norwegian requirements to align with international regulations. Size and placement are particularly important for FPSOs and similar moving decks. Today's FPSOs are difficult to land on with small decks, poor visual references and movement in addition. Different placement of helidecks on FPSOs was suggested in 1999 as the result of a safety study initiated by Statoil and the helicopter operators, without this having any effect on the regulations. Few new FPSOs have been built in recent years.

Helideck Monitoring System (HMS)

Helideck Monitoring System (HMS) is a system for registration of all types of movements of floating helidecks (the measured variables are *pitch, roll* and *heave).* A warning is given when one of the variables exceeds a maximum limit, depending on the size of the ship. The helicopter calls up ten minutes before landing to receive information about weather conditions and helideck movements. These conditions must have been favourable in the last 20 minutes for landing to be approved. HMS data is logged and kept for at least 30 days. HMS is a Norwegian system which was developed in cooperation with OLF with the goal of maintaining better safety, and with background in a helideck study conducted by SINTEF. The System is now a regulatory requirement (BSL D 5-1). There have been no serious incidents on floating helidecks since HMS was introduced.

Norway is also a participant in a research programme led by the Helicopter Safety Research Management Committee (HSRMC), with regard to *Motion Severity Index* (MSI) and *Wind Severity Index* (WSI), where HMS forms a basis for the development work, and the goal is to reach a common solution for Norway and the UK.

3.4 Changes in Air Traffic Management

Air Traffic Management consists of:

- *Air Traffic Service;* ATS
- *Air Navigation Service*; ANS

[3] See also Chapter 3.6 on supervision of helidecks.

- Communication
- Weather service.

Helicopter Flight Information Service (HFIS)
An HFIS unit is an air traffic service unit offshore which renders local flight information service for helicopters up to 1500 feet. Today there are HFIS units on Tampen (Gullfaks, Statfjord, Snorre) and Ekofisk. Oseberg HFIS was discontinued on 1 September 2009 and the service was transferred to Stavanger Control Centre.

Improved flying weather service
BSL G 7-1 came into effect on 1 July 2008 and will be fully implemented in 2010. Requirements for flying weather service which were formerly stated in BSL D 5-1 have now been included in BSL G 7-1.

3.5 Organisational development

Requirements for Safety Management System (SMS)
ICAO requires the establishment of a Safety Management System (SMS), and EASA is working on updating the regulations. This is expected to be finished in 2010. EASA has published a draft for acceptable means of compliance. In connection with ICAO's recommendation, all helicopter operators must, by January 2009, establish their own Safety Management System, SMS. This will be implemented in Norway later on, in part because of lack of capacity on the supervision level (cf. Chapter 3.6 regarding the move of LT).

Many functions and routines are already in place with the helicopter operators; the challenge will be to structure and describe what already exists in relation to the new regulations, which are still not in place. SMS requires a continuous improvement in relation to an acceptable safety level. The challenge for the authorities will be to define an acceptable safety level.

Helicopter operators are always concerned with safety work. Emphasis on *Crew Resource Management* (CRM) from 1970, *Line Oriented Flight Training* (LOFT) and improvement of pilot training can attest to in this. In recent years there has been international focus on *Line Operations Safety Audit* (LOSA). This was recommended by ICAO in 2002 to monitor normal operations of pilots combined with *Threat and Error Management* (TEM) to handle incidents. LOSA and TEM are recommended tools in the Safety Management System. Not all companies agree with the LOSA approach, because it mainly deals with human factors. In later years LOSA has also been developed for Air Traffic Management under the description *Normal Operation Safety Survey* (NOSS). In 2008, ICAO recommended that LOSA be used for maintenance activities. In Norway, SAS Norway was the first airline in Europe which put LOSA into use.

Tightened requirements for SMS are regarded as having a positive effect on the risk level through a systematic improvement of safety management throughout aviation and with the authorities. In the companies, the focus on the safety work is broadened from only crew to include the company as a whole, also including administration, maintenance, and ground services.

Increased reporting of incidents
A significant change in aviation is that persons with a reporting obligation are now protected against negative consequences of reporting incidents. This is due to the provisions in the

Aviation Act and BSL A 1-3 which came into effect on 1 January 2007. Provisions regarding electronic reporting of incidents ("NF 2007") came in July 2007. The new reporting provisions have led to a dramatic increase in reported offshore aviation incidents. This does not reflect a negative development, rather that now "everything" is reported as a tool in safety work. There is also an increase of reporting from technical personnel and helideck personnel, as well as from pilots. Review and analysis of incidents are included in transfer of experience and training with the helicopter operators. Increased access to digital reporting systems also probably contributes to making the reporting of minor incidents easier. The helicopter operators practice a semi-anonymous, non-punishable reporting regime. This contributes, as mentioned, to a greater will to report from involved personnel. However, under-reporting still remains a challenge for the helicopter operators, as is the Civil Aviation Authority – Norway's (CAA-N)'s analysis of the reports.

Organisation and ownership arrangements

Both the large helicopter operators on the Norwegian Shelf have come under new ownership in the last decade. Norsk Helikopter AS has from the start in 1993 been owned by the Norwegian Ugland family and Bristow Group Inc. In the fall of 2008, Bristow bought out Ugland, and is today the sole owner in what is now called Bristow Norway AS. The technical functions which provide the terms for North Sea operations are divided between Bristow in Aberdeen and Bristow Norway AS, Stavanger Airport – Sola. Helikopter Service AS has been a part of the Canadian Helicopter Corporation (CHC) since 2000, first under the name of CHC and ASTEC (the maintenance organisation), and then CHC Norway and CHC Heli-One (the maintenance organisation). The entire CHC Corporation was bought by the American venture company American First Reserve in 2008.

There can be many benefits to smaller helicopter organisations merging into larger units. Mergers often have an economic motivation, but can also lead to the technical and human resources joining and becoming more efficient. For both Bristow Norway and CHC Norway, the change in ownership has lead to changes in management, internal framework conditions and other conditions which some think could have the potential to negatively impact safety. In terms of safety, it could pose challenges when different cultures and regions must be harmonised. Forced standardisation, reduced local decision-making authority and increased distance to senior management are factors which can be mentioned in this context.

3.6 Development in authority and customer relationships

Establishment of EASA

EASA (*European Aviation Safety Agency*) was established in 2002 as the new EU body for civil aviation. EASA will gradually take over all of the functions of JAA (*Joint Aviation Authorities)*, which is a federation of the aviation authorities in several European countries, including Norway. Norway is also tied to EASA through the EEA agreement. The new regime has entailed comprehensive administrative work for Norwegian aviation.

The Norwegian Air Traffic and Airport Management was split into Avinor and the Civil Aviation Authority - Norway (CAA-N)

The Norwegian Air Traffic and Airport Management (LV) was split into a management and supervision part (the Civil Aviation Authority - Norway (CAA-N) and an operation part (Avinor) in 2000. Avinor is responsible for providing services (e.g. aviation safety) and infrastructure, while CAA-N is responsible for access control, supervision, etc.

Move of the Civil Aviation Authority - Norway (CAA-N)
It was decided that the CAA-N was to move to Bodø in 2006/2007. In connection with the move, a large part of the staff was replaced. This entailed major challenges connected to continuity, capacity and quality, and CAA-N has had problems with safeguarding its tasks in relation to the helicopter operators. There has also been a significant shortage of operative inspectors on the helicopter side, and it has also taken time to implement the EASA directives. This is about to be resolved as the new organisation will have the chance to "establish" themselves. It is unclear whether the move has entailed any change to the safety level, but there are some who claim that after the move, CAA-N does not have the same relationship to aviation safety as before, but now focuses instead on the more formal (legal) aspects. Among other things, exemptions have been given for missing M-ADS. From a safety perspective, is it claimed that such exemptions should not have been granted.

Establishment of the Petroleum Safety Authority Norway
The Petroleum Safety Authority Norway (PSA) was established on 1 January 2004 in connection with the split of the Norwegian Petroleum Directorate (NPD) into a resource management part, and a supervision part (PSA). PSA reports to the Ministry of Labour and continues the tasks NPD had within the HSE area.

Since 2000, the PSA has annually released the publication "Risk level in the Petroleum Activities" (RNNP, formerly "Risk level on the Norwegian Shelf"; RNNS). An assessment of the development of the risk level associated with helicopter transport offshore is included.

Supervision of helidecks
The responsibility concerning the supervision of helidecks has long been unclear and unfortunate, and this is a major concern in the industry. It is claimed that the regulations are unclear and have room for interpretation. The helideck represents the interface between two supervisory domains; the facility and activities there (responsibility: PSA) and the flights to and from the facility (responsibility: CAA-N).The PSA has traditionally (from 1985) had supervision responsibility for the helideck as a part of the facility. A recommendation in NOU 2001: 21 was that CAA-N should have the main responsibility for all factors affecting flight operation from departure to landing on the helideck. This was rejected by the PSA, and the Ministry concluded that the existing responsibility roles should be maintained. CAA-N therefore supervises the helidecks as capacity allows. In addition, the helicopter operators have an independent responsibility to ensure that the helidecks they land on fulfil the requirements. The helicopter operators often end up inspecting the helidecks themselves.

The Accident Investigation Board; from HSLB to SHT
The Accident Investigation Board for Civil Aviation and Railroad (HSLB) changed its name to the Accident Investigation Board Norway (AIBN / SHT) in 2005. The name change reflects changing new areas of responsibility for SHT; today SHT is a commission for the transport sectors civil aviation, railroad, road traffic (from 2005) and shipping (from 2008). The reorganisation has required significant growth in the last few years. At the same time, SHT has had challenges with personnel resignations on the aviation side. The capacity problems may have had significance for the number of incidents being investigated, as well as the delayed production of reports.

New players on the Shelf
In the last decade, a number of smaller oil companies have engaged in the activities on the Norwegian Shelf. In connection with their entry it has become more relevant to use entirely new helicopter operators, also foreign operators. The combination of new, small and foreign,

gives grounds for scepticism regarding the new players' knowledge of – and willingness to conform with – Norwegian regulations and established practices.

Increased number of mobile facilities
An increased number of mobile facilities in the last decade has resulted in a bigger number of floating helidecks. This gives increased risk contribution in relation to a lack of clarity regarding which regulatory requirements are applicable, in addition to wind, turbulence, size of helideck, movement of helideck during landing and take-off, sea spray on the helideck, as well as errors in the facilities' position report.

Contracts, price, competition
Contract practices have purportedly undergone significant change in recent years. In particular, some contracts have been signed between helicopter operators and the large oil companies which have led to economic under-coverage. The helicopter operators claim this is because contract prices for helicopter services have not kept pace with cost increases. The customers have a dominant position and have constructed their own escalation formula based on the transport business as a whole. This does not reflect the difference in cost increases for helicopters, as compared with other transport. The result can be that the helicopter operators achieve a satisfactory profitability in the start of the contract period, which is often five years plus up to five years' option, but deficits at the end of the period. The helicopter operators' cost level is strongly dependant on the subcontractors (of fuel, components, maintenance services, etc.). Previous experience has shown that this gives a 6-7 per cent annual cost increase for the helicopter operators. Some suppliers (for example Turbomeca) have in this period had a price increase of 12 per cent in some years. In comparison, the rest of the transport sector has 2-3 per cent annual cost increases. Inventories, especially rotor blades and gear boxes, tie up a lot of capital. The labour unions in the sector also have a strong position, which influences the salary levels for the pilots.

The safety consequences of the poor profitability are that the helicopter operators' management must dedicate disproportionate attention to keeping costs low. Safety is expensive, and is subject to a tougher prioritising with the helicopter operators towards the ends of the contract period. On the up side, the helicopter operators are satisfied with the change implemented in the customers' compensation model – from only hourly compensation to fixed day rates plus hourly compensation – which has reduced the helicopter operators' economic risk associated with fluctuations in the number of flight hours used.

From the large customers' side it is claimed that the oil companies' policy in relation to tender processes in a competitive market is transparent and consistent. It is expected that the bidders (helicopter operators) price their services in relation to this. From the large customers' perspective, Norwegian helicopter operators still seem immature in relation to the fact that they are operating in a competitive market, compared with other supplier groups. The customers claim that the alternative will remove the helicopter operators' incentives to negotiate prices with their subcontractors, and will therefore contribute to uncontrolled cost growth. The large oil companies have good procurement expertise and claim to be genuinely concerned with safety. This means that they can and will adjust, if unfortunate contract outcomes are discovered.

3.7 Development within emergency preparedness

New helicopters – Better impact absorption and easier evacuations
With new helicopters (see Chapter 3.1) new improvements and requirements related to emergency preparedness are also introduced. The new helicopters have improved impact absorption during hard landings and the seats are adjusted so that the passengers will not faint in case of a hard landing. The new helicopters (S-92 and EC225) also have more and larger emergency exits, for easier evacuations in connection with emergency landings or accidents. S-92 and EC225 are upgraded to Sea state 6 (equivalent to approx. three metre wave height) as a consequence of customer requirements, by mounting two extra pontoons. The new helicopters are also equipped with the latest generation life rafts, which are more automatic.

New survival suits
Significant improvements of the survival suits have been implemented as regards thermal characteristics. This increases the probability of surviving in water. On the other hand, the suits are regarded as being more complicated to use. The procedure which is described in the safety video before departure consists of several steps, and uncertainty has been expressed with regard to how easy it would be to remember all the steps in the correct order in a potential emergency situation.

Emergency location equipment
In the previous period, requirements were introduced to include emergency location equipment (*Emergency Locator Transmitter,* ELT) in helicopters. This has provided greater accuracy in regard to locating the helicopter after an emergency landing or accident. ELT also indicates the machine's identity. Personal emergency location equipment (*Personal Locator Beacons*, PLB) was transferred to another satellite system in 2006.

Other emergency preparedness developments in the period 1999–2009
Other trends within emergency preparedness in the period 1999-2009 have been:

- Two new SAR-helicopters are stationed offshore, an *All Weather Search And Rescue* (AWSAR) helicopter on Ekofisk and a shuttle machine on Valhall, classified as *Limited SAR (Lim*SAR)
- Increased area preparedness with SAR-helicopters has been established for Troll-Oseberg and Heidrun.
- Introduction of on-site duty for Sea-King helicopters. This has provided a 15-minute response time, as compared with the previous up to one hour response time.
- In the event of major incidents and accidents, air traffic controllers can assist the rescue centre from an air traffic controller position on the Joint Rescue Coordination Centre Southern Norway, Stavanger (HRS)
- Larger helidecks have led to less chance of the helicopter falling off the deck if it tips over.
- Improved fire-fighting equipment has been installed on new facilities.

3.8 Other changes

Challenges linked to weather conditions have appeared to be more significant during the last period, because the traffic has moved further north to the Norwegian Sea and more recently to the Barents Sea. The activity in the north is expected to increase further. In the northern areas, polar low pressure fronts can arrive with little forewarning, with strong wind, and large amounts of precipitation, often in the form of snow.

The special meteorological challenges associated with operations in the Norwegian Sea and northern areas compared with conditions in the North Sea are:

- The helicopters are more exposed to icing
- There can be greater lightning activity during winter (especially in the Norwegian Sea)
- More and stronger wind
- Darker during the winter months

4. DEVELOPMENTS IN THE NEXT DECADE (2010–2019)

4.1 Trends in the next decade (2010–2019)

Most of the development expected by the informants in the next decade is related to consolidation and improvement of systems, technology and already existing practices. Typical examples of these are:

Helicopter

- Phase-in of "new" helicopter types will be completed. At the same time, we will gain more experience with these types, especially S-92 and EC225
- Older helicopter types will be phased out
- The introduction of new helicopter types is expected, e.g. EC 175 and AW 139
- Further development, upgrading and increased use of HUMS. Research on the utilisation of HUMS data is ongoing and there will be a gradual development with improved interpretation of the data
- Improved reliability of anti-ice equipment on the new helicopter types.

Operational

- More and better simulators will provide easier access to simulator training. This will make it easier to increase the number of hours of simulator training.
- Improved aviation weather service and weather observations through "*Automated Weather Observing System*" (AWOS). This is a result of the implementation of BSL G 7-1 (BSL MET), Regulations relating to aviation weather service, which came into effect on 1 July 2008.
- Further development, upgrading and increased use of FDM, as well as better utilisation of FDM data. The gains from FDM are expected in the period 2010-2019.

Helideck

- Improved system for monitoring helideck movements (*Helideck Monitoring System)* which will be harmonised with the UK.
- Better labelling[4]
- More helidecks sized 1.25 D.
- Better picture of turbulence conditions around the helidecks based on FDM information.

A new generation of Norwegian technicians and pilots

A generational shift among Norwegian technicians has been ongoing in the last two to three years, but is expected to become more noticeable in the coming years. The helicopter operators will hire a significant number of technical apprentices. This will result in an increased need for training. Requirements from EASA have also made the training regime stricter compared with previous practices. There is a corresponding generational shift among pilots, and more pilots are needed. Younger pilots have fewer hours of flight experience, but a different type of

[4] In addition to the existing lighting system for helidecks, a system is currently being developed in Norway, with the goal of considerably improving the visual references for positioning of helicopters during night conditions. The system's function is to ensure exact references for the pilot, both in longitude and latitude, at the same time as the helicopter can be positioned into the wind during landing. The system has similar properties for positioning and wind indication during take-off. The system is being developed by local talent in Rogaland, under the working title HeliGuide®.

training compared with older pilots. It is therefore uncertain whether a generational shift will have a positive or negative impact on safety.

Introduction of Performance Class 2 enhanced (PC2e)

The risk reduction as a result of increased engine power in relation to weight is particularly important during take-off from low helidecks and in the landing phase. PC2e will be introduced at the end of 2010 along with the implementation of JAR-OPS 3 Amendment 5 which is expected to be completed at the end of 2010. The Civil Aviation Authority - Norway (CAA-N) declared that all helicopter operators within that time must have completed their manuals, helicopter documents and instructions, and conducted the necessary training so that PC2e can be implemented simultaneously with Amendment 5. The introduction of PC2e is expected to prevent an accident in 19 out of 20 cases where an engine fails during the take-off or landing phase. Note that the introduction of PC2e in practical terms means that the take-off/landing weight must be reduced. This means more trips for the pilots, i.e. increased exposure which leads to increased probability of an incident. On the other hand, the number of fatalities per person flight hour is expected to decrease. There could also be a need for more pilots, which could pose a challenge in relation to the generational shift described above.

New regulations

In a few years the new BSL D 5-1 “Regulations relating to aviation on the continental shelf – Commercial aviation to and from helicopter decks on facilities and vessels at sea”, will come into effect. There will, among other things, be requirements in relation to obstacles around and near helidecks, including reducing the maximum allowed height of obstacles located around helidecks from one metre to 25 cm.

The new EASA OPS is expected to be operative around year 2015. In the meantime, JAR-OPS will still be the standard. The transition from JAR-OPS 3 to EU-OPS 3 is distinguished by a lack of continuity.

There is uncertainty tied to the introduction of international regulations on the Norwegian Shelf and the Norwegian authorities’ opportunity to maintain additional Norwegian requirements in offshore aviation. The customers (oil companies) can still impose stricter safety requirements in their contracts, but it is not given whether new, smaller players will do the same. As the market changes, it could prove to be difficult over time for the large companies as well – both customers and helicopter operators – to maintain the self-imposed, strict requirements that are currently in effect.

Controlled airspace[5]

A precondition for controlled airspace is approved surveillance (traditionally radar, not M-ADS). A radar is being installed on Heidrun and from the fall of 2010 this area is expected to have controlled airspace. ADS-B is about to be implemented on Ekofisk and will be ready to replace radar in the Ekofisk area in 2013. Most likely, ADS-B will also be implemented in the Sleipner, Heimdal, and Norne areas in the coming ten-year period.

As ADS-B is the technology of the future and is much more reasonably priced than radar, it should be relatively easy for large parts of the continental shelf to be covered by surveillance within a short time period.

[5] See also Chapter 3.1. where M-ADS is described

Changes in the traffic picture
More traffic is generally expected in the air, both helicopters and fixed-wing airplanes. The use of unmanned aircraft (UAV; *Unmanned Aerial Vehicle*) is also a concern.

Increased activity in the northern areas is expected in the years to come. These are areas with poor infrastructure and demanding approaches to airports. Flights in these areas pose some extra challenges, e.g. with regard to weather forecasts. In the far north there is also a greater probability of extreme weather in the form of polar low pressure fronts. Large distances are considered to be the most problematic factor in regard to accidents, since this demands more from the emergency response services. In addition, cold water and dark in the winter months are factors which will complicate any rescue missions.

4.2 Changed framework conditions internally within the two largest Norwegian helicopter operators

4.2.1 General

The period 1999-2009 has been marked by the following changes in ownership within the two dominating helicopter operators on the Norwegian Shelf. (cf. Chapter 3.2):

- 1990–2000: Both helicopter operators were Norwegian-owned and had Norwegian management and administrative boards with experience within aviation safety
- 2000–2009: Helikopter Service AS was reorganised into CHC Helikopter Service AS (operator company) and CHC ASTEC (maintenance organisation), and then into CHC Norway AS and CHC Heli-One. Norsk Helikopter is now called Bristow Norway AS
- From the beginning of 2010, both helicopter operators are completely foreign-owned. CHC Norway is owned by Canadian Helicopter Corporation (CHC), which is owned by the venture company American First Reserve. Bristow Norway is owned by the British company Bristow Group Inc.

The objective of this part of the study is to identify possible challenges as a result of changed framework conditions internally after the ownership change on the part of the two dominating Norwegian helicopter operators. The mapping was completed at the end of the project period. To gain access to how the situation is experienced and interpreted in the companies in question, an open qualitative approach has been used. Interviews were conducted based on a list of topics, but the interviews mostly took place as a dialog where the interview subjects had a chance to offer their own input on central topics. The data material consists of a strategic selection of representatives from management and employee representatives from the operative and technical departments in CHC Norway, CHC Heli-One and Bristow Norway. A total of nine persons were interviewed during January 2010. Each interview lasted 1.5 hours. As the employees had backgrounds from different positions as representatives, they also spoke on the behalf of other employees. Four main topics formed the basis of the interviews:

- Change of decision-making authority / management of resources and significance for work practices
- Changes and their significance for maintenance routines
- Changes in competence and training
- Changes in cooperation and communication with local management.

The result is rich data material, but due to time and resource limitations, we will present the essential elements in a condensed form. There has not been an opportunity to conduct an in-depth analysis and include the extensive assortment of examples. For each main topic, the elements discussed during the conversations are described, and a short summary and analysis of central changes and the informants' interpretation of the situation is given in the form of examples. Finally, our conclusion is presented in the form of organisational challenges.

4.2.2 Change of decision-making authority, management of resources and work practices

Changes in work practices are discussed here in regard to what must be approved by the foreign owners and who is involved in the decision-making processes. Does this make safety work more difficult, for example in regard to investments?

Differences and similarities between the two companies

Both of the afore-mentioned helicopter operators are now fully foreign-owned. One company has "financial owners", while the other has "helicopter expert owners". This was one of the differences discussed in the interviews.

We have identified several common trends in the companies. Figure 4.1 illustrates the before and after situation. As shown, after the ownership change the organisations have acquired a new *Business Unit* between the upper management and the operations director and technical director respectively. The latter two are placed as a link between the "nominated postholders", meaning they are responsible to the Civil Aviation Authority - Norway (CAA-N) for ensuring the compliance with requirements of the Air Operative Certificate (AOC) in Norway at all times. The change means that now "nominated postholders" do not have a direct reporting hierarchy to the Accountable Manager. This could lead to the "nominated postholders", who have been personally approved by the CAA-N, having great responsibility but less power to make decisions and put (cost intensive) measures related to safety into effect. The technical director and operations director have not been personally approved by the CAA-N, but report directly to the Accountable Manager. In this organisation the operative and technical directors will have great power, but not the responsibility in relation to regulations, etc.

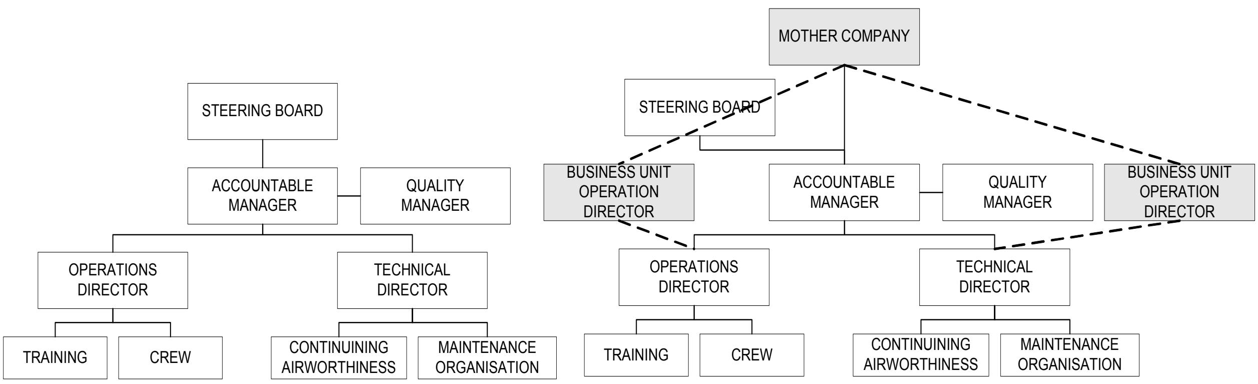

Figure 4.1. Organisational structure (simplified) in 1999 (left) and 2010 (right). A change is shown from traditional structure to a form of matrix organisation.

On the positive side, our interview subjects point out that having one large owner could provide better liquidity and access to capital, a larger fleet and more available material. However, the study documents that the local management does not have the authority to hire people, pay larger bills or to close cost-intensive deviations. Purchasing of material or hiring of personnel has become more difficult to accomplish when decisions entailing larger costs are not made locally in Norway, but must be approved from abroad (“remote control”). It was also claimed that the tendency to save on small amounts could cost millions. The following quotes illustrate how employees perceive the situation, and how they exert extra effort to maintain good regularity:

”Employee X had to leave to buy diesel, fill the tractor with diesel and pay with a private credit card, that’s how you get diesel on the tractor so that you can fly.”

”Many things work because many employees try to make it work in the best way possible.”

The Civil Aviation Authority – Norway (CAA-N) has undergone a demanding readjustment process after the move to Bodø (cf. Chapter 3.6). Over several years CAA-N has had low capacity and a lack of key persons with expertise on offshore helicopters (DIFI, 2008). Literature and the interviews indicate that CAA-N should be more present when new owners arrive. After the ownership change, the group management in one of the companies wanted to change the managing director in Norway, and this process was lengthy. There is agreement in the sector that it is the helicopter operators’ own responsibility to find the best solution to different problems or challenges. Nevertheless, the CAA-N’s influence and help to contribute to a satisfactory change process is important in such cases. It was expressed that the Civil Aviation Authority – Norway (CAA-N) enters into organisations and takes a “snapshot” in the form of a short inspection, after they have warned the organisations well in advance. It was pointed out that documents about management of change might work on paper, but there is room for improvement in practice. It is also pointed out that conditions the employees perceive as important deviations, are often classified as observations in the audit reports. As we know, the observations do not require any measures.

In connection with the conditions described, SINTEF sees the following organisational challenges:

- Strategic decisions regarding investments are made abroad. It is therefore uncertain whether the access to a larger fleet and more capital will reap benefits for the Norwegian companies.
- A matrix-structured organisation can introduce ambiguities which need to be managed in a considerate way (cf. Failure to learn, the BP Texas refinery accident, Hopkins 2008). Currently it is difficult to know “where one stands” and who one should relate to. There is confusion if responsibility and authority are not followed through.
- Insufficient management of change may have a negative impact on safety. A more active role is needed, as well as organisational and technical helicopter experience from the Civil Aviation Authority - Norway (CAA-N)’s side, so that negative consequences of changes can be identified and a good process with the helicopter operators can be promoted as soon as possible.

4.2.3 Importance for maintenance routines

The following elements are discussed:

- Maintenance programme
- Spare parts
- Duplicate inspection

Helicopter maintenance is conducted in different ways in the respective countries. It was regarded as unfortunate to standardise maintenance across national borders. Norway's maintenance work is divided into areas such as cabin, rotor, fuselage, tail section. In other countries, work descriptions are used which cover more areas. This results in there being more people working on the entire aircraft. From a Norwegian perspective "going to and from" in this way makes it difficult to get the whole picture, and it is asserted that this approach leaves more room for mistakes.

It has been pointed out that a shortage of spare parts can constitute a safety risk. Generally, today is takes a "very long time" to get spare parts. The lack of resources and spare parts can be seen in an increase in the trend of applications for "*Maintenance Deviation Request*". This, along with changes in management, creates frustration among the maintenance personnel. There is much pressure on regularity, but if a machine has critical faults, the helicopter will of course be grounded. To be able to keep the helicopters in the sky, an increase in "cannibalism" is experienced. "Cannibalism" means that helicopters grounded for heavy maintenance are used for spare parts for other machines. (Quote: "Lack of parts controls maintenance".) "Cannibalism" is fully legal as long as the specified procedures are followed, but this results in two operations being performed instead of one. With this, there is increased pressure on the maintenance organisation, especially if helicopters must wait, and it can possibly lead to penalties from the customer.

Quote: "*An email came from the management saying that if we could maintain over 90 per cent regularity for one week, they would buy cake for all the bases. But then the employees answered in an email saying that if the management could provide parts for the entire week, they would buy cake for the entire management.*"

This is an example of how employees use humour as a disarming or counter power strategy.

There has been no change in how duplicate inspection is accomplished. For offshore helicopters this is always practised, but exemptions may be granted in exceptional cases also.

In connection with the conditions described, we see the following organisational challenges:

- Standardisation of maintenance programs across national borders could be a hindrance. There is a need for local/national standardisation, in other words, adjustment to Norwegian conditions
- The lack of spare parts is a large problem and it leads to extensive "cannibalism". The problem has grown recently, as a result of the "new" machine type (S-92) being put into use on the Norwegian Continental Shelf, and many components are of poorer quality than expected
- There are marginal resources for maintenance. A considerable share of the technicians have worked overtime for long periods. An organisation can be pressured for a short period, but not over long periods of time.

4.2.4 Changes in competence and training

The following elements are discussed:

- Simulator training
- Requirements for recruitment
- "Airmanship"
- Training of technical personnel.

Our analysis uncovers somewhat varying attitudes as regards the scope and content of the training. Many are satisfied with the increase in the number of simulator hours, but at the same time the importance of a review of what is offered, and in what ways is it being offered, is emphasised. This can be illustrated by some quotes.

“There is a high standard of training” … “The training is fairly standardised”…”There are a lot of courses but they get shorter and shorter (technically)”…”Compared with other countries, the training in Norway is at a fairly high level. It has improved considerably in recent years (operative)”

Towards the end of 2009, one of the companies has increased the number of hours in a simulator from six to eight hours per year. One interview subject says that it is important that the number of hours is viewed in relation to practicing special situations, for example landing on floating helicopter decks in the dark. Operational simulator training is now conducted according to requirements from the authorities, and there is little room for special training.

”These are six hours where you always have to move on to the next manoeuvre, and many tasks are only performed once. You never have time to repeat the same thing”.

Many pilots therefore want more time, so that they can repeat and train for special situations. Some point out that flying to a rig is demanding, and there is a need for more training of these types of operations in the dark, fog, wind, as well as other customer-related topics.

For technical and operative personnel, training has become more IT-based:

“If you are going through the entire helicopter with a pc, you end up “clicking” yourself forward, and you don’t even know where you are.”

In some areas IT works fine, but the downside is that you do not have the possibility to ask questions. This could therefore be a bad way to learn. There is an emphasis on being able to talk and reflect about the system and relate to your own and others practices and experience. For new helicopters, the customer-specific equipment is not in the standard courses.

From a technician’s point of view, concern is expressed that technical experience will be scaled down, and that there is a move towards a development where cheaper people are hired. Currently, technicians in Norway execute the work and sign off, but there are some changed practices in other parts of the parent companies. This is in connection with EASA’s new regulations allowing hired personnel with less experience to perform the work, while qualified technicians are responsible and approve/sign off. Concern was also expressed regarding future recruitment of technicians as well as pilots, because these occupations have become less attractive.

In connection with the conditions described, we see the following organisational challenges:

- Number of hours and content of the training should be expanded in relation to the authorities’ minimum requirements, so that the training also includes special operations and repetitions.
- There should be an optimal balance between IT-based training and experience transfer in classrooms. The quality of the training should be followed up, not just the number of hours.
- Much attention should be devoted to the recruitment of pilots and technicians.

4.2.5 Changes in cooperation and communication

This part of the study focuses on cooperation and communication between local management, group management and employee representatives in the companies. The following elements have been discussed:

- Cooperation
- Information
- Reporting of incidents.

It has been asserted that changes in ownership have lead to a more authoritarian management and control logic than what people were used to. In Norway, the norm is to work based on goals instead of directives, and that was the explanation for this. For those who are used to *"management by directives"* this can seem time consuming and "slow", because the work is based on processes, delegation and guidelines.

"In other countries when you say left, you go left. In Norway if we say we are going left, our people would ask why? In Norway we could rather have said: Today our goal is to go here, and the employees would achieve that by going left".

Some also mention that much of the local management's work capacity is spent reporting, and explaining to the foreign executives why some measures cannot be carried through in Norway, for example because of the Working Environment Act or because the aspect is governed by collective wage agreements. To outsiders, this can seem like a lack of arenas or will to understand each other, and that measures must be adjusted to the conditions and anchored to have be viable in a Norwegian setting:

"Much of culture and experience is ignored - the foreign owners roll out their concepts."

At the same time, there is a lag in the employees' perception of reality:

"The employees cannot keep thinking that we are not part of a large international player."

It is important to mention that some employees said they were content with being taken over by foreign companies because it had strengthened their market position. It was also said that that in one company the mood now is better than in the previous year. The integration between the new and old organisational models was regarded as a learning process which is time-consuming and created a lot of frustration, but where there were also some signs that the new owners were becoming more sensitive to the Norwegian work environment.

The local management have experienced that they are now part of a system with less freedom of action. For example, some individuals have experienced that it is not desirable to make a statement to the media and explain incidents.

Good relationships between employees and middle managers are reported, but communication with management further up in the system is characterised by mistrust. It is stated that there is good communication between labour unions and that this has developed positively. The good and close cooperation between pilots and technicians is also mentioned as an important element in maintaining a high quality production of helicopter services.

In relation to the topic of reporting incidents, the data material can be interpreted several ways and is to a certain degree contradictory. In the same company, the good reporting culture was emphasised by some, while others told of under-reporting. It was claimed that employees are still good at reporting minor things, especially if others made the mistake. It was also brought up that previously when one would report something, the case was brought up and discussed and everyone would learn from the incident. Now, however, it is said that fear of consequences has contributed to under-reporting.

In particular, there are three topics which do not get reported:

- Exceeding working hours for technicians
- Exceeding working hours for pilots
- Situations or incidents which might not have been thought through and which could have become dangerous.

It is added that it is often *"the old mistakes repeated by new people"*.

In one of the companies, it was pointed out that you now must go into the system individually and actively click your way in to see what has been reported. In other words, the results from the reports are no longer automatically communicated out and discussed jointly with the intention of organisation-wide learning. Some are therefore concerned that the reporting will only end up as statistical registration, with no real effects. In one of the companies, the flight safety advisor has been taken out of the "flight line".

There are plans to have joint operational procedures so that people can be sent anywhere in the organisation. In one of the companies, there have been several meetings for experience transfer, e.g. in the training department and the technical department. The method for conducting maintenance in Norway has been adopted in other parts of the company(ies).

In connection with the conditions described, we see the following organisational challenges:

- The companies appear as organisations with dysfunctional/defective traits, such as unclear reporting lines, instability (frequent replacement of management), unrest, uncertainty, mistrust and fear of sanctions.
- There appears to be a culture collision between two different management models; one authoritarian foreign model ("management by directives") and the Norwegian model where management and employee representatives represent different interests, but cooperate.
- There appears to be improvement potential as regards under-reporting, individualisation of reporting and possibility for experience transfer. There is a tradition of reporting technical errors; it is less common to report operative incidents.

4.2.6 Penalties

It is reported that penalties lead to increased pressure and that "limits are pushed", e.g. in relation to purchasing days off. A representative from the operative side says he is not worried about safety, but says that the margins are shrinking. It is also said that, in the long run, it is unfortunate that so many things are put under pressure, and that this could reduce alertness. The pressure is felt most during delays. Much time and resources are spent on assessing how such situations should be handled. A high level of pressure can lead to more room for mistakes.

A warning from technical literature about incentive-based reward structures: When determining a performance indicator for reward or punishment, it is important to consider the consequence. A consequence is that you could become more preoccupied with controlling the indicator quantity than controlling the processes that the indicator is meant to provide information on (Hopkins 2009).

In connection with the conditions described, we see the following organisational challenges:

- Penalties for delays can be perceived as a pressure to deliver, and it can lead to less understanding in the organisation for holding a helicopter back. (We do not have a clear picture of the extent to which the contracts with the customers include penalty clauses.)

4.2.7 Conclusion regarding changed framework conditions

Our study documents relatively extensive changes in the internal framework conditions within the two helicopter operators. The changes are both positive and negative. The positive being that the helicopter operators have gained access to more capital and a larger fleet, and that they now are a part of international corporations. On the other side, the encounter with different management cultures results in demanding learning and integration processes. We have identified a set of organisational trends which have contributed to the focus shifting away from the primary, operational work tasks. While these changes have not yielded any concrete effects on safety in the form of incidents, but in a business which is based on alertness at every level, it is unfortunate to have unclear reporting lines, a lack of concurrence between power and authority, unrest, and uncertainty in the organisation. In the long run, such conditions could pose a threat to safety. Pilots and technicians have high standards in Norway and this has most likely contributed to everything working out, despite the unrest.

4.2.8 Suggested measures

The following measures have been identified in relation to changes in the internal framework conditions on the part of the Norwegian helicopter operators:

- The oil companies should maintain the requirement of Norwegian AOC with the helicopter operators. The contracts should ensure that Norwegian management has the authority to make strategic decisions which are adapted to Norwegian operations. This will provide improved local control. At the same time, it could complicate cooperation with other countries.
- The Civil Aviation Authority – Norway should monitor the development actively to further promote good change processes, cf. HSLB, 2005, Safety Recommendation 1:
  "The Civil Aviation Authority should consider putting greater emphasis on systemoriented
  holistic and risk-based supervision and develop/recruit personnel with
  relevant expertise - not least in order to follow up and become aware of potentially negative safety consequences of the change measures at those they supervise."
- In relation to current practices, the helicopter operators and the CAA-N should consider classifying organisational deviations as deviations and not "observations"
- The helicopter operators should make the new organisation structure, responsibility, authority and reporting lines more clear. Due consideration for possible culture differences should be included, cf. HSLB, 2005, Safety Recommendation 11:
  "*The airlines are advised to survey cultural differences before considering association/mergers and integrating courses from the original companies in such a way*

that a "new" corporate culture can be established in a clear way for everyone involved."

- The helicopter operators should consider putting measures into effect which could improve the cooperation between labour unions and senior management.

4.3 Norwegian additional requirements to offshore helicopter traffic

The goal of this part of the study is to map which Norwegian additional requirements have contributed to a positive safety development in the Norwegian sector in recent years, the extent to which it will be possible to maintain these requirements, or to establish new Norwegian additional requirements for helicopter operations on the Norwegian Continental Shelf.

The establishment of EASA has contributed to the development of joint rules for European aviation (cf. Chapter 3.6). In the fall of 2009, the Ministry of Transport and Communications submitted EU regulation 1008/2008 for consultation. The regulation deals with joint rules for the conduct of aviation transport services. Helicopter transport to and from offshore petroleum installations on the Norwegian Shelf is conducted under particularly demanding weather and landing conditions compared with commercial passenger flights with fixed-wing aircrafts. Through the years in Norway, there has been a considerable effort to continuously improve the safety of offshore flights. Several safety studies have been conducted and several measures have been put into effect to improve safety. The helicopter operators, Air Traffic Services and helicopter decks on the Norwegian Shelf currently use technology, procedures and practices which are specially adapted for Norwegian conditions. Today's requirements for these operations are stricter than any other (land-based) helicopter transport and require larger investments. Joint European requirements open up possibilities for other helicopter operators that do not necessarily have the distinct technology, routines, and experience that the industry perceives as being necessary for safe helicopter transport on the Norwegian Shelf. The international economy is currently under considerable pressure, and the Norwegian Shelf is regarded as an attractive area for potential new helicopter operators. Helicopter operators who have not made the same investments in secure technology and special procedures required by Norwegian authorities and the larger oil companies, will be able to offer their services at a lower price than the established Norwegian helicopter operators. Concern has therefore arisen in the industry about the effect of joint European rules for helicopter transport on the Norwegian Shelf.

The most central Norwegian additional requirements and the special practices established for helicopter transport on the Norwegian Shelf are the following:

- Requirement for Norwegian *Air Operative Certificate;* AOC
- Special requirements for helicopter operators and helicopter decks. (cf. BSL D 5-1; Commercial aviation to and from helicopter decks on installations and vessels at sea)
- Requirement for "*Modified Automatic Dependant Surveillance*" (M-ADS), a Norwegian developed system which states the helicopter's position at all times. The Norwegian Shelf does not have full radar coverage, and M-ADS has contributed to making it easier to locate a helicopter in trouble. (cf. BSL D 2-10 Regulations relating to use of Modified Automatic Dependant Surveillance (M-ADS) equipment in civilian helicopters)
- The helicopters shall be equipped with a system for vibration monitoring (Helicopter Health and Usage Monitoring System, HUMS, cf. BSL D 1-16 Requirement for design and fitting of vibration monitoring system)

- There are special requirements for aviation weather service (cf. BSL G 7-1 Regulations relating to aviation weather service)
- Use of OLF's guidelines for helicopter transport. These coordinate operative and technical requirements for the helicopter operators, the helicopters and helidecks (cf. OLF 066 – Guidelines for flight to/from petroleum installations and OLF 074 – Guidelines for helicopter deck personnel). The guidelines include distinctive Norwegian recommendations regarding recruiting, training and experience requirements for pilots, technical personnel and helicopter deck personnel. Even though the documents are guidelines, they are loyally followed up by OLF's members, i.e. most Norwegian users of helicopter services offshore.
- Implementation of measures identified in NOU 2002: 17 Helicopter safety on the Norwegian Continental Shelf. These measures have required further development and considerable investments in:
    - Helideck design
    - Helicopter's impact absorption ability during hard landings and emergency landing at sea
    - Helicopter stability on the sea
    - Approach to installations
    - Interpretation of signals from the vibration monitoring systems
    - Improvement of air traffic/air navigation service organisations and aviation weather service
    - Stricter requirements for engine performance
    - Improvement of helicopter's maintenance programmes
    - Communication of criticality analyses of helicopter design
    - Simulator training

In Norway the petroleum industry, helicopter operators and supervision authorities cooperate to improve the safety level, and there is still room for further improvements. However, there is concern that a danger will be posed by the fact that new oil companies (demanders of helicopter services) and new helicopter operators will not necessarily feel bound by OLF's guidelines, but will only relate to the authorities' minimum requirements. In addition, the Civil Aviation Authority – Norway (CAA-N) can grant exemptions from provisions for civil aviation (BSL) when there are sufficient grounds.

EASA received about 14.000 comments on the consultation draft on EU's regulation 1008/2008. In Norway, the Ministry of Transport and Communications received viewpoints from central Norwegian players (including, Norwegian Airline Pilots' Association, the Petroleum Safety Authority Norway and the Federation of Norwegian Aviation Industries). A political decision is expected where, from the Norwegian side, there appear to be two possible strategies; either a EASA PART-OPS which safeguards offshore elements in joint European regulations, or that the Norwegian Continental Shelf is defined as being outside the EEA area, so that Norwegian additional requirements can be maintained.

4.3.1. Conclusion regarding Norwegian additional requirements

The additional requirements which have been implemented in Norway have contributed to a positive development related to operational, technical and organisational factors. To prevent the development in Europe from being a step backward for helicopter safety on the Norwegian Continental Shelf, the best solution will most likely be that the Continental Shelf is regulated outside the EEA area. This will mean that Norway can follow the EASA PART-OPS requirements and maintain or establish Norwegian additional requirements for offshore flights. In addition, Norway should continuously give input to EASA PART-OPS to attempt to maintain provisions which promote safety work. OLF can encourage its members to follow OLF's recommended guidelines. Furthermore, the contracts between the oil companies and helicopter operators should include requirements adjusted to the operations on the Norwegian Shelf. Finally, the Petroleum Safety Authority Norway can encourage/motivate non-members of OLF to follow the same guidelines.

5. STATISTICS

This chapter provides an overview of relevant helicopter safety statistics with a focus on the Norwegian sector in the period 1999-2009. The following data sources have been used:

- Traffic volume in the Norwegian sector from RNNP
- Reported incidents from the helicopter operators to PSA in connection with RNNS/RNNP
- Reported incidents to CAA-N
- Investigation reports from AIBN
- Annual statistics from OGP with an overview over accidents and the traffic volume in the North Sea
- Accident data from CAA-UK
- Investigation reports from AAIB UK.

5.1 Summary of incidents in the Norwegian sector 1999–2009

During the period 1999-2009 there has been one accident and ten incidents classified as serious in the Norwegian sector. Table 5.1 and Figure 5.1 show the distribution of accidents and serious incidents in the eight accident categories. Figure 5.2 shows how these incidents are broken down per year in the period.

Table 5.1. Accidents and serious incidents in the Norwegian sector 1999-2009, divided by accident category (A1-A8).

Incident	Number	Accident category							
		A1 Heliport	A2 Helideck	A3 System failure	A4 Collision Air	A5 Collision Terrain	A6 Person inside	A7 Person outside	A8 Other/ unknown
Accidents	1	-	-	1	-	-	-	-	-
Serious incidents	7	2	2	2	-	1	-	-	-
Serious ATS incidents	3	-	-	-	3	-	-	-	-
Total	**11**	**2**	**2**	**3**	**3**	**1**	**0**	**0**	**0**

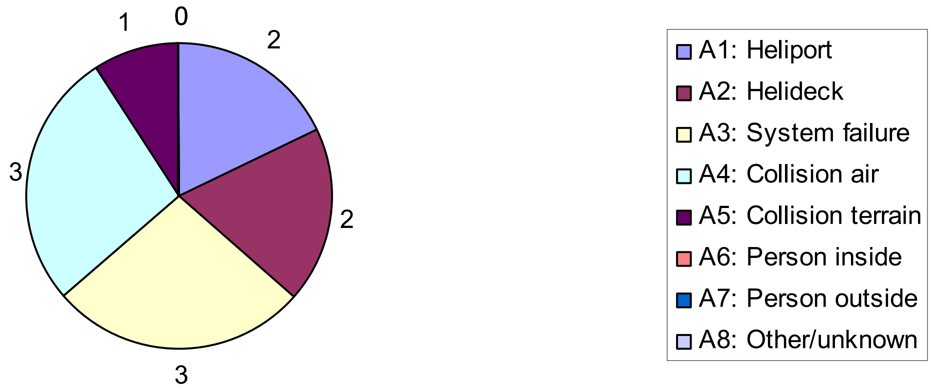

Figure 5.1. Accidents and serious incidents in the Norwegian sector 1999-2009, divided into accident categories (A1-A8)**.**

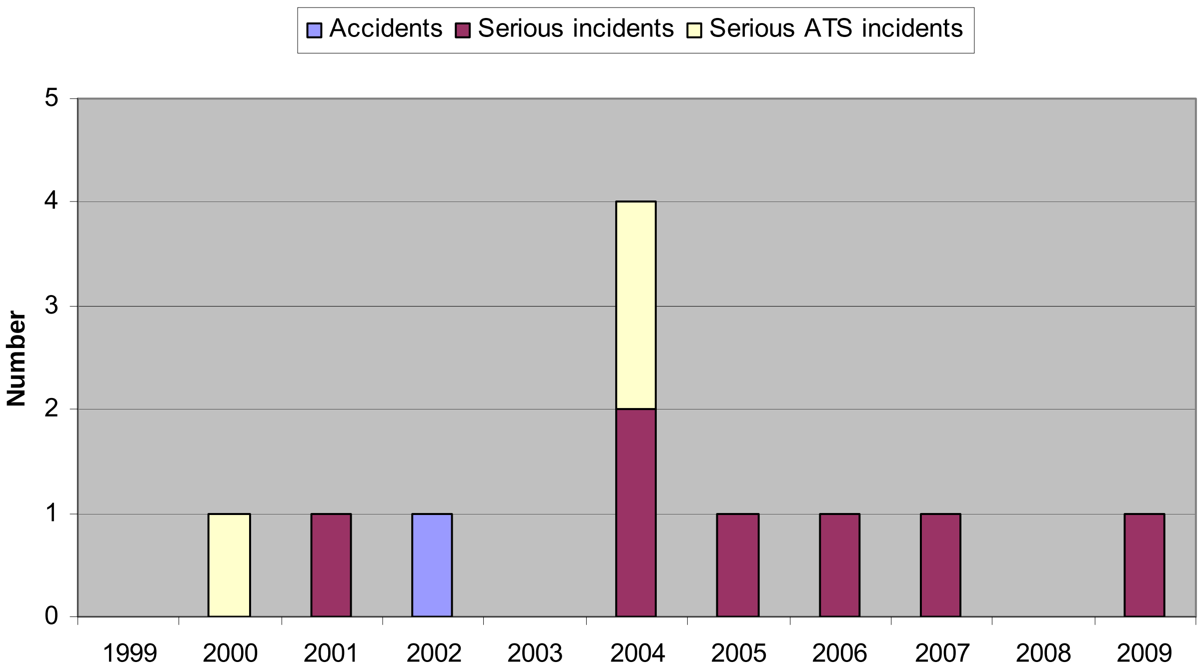

Figure 5.2. Accidents and serious incidents per year in the Norwegian sector 1999-2009.

5.2 Traffic volume

Table 5.2 and Figure 5.3 show the traffic volume for helicopter transport on the Norwegian Continental Shelf in the period 1999-2008, based on numbers from the PSA. Numbers from 2009 were not available. Flights in connection with testing, training, education, cargo missions, and rescue missions are not included.

Table 5.2. Traffic volume in the Norwegian sector 1999–2008.

Year	Transport service		Shuttle traffic		Total	
	Flight hours	Person flight hours	Flight hours	Person flight hours	Flight hours	Person flight hours
1999	37 912	618 087	4 840	89 456	42 752	707 543
2000	39 887	629 000	5 352	98 134	45 239	727 134
2001	40 670	676 821	5 692	98 887	46 362	775 708
2002	38 016	634 513	5 140	90 550	43 156	725 063
2003	38 877	616 559	5 356	89 394	44 233	705 953
2004	36 269	611 811	5 517	85 996	41 786	697 807
2005	38 280	637 282	5 279	83 086	43 559	720 368
2006	39 207	567 558	5 608	91 518	44 815	659 076
2007	39 848	583 228	5 092	88 109	44 940	671 337
2008	38 115	646 679	4 566	79 111	42 681	725 790

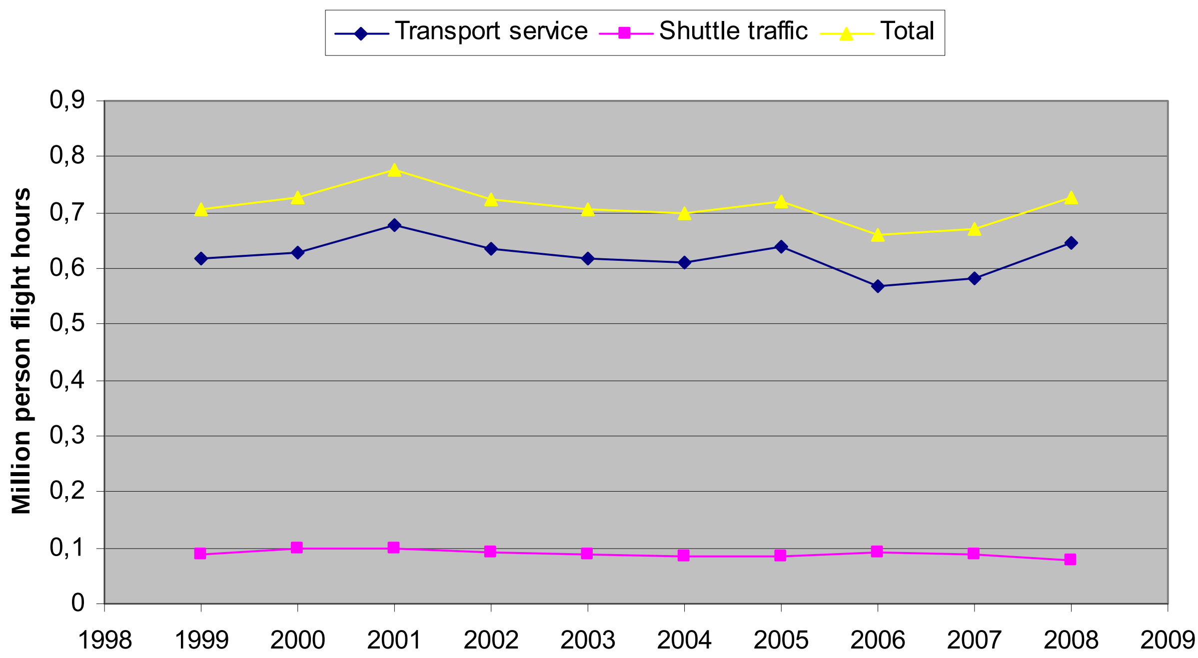

Figure 5.3. Traffic volume in the Norwegian sector 1999–2008.

Figure 5.4 shows the development in total traffic volume in the period 1990-2008. We can see that the traffic volume varies a bit in the period 1990-1998, but stabilises at a higher level in the period 1999-2008. The average traffic volume in the two periods is 0.58 and 0.71 million person flight hours, respectively.

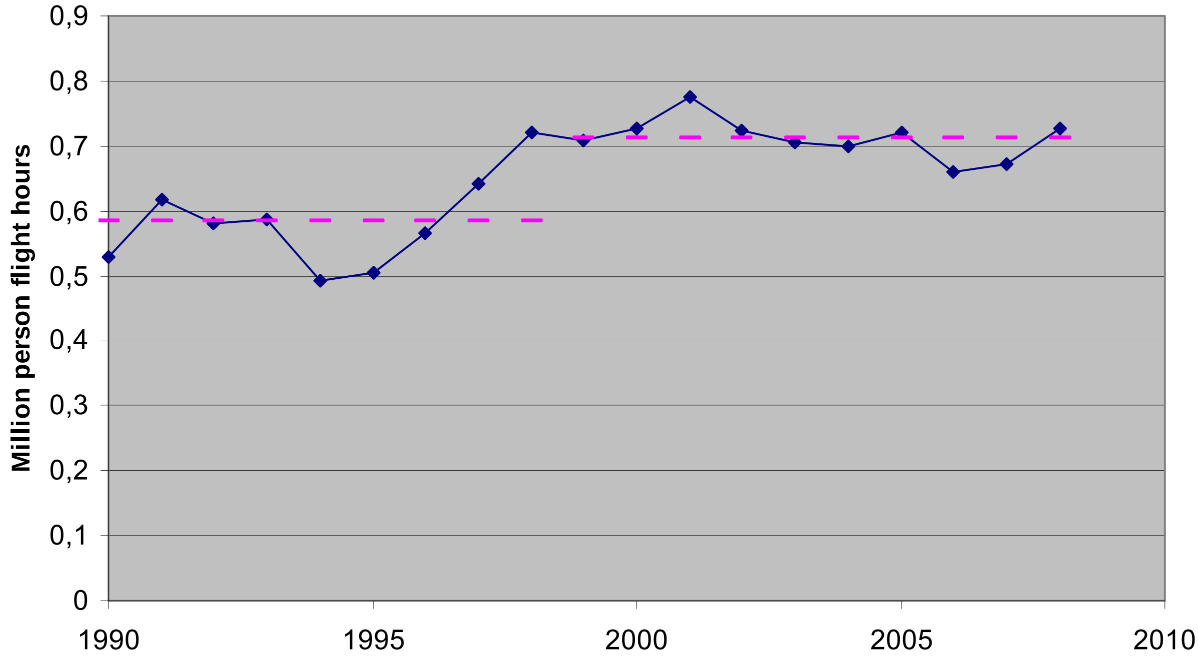

Figure 5.4. Traffic volume in Norwegian sector 1990-2008. (The average level in the two ten-year periods is indicated with a dotted line.)

5.3 Accidents in the North Sea 1990–2009

In the period 1999–2009 a total of 12 accidents occurred in the North Sea; 11 of these occurred in the UK sector and one in Norway. The accidents are summed up in Table 5.3. A more detailed overview is provided in Chapter 7.3.

Table 5.3. Accidents in the North Sea in the period 1999–2009.

No.	Date	Helicopter	Country	Fatalities	Survivors
1	2000-02-15	AS332L	UK	-	-
2	2001-07-12	S-76A	UK	-	-
3	2001-11-10	AS332L	UK	-	-
4	2002-02-28	AS332L	UK	-	-
5	2002-07-16	S-76A	UK	11	0
6	2002-11-05	AS332L2	NO	-	-
7	2006-03-03	AS332L2	UK	-	-
8	2006-12-27	SA365N	UK	7	0
9	2008-02-22	AS332L2	UK	-	-
10	2008-03-09	SA365N	UK	-	-
11	2009-02-18	EC225	UK	-	-
12	2009-04-01	AS332L2	UK	16	0
Sum				**34**	**0**

Note: There was another accident registered 2006-10-13 in the UK sector, but it is still under investigation. This has not been included in the further analysis.

Table 5.4 summarises accident data and traffic volumes in the Norwegian sector, UK sector and the North Sea in total for the periods 1990-1998, 1999-2009 and the merged period 1990-2009. For the period 1990-1998, the numbers are from HSS-2. The 2009 traffic volume for the Norwegian sector is not available, but it is estimated to be the same as in 2008. For the UK sector and the North Sea the traffic volumes are mainly from the OGP, which contains data for the period 1999-2007; traffic volumes for 2008 and 2009 are not available and have been estimated as the same as in 2007. Exact traffic volumes for the UK sector have not been available; these are stipulated as the volumes from the North Sea minus Norway.[6]

Since (smaller) parts of the traffic volumes are estimates, parts of the statistics in Table 5.4 are not completely "clean". This is indicated by *italics* in the table.[7]

Table 5.4. Traffic and accident statistics in offshore helicopter traffic. Numbers in *italics* are estimates.

Parameter	**1990–1998**			**1999–2009**			**1990–2009**		
	NO	UK	North Sea	NO[1)]	UK[2)]	North Sea[3)]	NO	UK	North Sea
Million person flight hours	5.2	10.5	15.7	*7.8*	*6.1*	*13.9*	*13.1*	*16.6*	*29.7*
Number of accidents	4	11	15	1	11	12	5	22	27
Number of fatal accidents	1	2	3	0	3	3	1	5	6
Percentage fatal accidents	0.25	0.18	0.20	0	0.27	0.25	0.20	0.23	0.22
Number of fatalities	12	17	29	0	34	34	12	51	63
Accidents per million person flight hours (accident rate)	0.76	1.05	0.95	0.13	1.81	0.86	0.38	1.33	0.91
Number of fatalities per accident	3.0	1.5	1.9	0	3.1	2.8	2.4	2.3	2.3
Number of fatalities per million person flight hours	**2.3**	**1.6**	**1.8**	***0***	***5.6***	***2.4***	***0.9***	***3.1***	***2.1***
FAR	230	160	180	*0*	*560*	*240*	*90*	*310*	*210*

1) Traffic volume for Norwegian sector in 2009 was stipulated the same as in 2008.
2) Traffic volume for UK sector for 1999-2009 was stipulated the same as for the North Sea minus Norway.
3) Traffic volume for the North Sea in 2008 and 2009 was stipulated the same as in 2007.

6 This gives a somewhat too high number for the UK sector, but the difference is not considerable since the traffic in the remainder of the North Sea (Denmark and the Netherlands) is relatively modest.

7 It is important to establish the best possible overview for the *entire* period 1999-2009 instead of keeping the statistics completely clean for a shorter period. There is, however, nothing which points to a significant change in the traffic numbers in 2008 and 2009, so the estimates are considered to be relatively sound. The use of estimates has no effect on the conclusions drawn based on this material. It is therefore still expedient to use the word "statistics" for all contents of the table.

The number of fatalities in accidents per million person flight hours in the Norwegian sector in the period 1990-1998 was **2.3**. The corresponding number for the period 1999-2009 is **0**, since there have been no accidents with fatalities in the Norwegian sector during this period.

For the North Sea in the period 1999-2009 there are a total of **2.4** fatalities per million person flight hours. This is an increase from the previous period (1990-1998) where **1.8** fatalities per million person flight hours were registered. In the UK sector there are **5.6** fatalities per million person flight hours registered in the period 1999-2009; as compared to **1.6** in the period 1990-1998. Figure 5.5 illustrates the development in number of fatalities per million person flight hours over the three HSS periods for the Norwegian and UK sectors respectively and the North Sea total.

Figure 5.6 shows a five-year moving average for the number of fatalities per million person flight hours for the North Sea in the period 1975-2007. The figure indicates a strong and stable improvement after around 1990, with somewhat more variation toward the end of the period.

The statistics form an essential basis for estimation and discussion of the risk level in helicopter transport, in relation to the goals for helicopter safety given in public report NOU 2002: 17. This is done in Chapter 7. But first, Chapter 6 will present results for quantification of risk as a consequence of expert judgments based in the risk model.

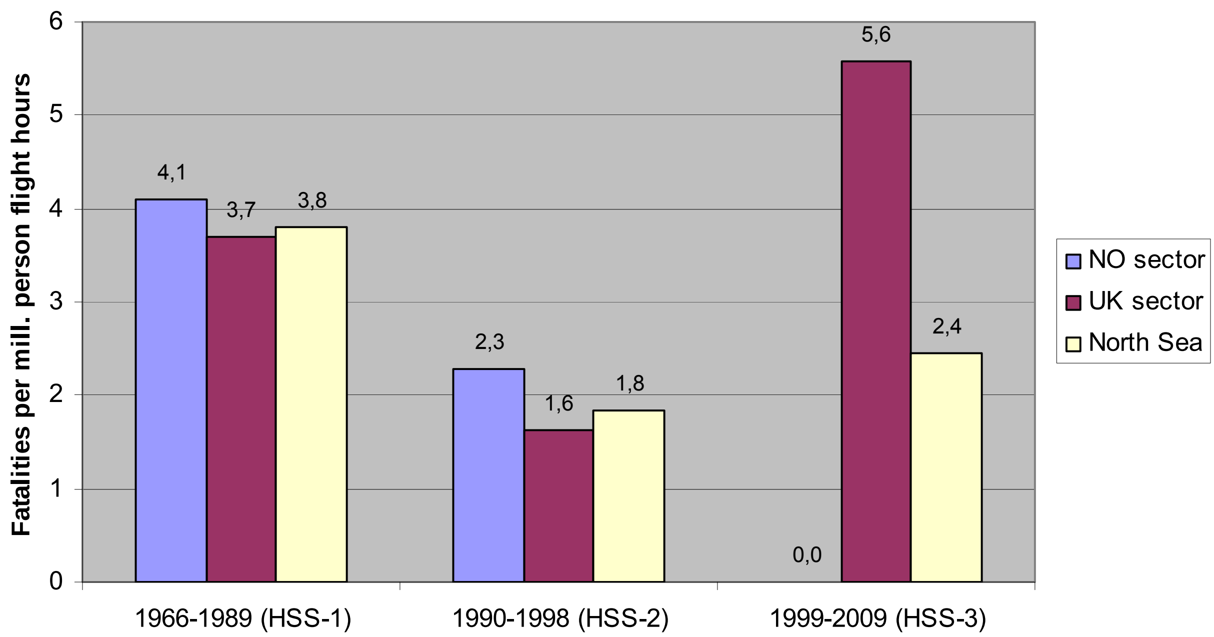

Figure 5.5. Number of fatalities per million person flight hours for Norwegian and UK sector and the North Sea for the periods 1966-1989, 1990-1998 and 1999-2009.

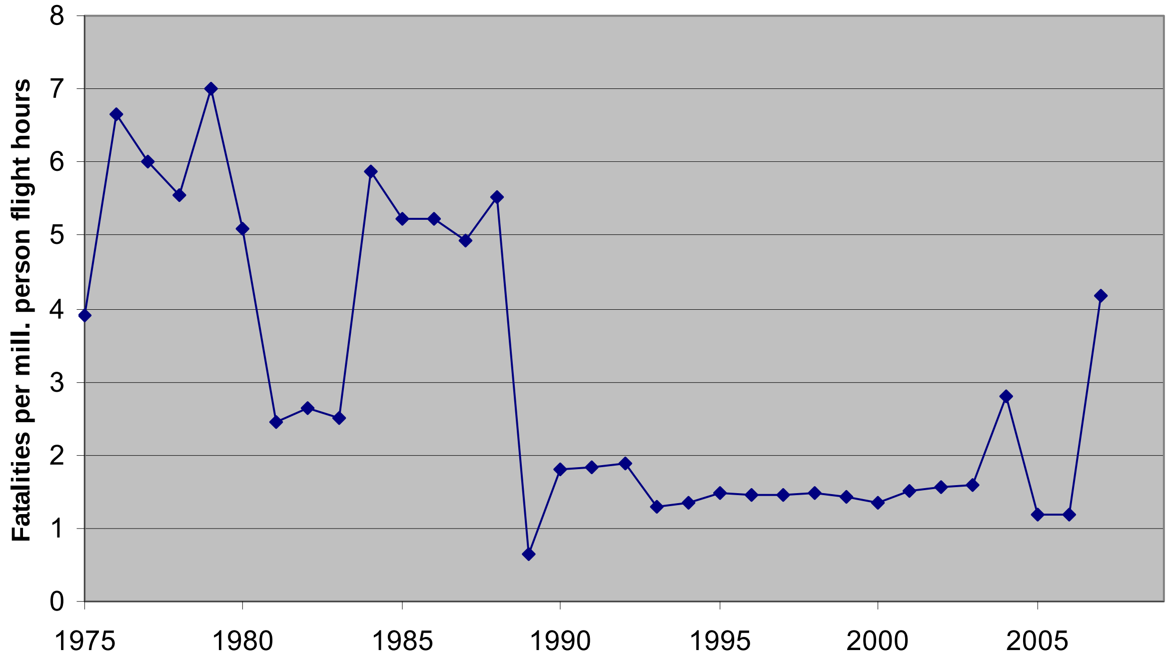

Figure 5.6. Number of fatalities per million person flight hours for the North Sea in the period 1975-2007, five-year moving average.

6. QUANTIFICATION IN THE RISK MODEL

The risk model is used to analyse and quantify the significance of the different risk influencing factors (RIF) as regards accident frequency, accident consequence and risk. Both statistics and expert judgments have been used to quantify the *change* in the risk level. Note that this chapter does not present numeric values for risk, but only quantifies relative contributions to risk and change in risk.

6.1 Contribution to accident frequency from operational RIFs

Table 6.1 shows the relative distribution of contributions to accident frequency from the 11 operational RIFs for frequency (cf. Figure 2.2). The table shows both total contributions and contributions from each of the eight accident categories (A1-A8, Chapter 1.5). The main results (last row and last column) are shown graphically in Figure 6.1 and Figure 6.2.

Table 6.1. Contribution (in per cent) to accident frequency from RIFs and accident categories.

RIF		Accident category								Total
		A1 Heliport	A2 Helideck	A3 System failure	A4 Collision air	A5 Collision terrain	A6 Person inside	A7 Person outside	A8 Other/ unknown	
1.1	Helicopter design	1.7	4.1	18.7	0.0	0.4	0.4	0.7	1.2	**27.2**
1.2	Continuous airworthiness	1.2	4.2	11.4	0.0	0.4	0.4	0.1	0.0	**17.7**
1.3	Operational working conditions	0.1	0.9	0.5	0.0	0.9	0.0	0.0	1.0	**3.4**
1.4	Operational procedures	0.6	5.9	0.0	0.0	1.6	0.0	0.7	1.0	**9.9**
1.5	Pilot competence	0.9	6.5	2.7	0.2	3.1	0.0	1.1	0.5	**15.0**
1.6	Passenger behaviour	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	**0.3**
1.7	Heliport	0.3	0.0	0.0	0.0	0.0	0.0	0.6	0.7	**1.6**
1.8	Helideck	0.0	9.0	0.0	0.0	0.0	0.0	0.6	0.7	**10.3**
1.9	ATS/ANS	0.5	0.0	0.0	0.4	1.1	0.0	0.0	0.0	**2.0**
1.10	Weather conditions and climate	1.2	2.3	4.8	0.0	1.1	0.0	1.4	0.6	**11.3**
1.11	Other activity	0.1	0.0	0.0	0.1	1.0	0.0	0.0	0.0	**1.2**
Total		**6.7**	**32.9**	**38.1**	**0.7**	**9.7**	**0.8**	**5.4**	**5.7**	**100**

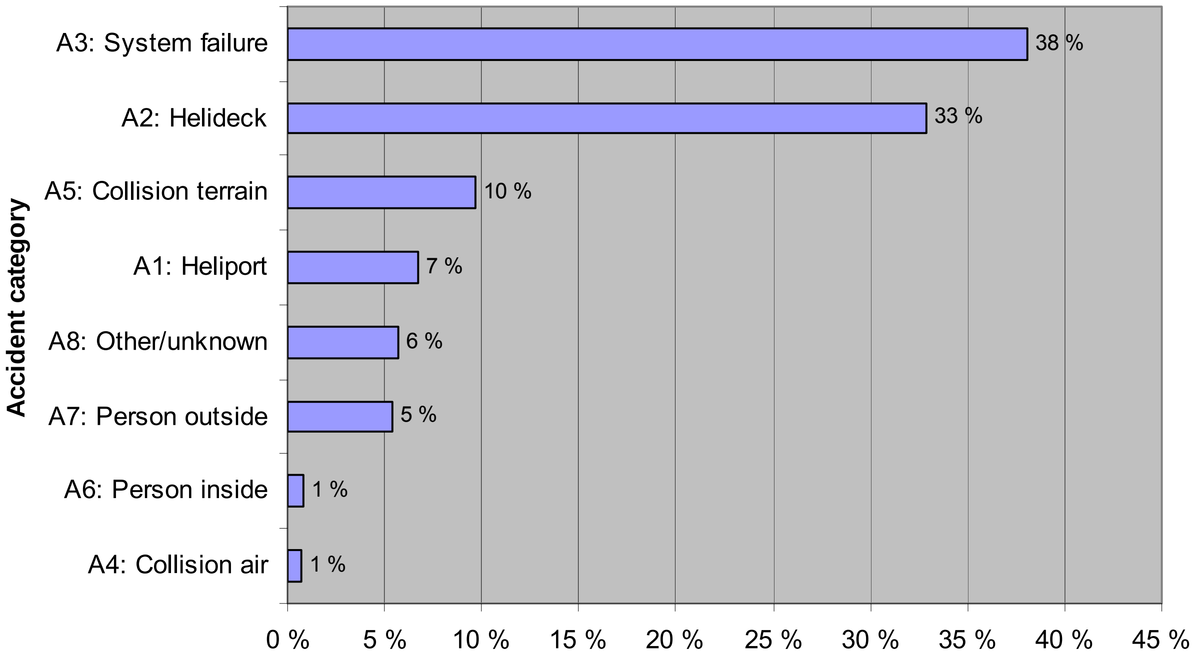

Figure 6.1. Contribution to accident frequency from the eight accident categories.

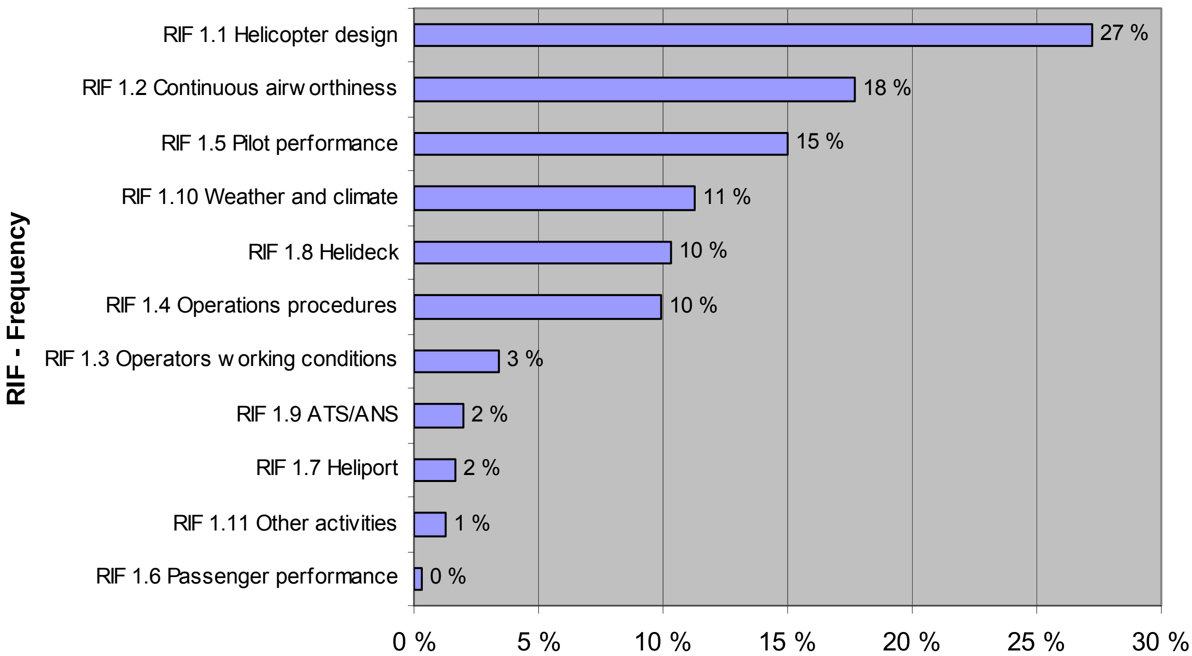

Figure 6.2. Contribution to accident frequency from the 11 operational RIFs for frequency.

Figure 6.1 shows that the two accident categories which contribute the most to accident frequency are A3 Critical system failure during flight and A2 Helideck. Figure 6.2 shows that the RIFs that contribute most to accident frequency are RIF 1.1 Helicopter design and RIF 1.2 Continuous airworthiness.

6.2 Risk contribution from operational RIFs for frequency

The number of fatalities in a helicopter accident is strongly dependent on the accident category, but also the circumstances surrounding the accident. Figure 6.3 shows expected (average) number of fatalities (pilots and passengers) per accident for the eight accident categories. The results are based on expert judgments concerning two aspects (see details in the appendices):

1. Per cent of accidents which are fatal
2. Per cent fatalities in fatal accidents, assuming 17 persons onboard.

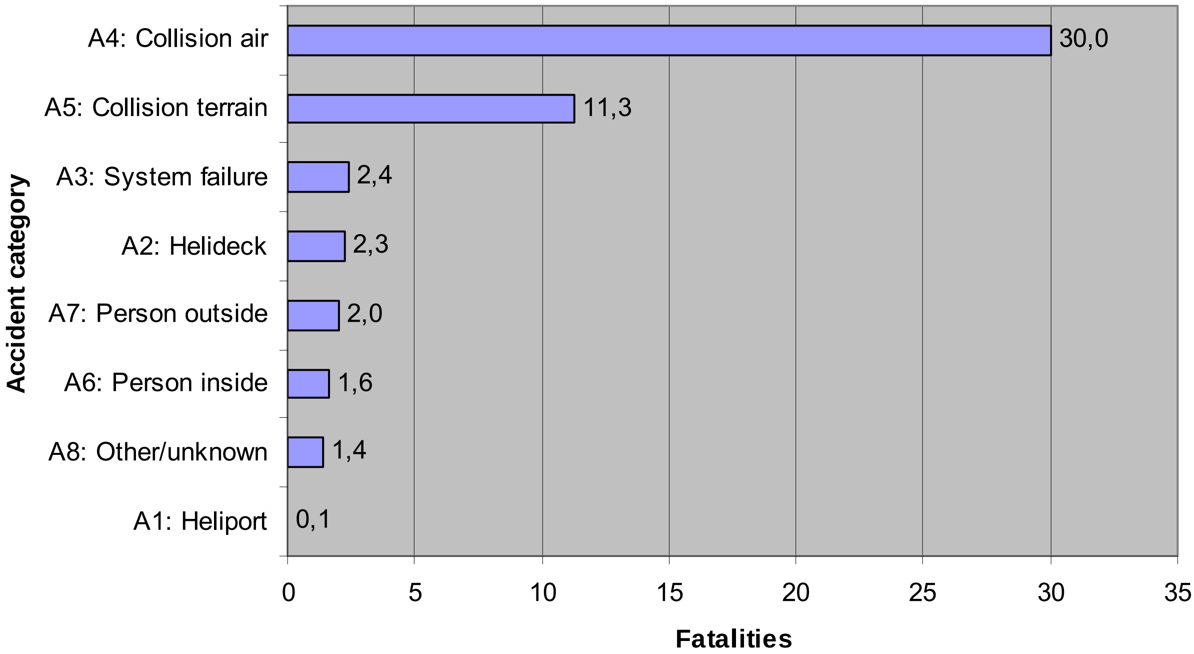

Figure 6.3. Expected number of fatalities per accident category (with 17 persons onboard).

Figure 6.3 shows that the two accident categories with the most fatalities are when the helicopter collides, either with another aircraft (A4) or with the surroundings (A5). The most severe accident category is clearly A4 Collision with another aircraft, which assumes that everyone on board dies. In this category, fatalities in two helicopters are taken into consideration.[8]

By combining the results in Figure 6.3 with the distribution of frequency for the different accident categories, the average number of fatalities (in any accident) is calculated at **3.2**. This result is used in the discussion of the risk level in Chapter 7.1.1.

Figure 6.1 above showed the contributions to accident *frequency* from the eight accident categories. Figure 6.4 gives the accident categories' relative contributions to accident *risk* (combination of frequency and consequence). The results are achieved by weighting the frequency contributions with the number of fatalities in each accident category.

The results show that the three most critical accident categories are A5 Collision with terrain/sea/obstacle, A3 Critical system failure during flight and A2 Helideck. Furthermore, we

[8] In previous periods, the risk was greatest for collision between helicopters and military planes on exercise. Today, two commercial helicopters colliding presumably poses the greatest risk.

can see that the most serious category in regards to number of fatalities, A4 Collision with another aircraft, has a modest risk contribution because the probability of this type of accident is low.

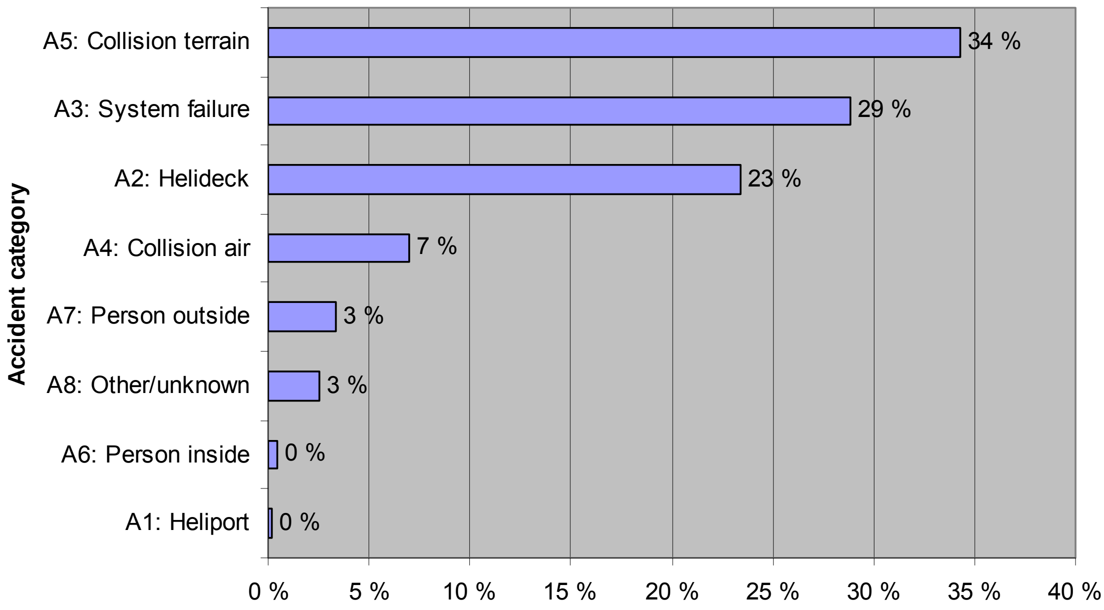

Figure 6.4. Risk contribution from the eight accident categories.

Figure 6.2 above showed the contributions to accident *frequency* from the 11 operational RIFs. Figure 6.5 provides the same RIF's relative contributions to accident *risk*. The results are achieved by weighting the frequency contributions with the number of fatalities in each accident category. We can see that the two RIFs which contribute most to risk are RIF 1.5 Pilots' competence and RIF 1.1 Helicopter design.

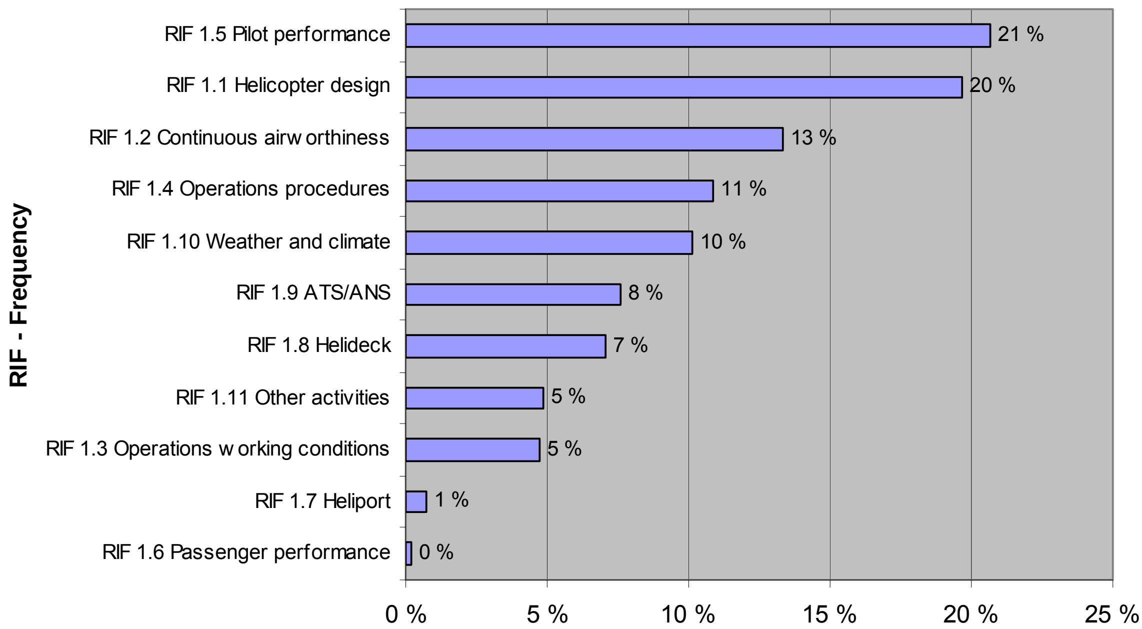

Figure 6.5. Risk contribution from the 11 operational RIFs for frequency.

6.3 The importance of operational RIFs for consequence

The operational RIFs for consequence are assigned a value for each accident category which reflects to what degree the RIF will influence the number of fatalities in an accident. The scale goes from 0 (not important) to 10 (very important), and the results are given in Table 6.2. The last column provides a total value for each RIF, and is an average weighted with the risk contribution from the different accident categories (from Figure 6.4 above).

Table 6.2. Relative importance (0–10) of operational RIFs for consequence.

RIF		Accident category								Total
		A1 Heliport	**A2** Helideck	**A3** System failure	**A4** Collision air	**A5** Collision terrain	**A6** Person inside	**A7** Person outside	**A8** Other/ unknown	
1.1	Impact absorption	9	10	8	1	9	3	0	0	**7.8**
1.2	Stability at sea	1	9	10	1	9	5	0	0	**8.1**
1.3	Cabin safety	8	9	8	2	8	9	0	0	**7.5**
1.4	Survival equipment	2	7	9	2	8	6	0	0	**7.0**
1.5	Emergency location equipment	1	4	9	2	8	3	0	0	**6.5**
1.6	Pilot's competence	5	8	10	3	7	10	8	0	**7.8**
1.7	Passenger's competence	5	9	9	2	6	9	8	0	**7.1**
1.8	Emergency preparedness procedures	8	8	9	2	7	8	5	0	**7.4**
1.9	Emergency preparedness heliport	9	0	3	2	4	4	6	0	**2.5**
1.10	Emergency preparedness helideck	0	9	4	2	3	4	7	0	**4.6**
1.11	Helideck design	0	8	3	1	1	3	6	0	**3.4**
1.12	Search and rescue (SAR) preparedness	3	9	9	4	9	5	4	0	**8.4**
1.13	Organisation, coordination	6	7	9	4	8	4	4	0	**7.8**
1.14	Weather/climate, other activity	1	6	9	4	8	4	3	0	**7.1**
Total		58	104	110	33	95	78	50	0	**92.9**

The absolute values of the scores are of lesser interest, it is the relative distribution between RIFs which is important. The total score for the 14 RIFs is shown in Figure 6.6, but the scores are standardised to add up to 100 to provide results analogue that can be compared to the operational RIFs for frequency. The results are then comparable, and one can talk about risk "contributions" from the RIFs for consequence.

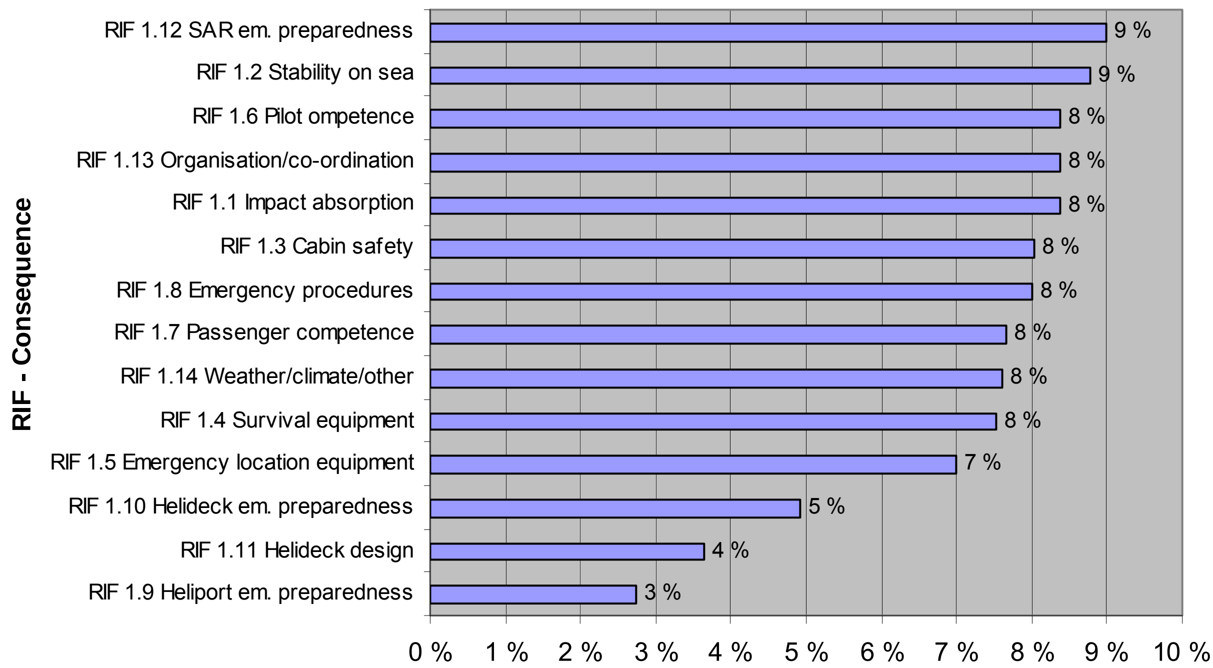

Figure 6.6. ”Risk contributions” from operational RIFs for consequence.

Figure 6.6 shows a remarkably small variation between the RIFs. Conditions related to heliport/airport and helideck (RIF 1.10, 1.11 and 1.9) appear to be less important than the other RIFs. This impression is amplified by grouping the operational RIFs in the four “super RIFs” (Level 0 in Figure 2.3) as shown in Figure 6.7. Furthermore, we can see that the RIF group RIF 0.1 Crashworthiness appears to be most important with almost 40 per cent of the total.

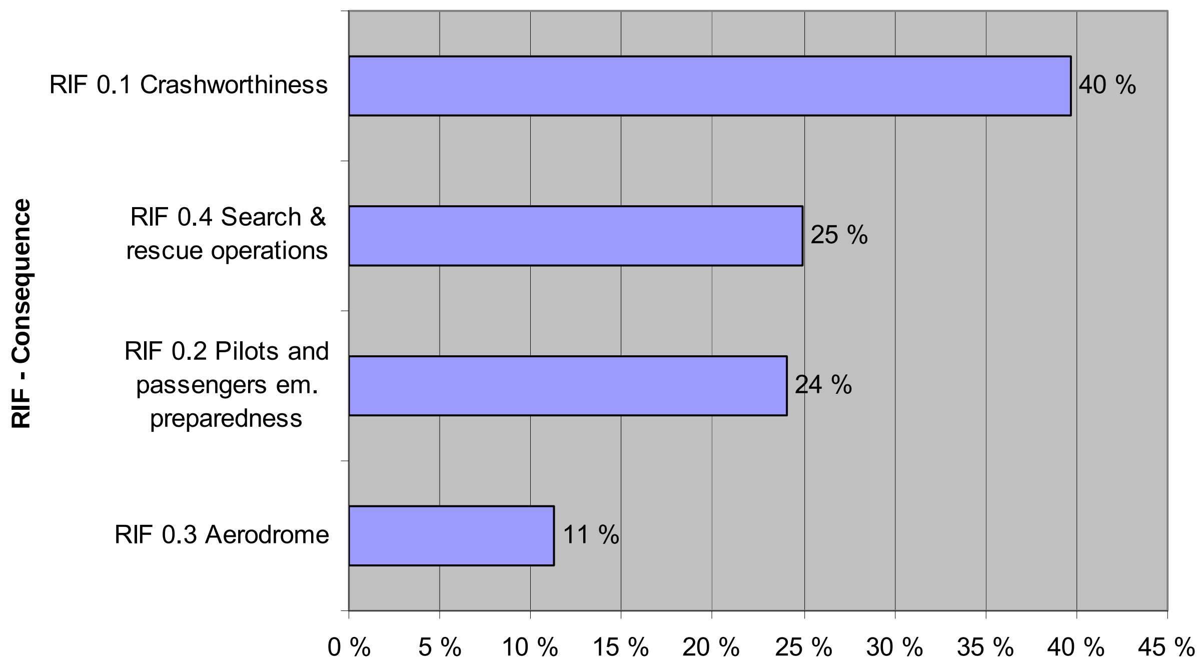

Figure 6.7. ”Risk contributions” from operational RIFs for consequence.

It must be emphasised that the scores do not imply anything about the contribution to risk from the RIFs in a direct sense. A high score on an RIF does not necessarily mean that a corresponding per cent of risk has its *cause* in this RIF, which is the case for the frequency RIFs. But “importance” is understood more as a *potential* for risk influence. You can thus view the score as a “safety contribution” at least as much as a “risk contribution”.

Reciprocal importance of the RIFs (e.g. scores) will be relatively stable over time and will not be influenced much by potential measures that are implemented within the different RIFs. On the other hand, measures can have an effect on the *quality* of the RIFs. “Quality” means a condition in the form of equipment, procedures, training, awareness, etc. A *high* score means that if the quality of an RIF is good, the RIF will contribute significantly to prevent fatalities in accidents. If the quality of an RIF is low, it means that a significant number of fatalities could have been prevented by improving quality. A *low* score on an RIF means however, that the quality of an RIF will not have much impact on the number of fatalities in accidents. Potential measures will therefore have the greatest effect within RIFs with a high score and low quality.

It is precisely by assessing the effect of measures that it is most meaningful to interpret the importance of the RIFs as risk contributors. A measure that provides a certain improvement of an RIF will reduce the risk proportionally with the importance of the RIF.

6.4 The importance of organisational RIFs

The organisational RIFs that can influence risk through the operational RIFs are found on Level 2 in the influence diagram. Five types of organisations are relevant both in the frequency and consequence diagram. There are five types which are relevant. For frequency there are:

RIF 2.1 Helicopter manufacturers/Design organisations
RIF 2.2 Helicopter operators/Maintenance organisations
RIF 2.3 Heliport/airport and helideck operators
RIF 2.4 ATS/ANS service organisations
RIF 2.5 Other organisations

The same organisations are relevant on the consequence side, with the exception that RIF 2.4 ATS/ANS service organisations is replaced by RIF 2.4 Search and rescue service. (ATS/ANS personnel can be incorporated into the SAR service by moving to the relevant Joint Rescue Coordination Centre and assisting in connection with incidents.)

The influence diagrams illustrate which organisational RIFs influence which operational RIFs (arrows from Level 2 to Level 1 in Figure 2.2 and Figure 2.3). Expert judgments have been carried out to describe and quantify the degree of influence from the organisational level to the operational level. Each arrow between the levels has been assigned a value on the scale from 1–10 for how strong an influence the relevant organisation has on the relevant operational RIF. The number indicates an overall assessment for all the accident categories. The following scale is used:

1 – The organisation has *little* effect on the RIF
5 – The organisation has *some* effect on the RIF
10 – The organisation has *considerable* effect on the RIF

Results of the expert judgments for frequency and consequence are shown in Figure 6.8 and Figure 6.9 respectively. The degree of influence is also indicated by the thickness of the arrows.

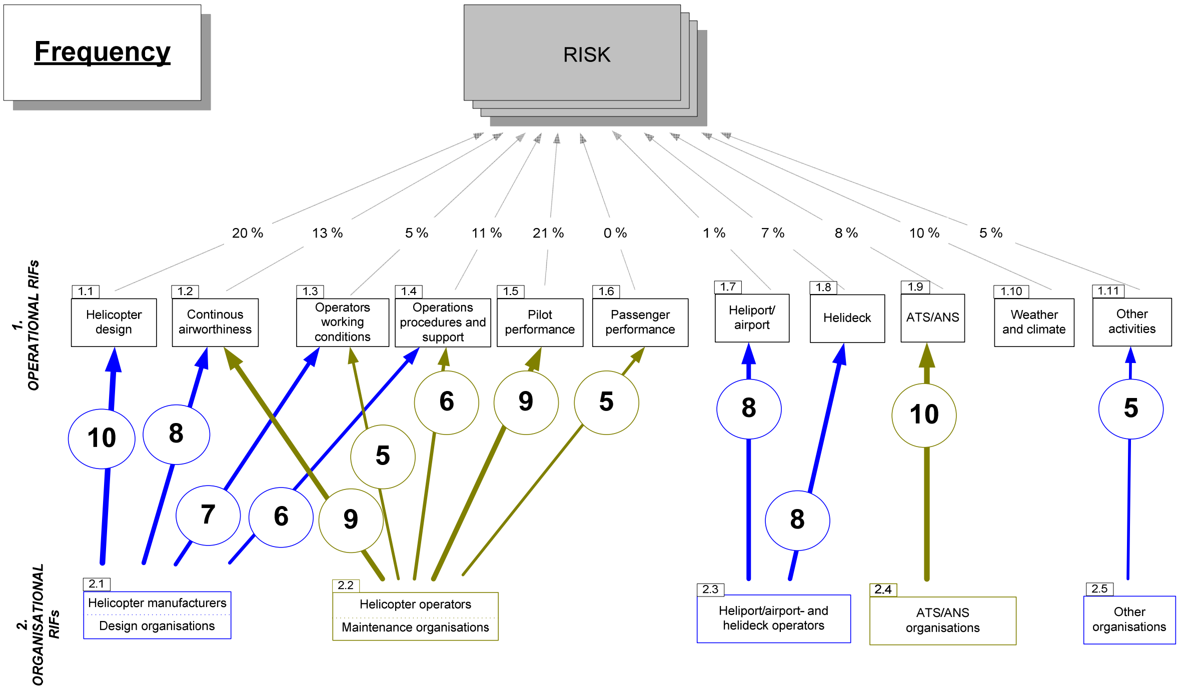

Figure 6.8. The effect of organisational RIFs on operational RIFs for frequency. (The thickness of the arrows reflects the scope of the effect. Two colours are used to improve readability.)

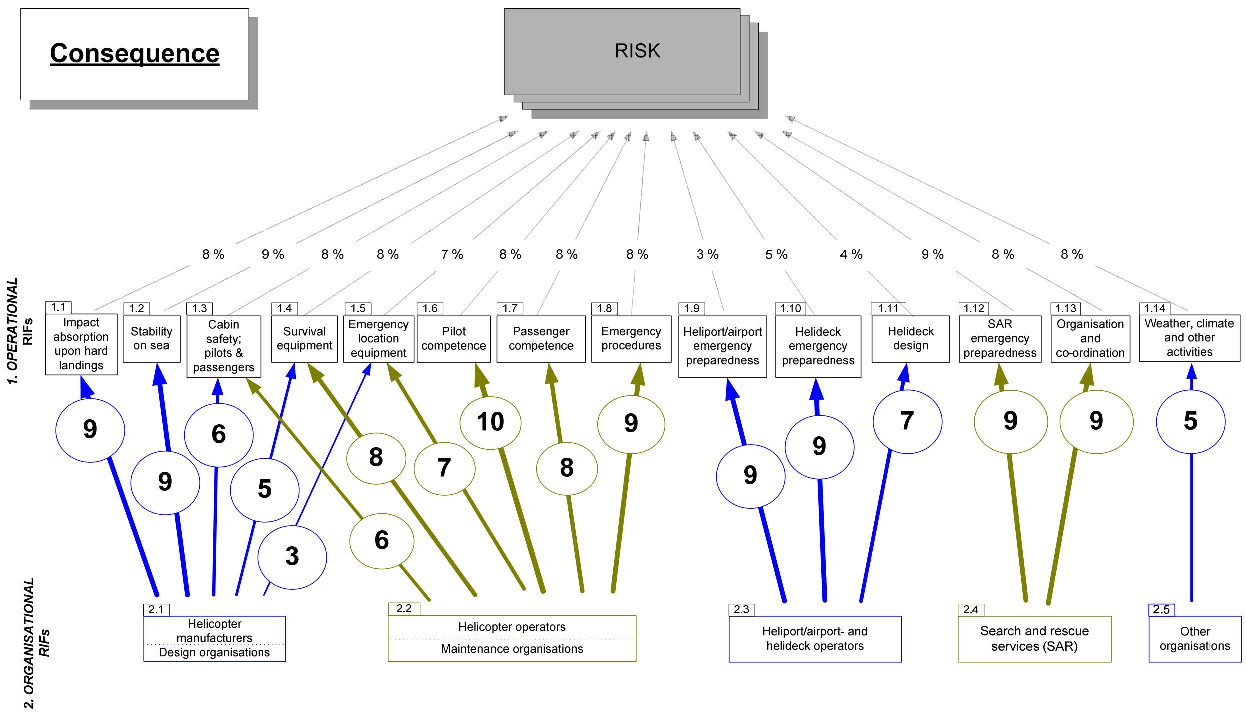

Figure 6.9. The impact of organisational RIFs on operational RIFs for consequence. (The thickness of the arrows reflects the scope of the impact. Two colours are used to improve readability.)

The importance of organisational RIFs in relation to risk is quantified by combining risk contributions from operational RIFs (Level 1) with the effect of the organisational RIFs. For example, the importance of RIF 2.1 Helicopter manufacturers/Design organisations for frequency is calculated in the following way, in relation to RIFs for frequency (cf. Figure 6.5):

$$\text{Importance of RIF 2.1} = 10 \cdot 20\% + 8 \cdot 13\% + 7 \cdot 5\% + 6 \cdot 11\% = 4.0\,.$$

Figure 6.10 shows the relative importance of the organisational RIFs with regard to influencing the risk (through the operational RIFs for frequency and consequence). The two organisational RIFs that have the largest influence are RIF 2.1 Helicopter manufacturers/Design organisations and RIF 2.2 Helicopter operators/Maintenance organisations, both on the frequency and consequence side.

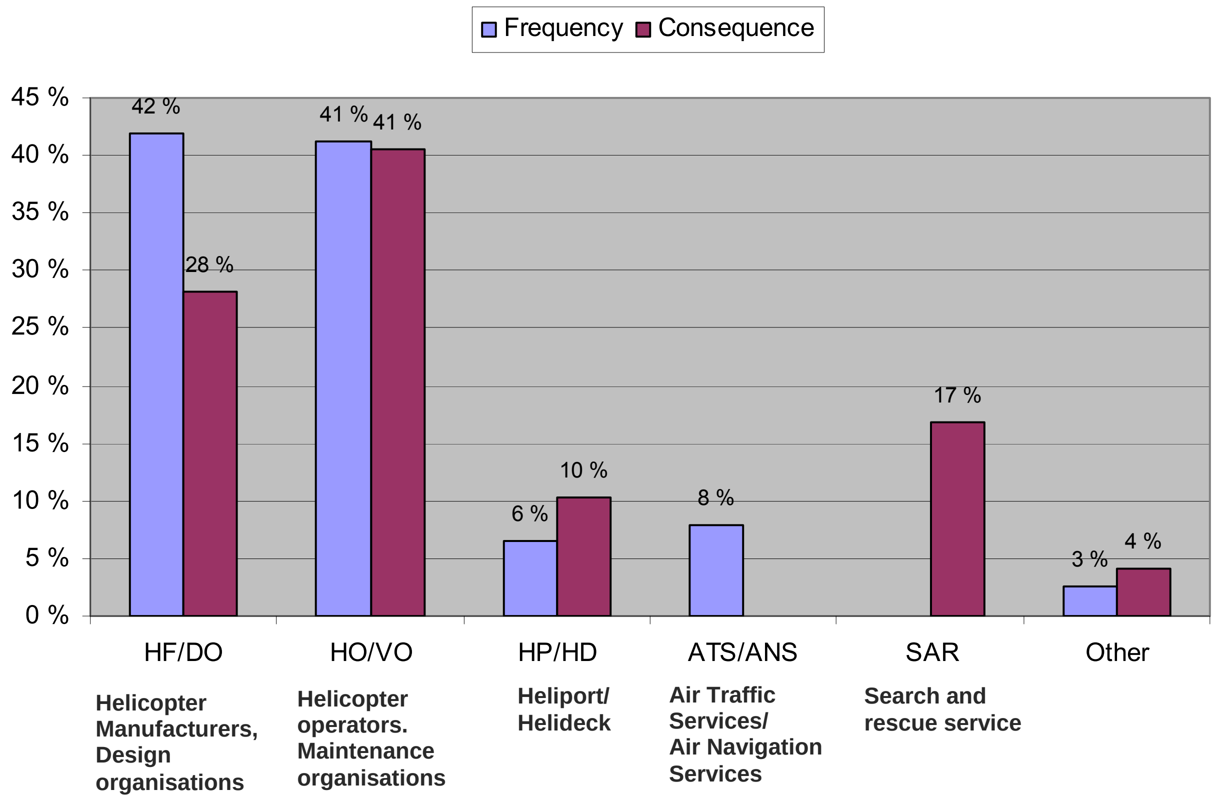

Figure 6.10. The importance of organisational RIFs as regards influence on risk (through operational RIFs for frequency and consequence, respectively).

6.5 Changes in risk 1999–2009 and 2010–2019

Table 6.3 sums up the following information for the periods 1999–2009 and 2010–2019:

- estimated changes in contribution to accident frequency from the 11 operational RIFs for *frequency* (upper half of the table)
- estimated changes in “contribution” to accident consequence from the 14 operational RIFs for *consequence* (lower half of the table).

Table 6.3. Changes in contribution to accident frequency (upper half) and consequence (lower half) from operational RIFs for the periods 1999-2009 and 2010-2019. (Negative sign means a reduction of risk)

RIF category		Operational RIF	1999–2009	2010–2019
Frequency	Aircraft technical dependability	1.1 Helicopter design	-10 %	-30 %
		1.2 Continuous airworthiness	-11 %	-30 %
	Aircraft operational dependability	1.3 Operational working conditions	-14 %	-35 %
		1.4 Operational procedures	-10 %	-15 %
		1.5 Pilots' performance	-10 %	-15 %
		1.6 Passengers' performance	0 %	-5 %
	Aerodrome and Air traffic management	1.7 Heliport	0 %	-2 %
		1.8 Helideck	-28 %	-10 %
		1.9 ATS/ANS	-20 %	-30 %
	Other conditions	1.10 Weather and climate	0 %	5 %
		1.11 Other activities	-12 %	10 %
	Total		**-11 %**	**-19 %**
Consequence	Crash-worthiness	1.1 Impact absorption	-17 %	-14 %
		1.2 Stability at sea	-20 %	-26 %
		1.3 Cabin safety	-14 %	-15 %
		1.4 Survival equipment	-13 %	-11 %
		1.5 Emergency location equipment	-13 %	-12 %
	Pilots' and passengers' emergency preparedness	1.6 Pilots' competence	-11 %	-10 %
		1.7 Passengers' competence	-9 %	-5 %
		1.8 Emergency procedures	-5 %	-5 %
	Aerodrome	1.9 Emergency preparedness heliport	-5 %	-1 %
		1.10 Emergency preparedness helideck	-4 %	-3 %
		1.11 Helideck design	-11 %	-8 %
	Search and rescue operations	1.12 Emergency preparedness SAR	-16 %	-14 %
		1.13 Organisation, coordination	6 %	7 %
		1.14 Weather/climate, other activities	0 %	0 %
	Total		**-10 %**	**-9 %**

Based on these results we can calculate the change of risk *within* the two periods:

- Estimated reduction in risk for the period 1999–2009 is **20%**
- Estimated reduction in risk for the period 2010–2019 is **27%**

The risk reduction in the *previous* period (1990-1998) was estimated at **12%** in HSS-2. Based on the per cent change within the three ten-year periods, we can calculate the change in average risk levels *between* ten-year periods:

- Estimated reduction in risk between the periods 1990–1998 and 1999–2009 is **16%**
- Estimated reduction in risk between the periods 1999–2009 and 2010–2019 is **23%**

These results are illustrated in Figure 6.11. A detailed overview of the most important contributors to risk reduction is provided in Chapters 11.5 and 11.6.

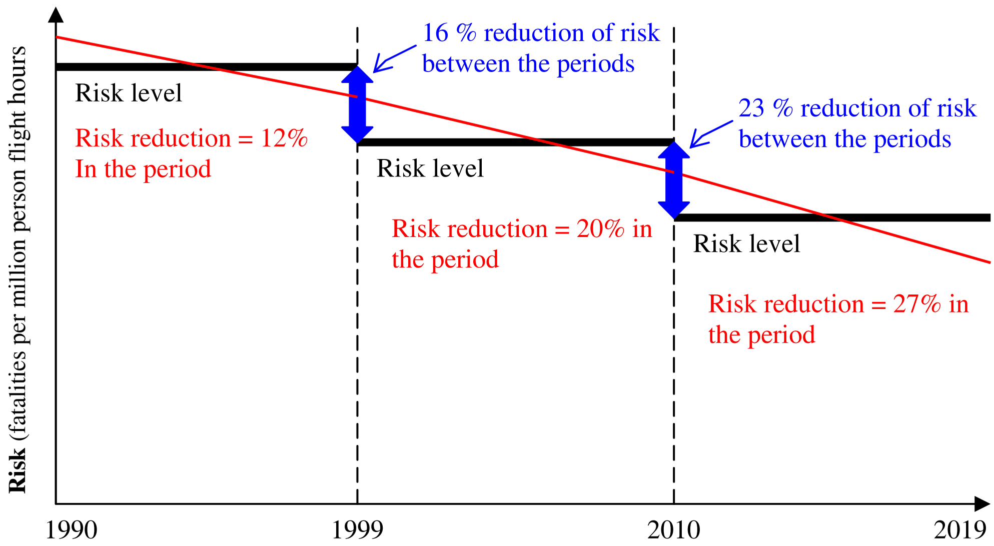

Figure 6.11. Estimated changes in risk over three ten-year periods.

7. ESTIMATED RISK LEVEL 1999–2009

This chapter estimates a risk level for the Norwegian Shelf in the period 1999-2009. In Chapter 7.1 we first find an estimate based primarily on the statistics summed up in Table 5.4. Then we discuss the robustness of this estimate in Chapter 7.2 Chapter 7.3 provides an analysis of the accidents on the UK Shelf and Canada in the period to assess to what degree these should influence the estimate for the Norwegian Shelf. In Chapter 7.4 a final risk level estimate is presented.

7.1 An introductory estimate for the current risk level

In this study, risk is measured in the number of fatalities per million person flight hours. The *observed* number of fatalities per million person flight hours in the Norwegian sector in the period 1999-2009 is zero, and therefore has little value as an estimate for the risk level in the period. However, we can see that a corresponding estimate can be found via the accident rate:

> Number of fatalities per million person flight hours =
> (Number of accidents per million person flight hours) x (Number of fatalities per accident).

For the Norwegian Shelf during 1999-2009, the first of the two factors (accident rate) is 0.13. The other factor, number of fatalities per accident is 0 (based on one accident). We can still obtain a better estimate for number of fatalities per accident through an alternative reasoning based on a larger base of data material. This is done in the following.

7.1.1. Number of fatalities per accident

Table 5.4 provides a basis for estimating the number of fatalities per accident (the estimates vary from 0 to 3.1). In a statistical analysis, it is presumed that these values are estimated for a theoretical “underlying” value, denoted as “*expected* number of fatalities per accident”. The theoretical value can be different in the two ten-year periods, and may vary between Norway and the UK. We assume, however, that the whole of the material can be used to estimate the expected value which applies to Norway from 1999-2009 (where there is only one accident with 0 fatalities).

We see that by including *all* of the data material (the North Sea) the value is 1.9 for the period 1990-1998 and 2.8 for the period 1999-2009; and then **2.3** in total for 1990-2009. For the *Norwegian* Shelf alone, the values are 3.0 for 1990-1998 and 0 for 1999-2009, and **2.4** in total for 1990-2009.

The number of persons onboard a helicopter will vary, so using “*per cent* fatalities in the fatal accidents can provide a more credible result than by only looking the “number of fatalities”. This is a relevant point when we observe that both the one fatal accident on the Norwegian Shelf (1997) and the three fatal accidents in the UK sector in the previous period (1999-2009) resulted in *everyone* onboard dying. An alternative reasoning can now be based on

> Number of fatalities per accident =
> (Per cent fatal accidents) x (Per cent fatalities in fatal accidents).

On the Norwegian Shelf we have, based on the period 1990-2009, the following estimate:

Per cent fatal accidents = 1/5 = 0.2.

Furthermore, if we assume that almost everyone perishes if there is a fatal accident, we have roughly:

Number of fatalities in a fatal accident = 15 (e.g. almost everyone onboard)[9].

This then provides the following alternative estimate:

Number of fatalities per accident = 0.2 x 15 = **3.0.**

This estimate is considered to be conservative (high), as it is based on the average of 15 fatalities in every fatal accident. But we can see that this number concurs with the estimate based on statistics for the Norwegian Shelf in the period 1990-1998. Therefore, we use the estimate 3.0 for the Norwegian Shelf for *both* ten-year periods. This seems sensible, because data will probably not provide a basis for claiming that the number of fatalities per accident has been reduced.

In the expert judgments based on the risk model, the number of fatalities on the Norwegian Shelf in 1999-2009 – independent of accident category – is estimated at **3.2** (based on 17 onboard, see Chapter 6.2). The *observed* number of fatalities per accident in the whole period 1990-2009 is, as shown, considerably lower than this. The conclusion is therefore that, in total, it is reasonable to use the estimate 3.0 for average number of fatalities per accident.

7.1.2. Number of fatalities per million person flight hours

Based on the discussion above, we have the following estimate for personal risk during helicopter transport on the Norwegian Shelf 1999-2009:

The number of fatalities per million person flight hours = 0.13 x 3.0 ≈ **0.4.**

We regard this estimate as a "best estimate" for the Norwegian Shelf in 1999-2009. The estimate represents a substantial reduction in risk (83 per cent) in contrast with the estimate **2.3** for the period 1990-1998. Even though the reduction is considerable, it is not statistically significant.

7.2. Discussion of risk estimate

7.2.1. Statistical significance

The statistics provide an indication of a risk reduction on the Norwegian Shelf from the period 1990-1998 to 1999-2009. The "best estimate" for risk, (either measured as an accident rate or FAR-value) will, for the period 1999-2009, be just one sixth of the estimated risk for 1990-1998 (FAR, in particular, has an estimated reduction from 230 to 40). Nevertheless, the data material is so small that this result is not statistically significant. *Statistically* speaking, there are therefore no grounds for claiming that the risk was reduced in the last period.

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[9] The average number of people onboard in the period 1999-2009 was 16.3.

Furthermore, we can conduct a thought experiment that estimates risk in the *next* ten-year period (2010-2019) will remain unchanged in relation to the current ten-year period, (e.g. that there is one new accident without fatalities in the next ten-year period as well). It will still not be a statistically significant risk improvement in relation to the first ten-year period. This illustrates what is needed to claim that there is a significant improvement by only looking at statistics.

7.2.2. Sensitivity in relation to individual accidents

When the statistical basis for estimating the risk level is thin, the estimate will be very sensitive to additions or removal of individual accidents. The periodization you choose will also be vital for the same reason, since moving the period boundaries easily leads to individual accidents changing periods. The uncertainty in the risk estimate arrived at is therefore very large. In Table 7.1, some examples are provided for different risk estimates which are all relevant – more or less – in the estimation of risk level on the Norwegian Shelf 1999-2009. The estimates are illustrated in Figure 7.1.

Table 7.1. Examples of alternative risk estimates based on accident statistics. All numbers are for the Norwegian Shelf (NO) and the period 1999-2009, if not otherwise stated.

Estimate		Description	Value
a)	NO	Statistical risk	0
b)	NO est	Risk estimate based on per cent fatal accidents and per cent fatalities in fatal accidents, cf. Chapter 7.1	0,4
c)	NO 90–98	Statistical risk in the previous ten-year period (1990-1998). This estimate is based on the Norne accident, and would be *zero* had this accident not occurred.	2,3
d)	NO 90–09	Statistical risk in the two ten-year periods combined (1990-2009)	0,9
e)	NO+Norne	Statistical risk if there had been another Norne accident (with 12 fatalities) in the period	1,5
f)	North Sea	Statistical risk for the North Sea	2,4
g)	UK	Statistical risk for the UK sector	5,6
h)	UK 99–08	Statistical risk for the UK sector excluding 2009	3,1

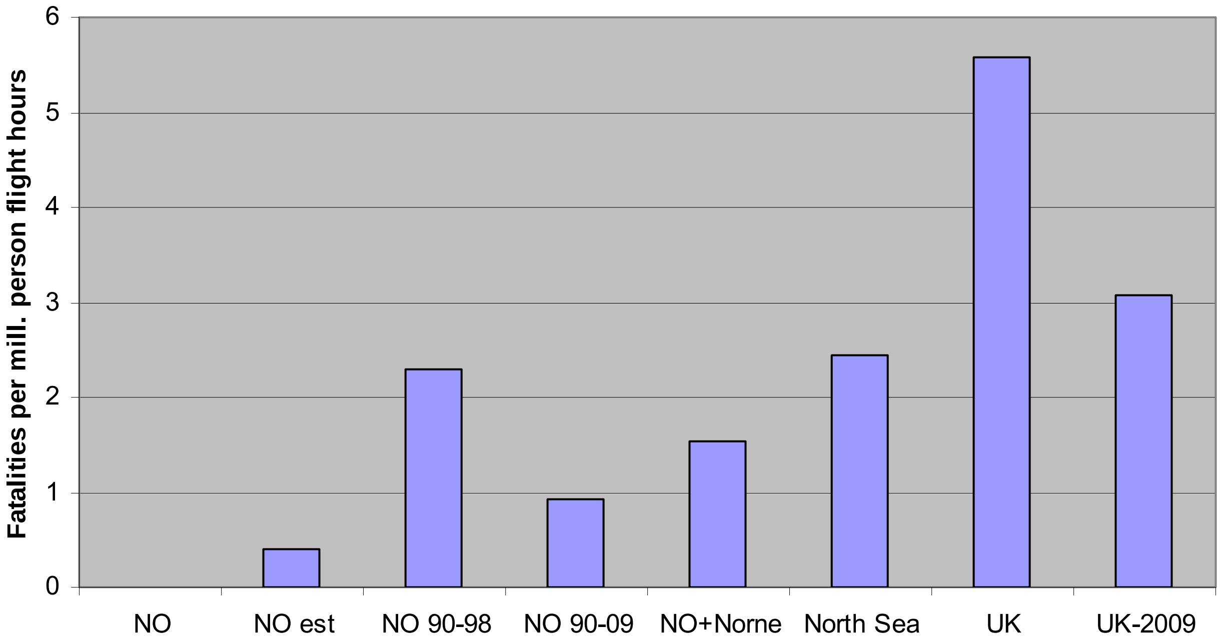

Figure 7.1. Examples of alternative risk estimates for the Norwegian Shelf 1999-2009 based on accident statistics (Table 7.1).

We can see that the span of estimates is considerable, from 0 (statistical risk for the Norwegian sector 1990-2009) to 5.6 (statistical risk for the UK sector 1999-2009).

A concrete example of the impact that an individual accident can have, is the Norne accident in 1997 where there were 12 fatalities. If this accident had occurred two years later, in 1999, it would have fallen within the period studied in HSS-3. The statistical risk for the Norwegian Shelf 1999-2009 would then have *increased* from 0 to 1.5, and the risk would have *decreased* from 2.3 to 0 in the previous period (1990-1998). In other words, the picture of statistical risk development in the two periods would have been exactly opposite.

7.3. Accidents on the UK and Canadian Shelf in the period 1999–2009

Accidents in the United Kingdom (UK) and Canada (CA) in the period 1999-2009 with helicopters also used in Norway, and under comparable conditions to Norwegian conditions, raises the question of to which degree these accidents could have occurred in Norway.

7.3.1. Overview of the accidents

Table 7.2 lists the accidents that are registered for offshore helicopter transport in the North Sea. We have also included one accident in Canada in the period 1999-2009; because it occurred at about the same time as two other helicopter accidents in the spring of 2009. Canada is also relevant because the same helicopters are used as in the North Sea and weather conditions are similar to the North Sea. For each accident, the course of events, contributing factors, and extent of damage are described in brief, based on excerpts from investigation reports and conversations with pilots and technicians. The final investigation reports are available for all accidents, with the exception of the three accidents that occurred in the spring of 2009.

The accidents are classified in relation to the accident categories U1-U8, which are used in the risk model. An assessment has also been conducted of which RIFs for frequency are the most important factors for each accident. SINTEF has based its assessments on expert judgments in regard to the accident's relevance for the Norwegian sector in the same period (1999-2009) and for the next period. For the coming period, consideration has also been given to implementation of already planned measures that will contribute to reduce the risk of similar accidents occurring in the Norwegian sector. For each accident we have asked the following questions:

A. Could the accident have occurred in the Norwegian sector in the same period (1999–2009)? (Yes/No)
B. Could the accident have occurred in the Norwegian sector today or in the future (2010–2019)? (Yes/No)

The comments section in Table 7.2 explains why/why not the accident could have occurred in the Norwegian sector at the same time and/or in the future, what the industry could potentially have learned from the accident, and potentially which barriers are in place in the Norwegian sector which would reduce the probability of/or limit the consequence of a similar accident.

Table 7.2. Overview over helicopter accidents in the North Sea (and Canada) in the period 1999-2009.

No	Date	Place	Heli-copter	Course of events	Contributing causal factors	Extent of loss/damage	RIF	Acc. Cat.	Q. A	Q. B	Comments (A/B)
1	15/2-00	UK	AS332L	Lightning strike. No errors in instruments or other systems	The captain saw a cumulus cloud, contacted Scatsta and received a message that there was no lightning activity at that time.	No fatalities	1.10	A8	Yes	Yes	Lightning strike
2	12/7-01	UK	S-76A	The captain decided that the mate should turn the helicopter 90 degrees so it would be easier for the passengers to embark. After the helicopter had been turned, the pilot was not paying attention and pulled the wrong lever (not the parking brake, as he should have done). The helicopter was lifted rapidly and the pilot pulled the lever back at once. The helicopter landed tail first.	Human factors. Unfortunate placement of lever for parking brake.	No fatalities	1.5 1.3	A7	Yes	**No**	Human factors and cockpit HMI design (especially for S-76). Would most likely not happen today because of new design and the work with CRM (*Crew Resource Management)*
3	10/11-01	UK	AS332L	The helicopter on the drill ship West Navion fills fuel while the rotors are running. The captain remains onboard while the mate assists the helideck personnel with the disembarking. Five minutes after landing, the ship's DP system changes to MANUAL. The ship starts rotating and the helicopter tips over.	The rig's DP system changes to MANUAL and the ship starts to rotate. Big change in relative wind gave strong aerodynamic power which had an effect on the helicopter and made it fall easier. In addition the ship had "roll" movements. Lack of procedures: -for the ship crew to transfer change in emergency preparedness status to the pilots -for the pilots onboard, if the control of the ship is lost/weakened	One person seriously injured (the mate, who was the only person outside the helicopter on the helideck was seriously injured by flying parts from the helicopter's main rotor, which had been damaged in connection with the collision with the helideck	1.8	A7	Yes	Yes	Somewhat better procedures today, but similar incidents could happen again. A system has been developed which measures "pitch" , "roll" and "heave" on floating helidecks and provides a *Motion Severity Index* (MSI); an indicator of movement on the helideck.
4	28/2-02	UK	AS332L	Bad weather (waterspout). During landing, the tips of the tail rotor blades touched the tail pylon.	Waterspout/tornado not visible to the deck personnel. Even though it was relatively far away and the pilots avoided the bad weather, there was severe turbulence.	No fatalities	1.10	A2	Yes	Yes	Could happen anytime, anywhere as long as the waterspout is not registered on the radar.

No	Date	Place	Heli-copter	Course of events	Contributing causal factors	Extent of loss/damage	RIF	Acc. Cat.	Q. A	Q. B	Comments (A/B)
5	16/7-02	UK	S-76A	While the helicopter is approaching, people on the platform hear a loud bang, and then see the helicopter fall into the sea. A witness also saw the main rotor head with the blades fall into the sea after the helicopter had hit the sea	Loss of separation between the rotor blade sections led to imbalance and to the gearbox falling off.	11 out of 11 fatalities	1.1 1.10	A3	Yes	**No**	Approach to offshore installation during reduced visibility (see separate chapter). This accident type has been incorporated in the newest generation proven helicopter technology and would probably not have occurred with the EC225 or S-92.
6	5/11-02	NO	AS332L2	During the descent to 1,000 feet for visual approach to Sola, severe vibrations occurred. The pilots sent a MAYDAY signal and informed Sola that they set course for two ships they saw near land. They landed on the helideck of the ship nearest land.	Loss of engine power as a result of fatigue in an axle for vibration damping. Weakness in the certification data for design. Other corresponding cases with this type of helicopter. The design for vibration damping is now modified.	No fatalities. Destroyed main rotor blade.	1.1 1.2	A3	Yes	**No**	Introduced new maintenance procedures and the newest generation proven helicopter technology which prevents this type of incident from happening.
7	3/3-06	UK	AS332L2	Lightning strike. No vibration or damage visible for the pilots, but there was a temporary disturbance on the instrument screens. Hydraulic system failure occurred, but the helicopter landed safely.		No fatalities. Damage to a main rotor blade and a tail rotor blade.	1.10	A8	Yes	Yes	Lightning strike.
8	27/12-06	UK	SA365N	During approach to the North Morecambe platform at night and in poor weather conditions, the mate loses control of the helicopter. The helicopter flies past the platform and crashes into the sea and sinks.	No correct transfer of control between mate and captain. The approach profile gave the wrong angle.	7 out of 7 fatalities	1.10 1.5 1.4	A5	Yes	Yes	Approach to offshore installation during reduced visibility.
9	22/2-08	UK	AS332L2	Lightning strike during flight. No system failures or impact to the helicopter's performance		No fatalities. Damage to main rotor blade.	1.10	A8	Yes	Yes	Lightning strike.

No	Date	Place	Heli-copter	Course of events	Contributing causal factors	Extent of loss/damage	RIF	Acc. Cat.	Q. A	Q. B	Comments (A/B)
10	9/3-08	UK	SA365N	During landing on a helideck, the helicopter's tail hits a crane.	Choice of approach profile, limited performance ability of helicopter, approach technique and possible fatigue.	No fatalities.	1.5 1.8 1.1 1.2 1.4	A2	Yes	Yes	In the Norwegian sector we have (since 2009) requirements for a helideck diameter of 1.25 D (compared with 1.0 D in the UK sector). A larger diameter provides better visual reference and clearance for obstacles, especially for large helicopter types and on installations with much turbulence and difficult flight conditions. The accident could happen in the Norwegian sector, but with less probability because of greater diameter of helideck.
11	18/2-09	UK	EC225	Collision with sea during approach to the ETAP platform in the dark and poor visibility.	Poor visibility, more clouds and fog than forecast. No automatic warnings in cockpit that the helicopter was close to the ground. This was because the pilot had disconnected the auto warning function.	No fatalities.	1.10 1.4 1.5	A5	Yes	Yes	Approach to offshore installations during reduced visibility. In this case several human errors were committed..
12	12/3-09	CA	S-92	The helicopter wrecked southeast of Newfoundland on the way to the Hibernia oil rig.	Broken titanium bolts in the main gear box led to an oil leak in the gear box. An emergency landing should have been conducted but this was not part of the applicable procedure.	17 out of 18 fatalities	1.1 1.2 1.4	A3	Yes	**No**	Under the same conditions this could have happened in Norway but the consequence could have been less extensive. This is because in Canada they flew at 9000 feet (higher than in the Norwegian sector) and therefore spent more time getting to the sea surface. As a result of the accident, the design and procedures are changed and the accident will not happen again. The same type of accident would not have happened with an EC225. This helicopter can fly for 30 minutes without oil pressure in the gear box.

No	Date	Place	Heli-copter	Course of events	Contributing causal factors	Extent of loss/damage	RIF	Acc. Cat.	Q. A	Q. B	Comments (A/B)
13	1/4-09	UK	AS332L2	The helicopter crashed on the way from the Miller platform to Aberdeen.	An error in the main rotor's gear box led to the main rotor head loosening from the helicopter and that the helicopter and rotor blades destroyed the pylon and tail boom.	16 out of 16 fatalities	1.1 1.2	A3	Yes	Yes	Even though procedures or maintenance practices are different on the UK and Norwegian Shelves, it is not likely that the same type of technical error would have been discovered in Norway either, not even for new machines.

In total, 13 accidents have been identified and assessed, of which 11 occurred in the UK sector with a total of 34 fatalities.

SINTEF's judgment is that all of the accidents could have occurred in the Norwegian sector in the same period.

Four of the 13 accidents will most likely not be able to occur again in the next period, mainly due to technological improvements and lessons learned from the accidents.

The accidents most likely to occur again can be put into the following groups:

- Lightning strike (3 accidents)
- Visual approach to offshore facility (3 accidents)
- Conditions at facility (2 accidents)
- Technological challenges (1 accident).

For all of the accident types, there are possible measures which can be implemented to reduce the probability of an accident.

The two accident types "Lightning strike" and "Visual approach to offshore facility" are discussed in more detail below.

7.3.2. Accidents caused by lightning strike

Three of the accidents in Table 7.2 are related to lightning strike, a phenomenon which is just as likely to occur in the Norwegian sector as the UK sector. Helicopters will always be exposed to this type of risk, and there is currently no satisfactory method to detect lightning before it strikes the helicopter. There are systems in place which register lightning, but these are reactive and do not warn of the *threat* of lightning. The helicopter can also have a static charge and trigger a lightning strike itself. The only ways of avoiding lightning is to have the helicopter grounded, fly low, or around exposed areas (e.g. snowy weather, cumulonimbus clouds and areas with a temperature from -3 °C to +3 °C).

The extent of damage caused by a lightning strike is less than it was ten years ago, due to the latest generation of proven helicopter technology. However, there is still a need for further technology development, also to help uncover hidden damages. Helicopters should be designed in a way that is robust enough to withstand a lightning strike, and they should also be able to withstand the largest discharges possible. In the Norwegian sector, there have been no accidents involving lightning strikes in the last period (1999-2009), but on average there are two to three lightning incidents per year. A possible cause of the decline in lightning strike accidents, could be because there is no flying when the weather conditions are hostile.

7.3.3. Accidents during visual approach to offshore facility

Three of the accidents in Table 7.2 are related to approaching helidecks during reduced visibility (dark or bad weather) conditions. There is a relatively high probability of this type of accident occurring in the Norwegian sector. There have also been incidents in the Norwegian sector where the helicopter is too close to the sea during approach. In such situations the helicopter was saved by the warning system (GPWS). Pilots, like most people, have a tendency to trust and act based on what they can see with their own eyes (which in some situations can be nothing due to "*white-out*") instead of trusting what the instruments show. Several risk reducing measures are relevant to reduce the probability of this type of accident, and the most important is the implementation of standardised approach procedures. Such procedures will reduce the risk of misinterpretations during approach. (Automatic approach all the way to the helideck is discouraged because it will lead to increased risk due to the many obstacles – cranes and other things – located on the facility and near the helideck.) Other important risk reducing measures which can be discussed are reduced night-time flights and more relevant training directly connected to landing on helidecks in the dark or in reduced visibility (e.g. simulator training with approach to specific facilities). Another measure could be that the two pilots help each other with reference points. A precondition for reducing the probability of such incidents is the existence of a culture where you can learn from incidents and pass on the knowledge to other pilots (both within and across helicopter operators).

7.3.4. Analysis of the accidents

Figure 7.2 provides a rough estimate of the distribution of accidents in the accident categories. The distribution is shown for the period 1999-2009 and for the next period (2010-2019). In the next period, four of the 13 accidents are *not* considered likely to occur again, including two fatal accidents with a total of 28 fatalities (see Table 7.2). This results in a reduction of 31 per cent in accidents and 55 per cent in the number of fatalities for these accidents.

Figure 7.2. Accidents in the North Sea (and Canada) distributed by accident categories.

In Figure 7.2, we can see that none of the accident categories are dominant. The distribution of these accidents is also somewhat in accordance with the expected distribution of accidents (cf. Figure 6.1). Three of the four accidents in category A3 Critical system failure during flight are considered to be eliminated in the next period.

Figure 7.3 shows the same accidents divided by RIFs in the two periods, still assuming that four of the accidents will not happen again in the next period.

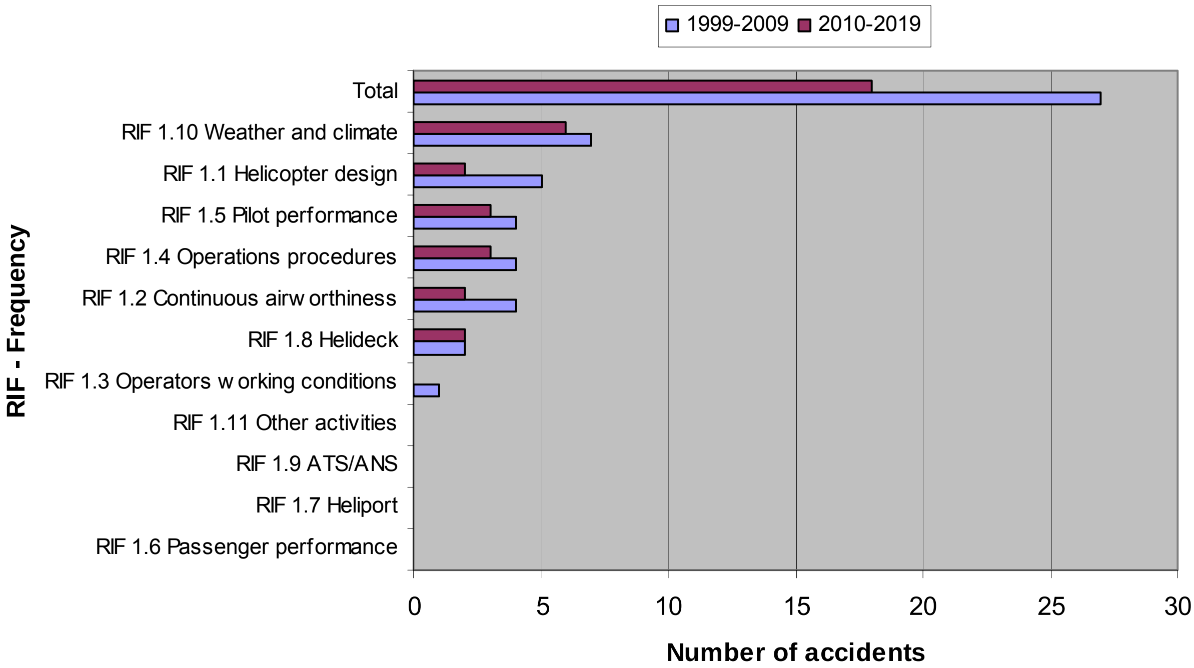

Figure 7.3. Accidents in the North Sea (and Canada) distributed by RIFs for frequency.

We can see that RIF 1.10 Weather conditions and climate contributes the most to accidents. This is because several of the accidents are related to lightning strikes or the approach to facilities during poor visibility conditions. The risk contributions from RIF 1.1 Helicopter design and RIF 1.2 Continuous airworthiness will be reduced in the next period because of new helicopter types, the latest generation proven helicopter technology and new maintenance procedures. Furthermore, we also see a decline in the contributions from RIF 1.4 Operational procedures and RIF 1.5 Pilots' competence. This can be attributed to new procedures and implementation of automatic approach procedures.

Accidents which can be related to lightning strikes and approach to facilities during poor visibility conditions are identified as especially important. The need for risk reducing measures for these types of accidents is further assessed in Chapter 10.

For several of the accidents (especially two of the accidents in 2009), the underlying causes have been assessed and measures have already been implemented to prevent or reduce the probability of the same type of accident occurring again. The review and assessment of accidents in recent years also shows that it is important to learn from past accidents, not just the latest accident, especially when the same type of accident has occurred several times.

7.3.5. Assessments of accidents and serious incidents in 2009

Two of the accidents in the UK sector and the accident in Canada (accidents 11, 12 and 13 in Table 7.2) occurred within a period of less than two months during the spring of 2009. In addition, there were three incidents reported in the Norwegian sector in the course of one week.

This caused considerable attention and uncertainty regarding the risk level in helicopter transport. We will take a closer look at these accidents/incidents in the following sections.

Accident no. 11
The accident occurred during approach to a helideck under reduced visibility conditions (A5). Similar accidents have occurred previously, and will most likely happen again, but the probability of such accidents can be reduced by implementing relevant measures. Human factors are considered to be the underlying cause of the accident.

Accident no. 12
The accident in Canada, where a critical system failure occurred during flight (A3), can be tied to the phase-in of new helicopter types. According to preliminary investigation reports, the accident could have been avoided if better criticality analyses (FMECA) had been conducted before the helicopter was used. If a similar accident had occurred in the Norwegian sector where the cruising altitude is lower than in Canada, the helicopter would have used less time to get to the sea surface; this might have reduced the consequence, but it would still have been an accident. It is not considered probable that the Canada accident could happen again because of changes in design and procedures implemented after the accident.

Accident no. 13
The accident occurred due to a critical system failure (A3), and it is considered that it could happen again, any place or time. It is also random chance that the accident occurred at that specific time.

Incidents in the Norwegian sector
Regarding serious incidents in the Norwegian sector, data from CAA-N and AIBN show one serious aviation incident in 2009. This occurred due to system failure (accident category A3). Compared with previous years when there have been 0-2 serious incidents yearly, 2009 can not be considered an unusual year in the Norwegian sector, if you look at the period as a whole.

Accidents and serious incidents rarely occur in offshore helicopter transport, and experience shows that the number can vary greatly from year to year. The indication of a potential increase in risk for 2009 based on accident data is therefore not statistically significant, and can be viewed as a result of random occurrences.

7.3.6. Norwegian and UK sector

It is striking that the UK sector had ten accidents while Norway only had one accident in the period 1999-2009, with comparable amounts of person flight hours. All fatalities in the North Sea during the period have also occurred in the UK sector. The statistics show a significantly different development between the UK and Norwegian sectors from the previous period. The analysis has shown, however, that all accidents, in principal also could have occurred in Norway. This indicates that our low accident rate in the period could be a random result; this is also supported by sensitivity analyses.

The fact that the accidents could have occurred in the Norwegian sector does not necessarily mean that the *probability* of these accidents was just as great in Norway. The probability of the individual accidents could very well be considerably lower – or higher – than on the UK side; such assessments are not covered by the analysis.

On the other hand, you cannot ignore the fact that all of the UK accidents occurred there, in the UK sector and not the Norwegian sector. It cannot be ruled out that the observed difference between the Norwegian and UK sector is partly due to actual differences in how helicopter operations are conducted. In Norway, questions can be asked whether large and important steps towards increased safety have been made in recent years, while the progress in the UK has stagnated, perhaps even gone backwards. The question is difficult to answer, and will require thorough studies.

If we focus on Norway, we can highlight some safety promoting factors that are considered unique to the Norwegian Shelf:

- The publication of OLF's helideck manual which has a particular focus on addressing operational factors concerning operations on helidecks.
- The introduction of new helicopters and the latest generation proven helicopter technology (and the phase-out of older helicopters) has progressed quite far
- Especially strict requirements for equipment associated with flights, from both authorities and customers
- Additional requirements for simulator training, pilot experience and competence
- Strict limitations for night-time flights.

7.4. Conclusion as regards risk level on the Norwegian Shelf

On the basis of the discussion in the previous chapters, we can quantify estimates for the risk level on the shelf and the change in risk between the two last ten-year periods.

In Chapter 7.1 above, we have estimated a risk reduction on the Norwegian Shelf between the periods 1990-1998 and 1999-2009 to be 83 per cent based on historical data (statistics). This estimate is regarded as being unrealistically high, and we put our trust in the risk models' thorough estimates for risk reduction based on expert judgments of changes in the RIF level. This was a topic in Chapter 6.6, where the reduction of risk was estimated to be **16%**.

In regards to the risk level, we can first ascertain that the statistical basis is very thin, with only one accident and no fatalities in the Norwegian sector in the period. To estimate a level as well as possible on a statistical basis, we look at the *whole* 20-year period 1990-2009. With five accidents and 12 fatalities in the Norwegian sector, this results in a statistical risk of 0.9 fatalities per million person flight hours. To achieve the most robust risk estimate possible, we apply the method in Chapter 7.1, and go via the *accident rate* and the estimated *number of fatalities per accident.* The accident rate in the 20-year period was 0.38 accidents per million person flight hours, and the number of fatalities per accident was estimated at 3.0. This results in a risk level of **1.1** fatalities per million person flight hours on average for the entire 20-year period 1990-2009.

Based on these numbers, we can calculate the individual risk levels for the two periods 1990-1998 and 1999-2009. These are **1.2** for the period 1990-1998 and **1.0** for the period 1999-2009. Table 7.3 sums up the most important risk estimates in the study.

Table 7.3. Estimates for risk level and risk change on the Norwegian Shelf 1999-2009.

Result	**Value**
Risk reduction between the periods 1990–1998 and 1999–2009	**16%**
Average risk level for the 20-year period 1990–2009 (number of fatalities per million person flight hours)	**1.1**
Risk level 1990–1998 (number of fatalities per million person flight hours)	**1.2**
Risk level 1999–2009 (number of fatalities per million person flight hours)	**1.0**

The analysis of the UK accidents in the period 1999-2009 showed that all accidents could in theory have occurred in Norway, and that our low accident rate could be a result of random occurrences. It is therefore not considered unreasonable that a higher accident rate is used as the basis for the risk estimate for the Norwegian sector in the period 1999-2009.

A consequence of a new risk level estimate for the period 1990-1998, is that the previous estimate reported in HSS-2 (2.3 fatalities per million person flight hours) is no longer regarded as the best estimate for this period. In light of the discussion in the report so far, this is not unreasonable, since the old estimate was identical with statistical risk based on the one fatal accident in the previous period, the Norne accident. This assessment concurs with the fact that we also do not regard the statistical risk of 0 as representative for the period 1999-2009.

Figure 6.10 can now be updated with estimated risk levels for the three ten-year periods studied. The result is shown in Figure 7.4.

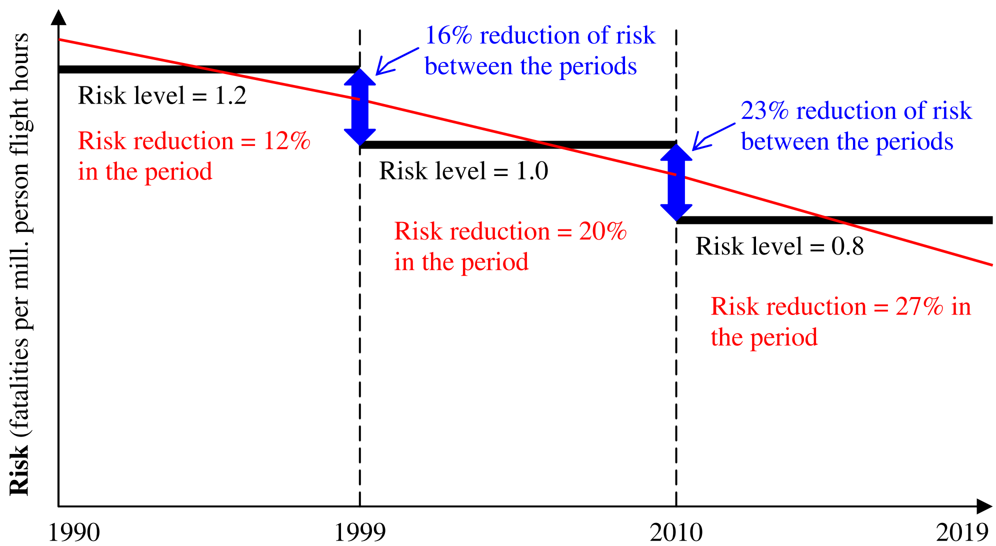

Figure 7.4. Estimated risk levels and changes in risk over three ten-year periods on the Norwegian Shelf.

7.5. Fulfilment of goals in public report NOU 2002: 17

Public report NOU 2002: 17 formulates the goals for safety in offshore helicopter transport for the ten-year period 2000-2010. We have chosen to use the periods 1990-1998 and 1999-2009 as a basis, which correspond to the periods studied in HSS-2 and HSS-3 (even though the first period has a duration of nine years and the other period 11 years). It proves that the choice of time period has little significance for the conclusions drawn. The distribution of accidents between the two periods remains the same, but of course the number of person flight hours in each period is somewhat impacted by this division.

7.5.1. The main goal

The main goal in public report NOU 2002: 17 is that *total probability of fatalities during helicopter transport shall be reduced by at least half in the next ten-year period, compared with the period 1990-2000.*

Table 5.4 shows that no fatal accidents have been registered in the Norwegian sector in the period 1999-2009. This can be an indication that the probability of fatalities during helicopter transport has been at least reduced by half from the first to the second ten-year period. However, it is not possible to claim that the observed reduction is statistically significant, that will require a longer observation period.

The main goal is formulated as the *probability* of fatalities, and you can therefore not use statistics alone to assess fulfilment, especially since the statistical basis is very thin. In our report from HSS-3, the risk reduction between the two ten-year periods is estimated to be approx. 16 per cent based on expert judgments in the risk model (see Chapter 6.6). This is relatively remote from the goal of reducing risk by half. The conclusion is that the main goal has *not* been fulfilled.

There could be several reasons as to why the main goal has not been fulfilled. Even though several improvements and measures have been implemented in the period up to today, the safety promoting impact is not expected to have full effect until the next period. The main goal can also be considered as being ambitious, and that there were not sufficiently thorough evaluations for selecting the main goal, which meant that the goal was unrealistic, especially with regard to the time frame.

7.5.2. Secondary goals

Regarding the secondary goals in public report NOU 2002: 17, we would point out the following:

- **Secondary goal 1:** *The observed number of fatalities per million person flight hours (passengers and crew) shall for no year exceed 1.0 in the next ten-year period, measured as a five-year moving average.*

  Secondary goal 1 has been fulfilled as of today.

  There have been no fatalities in the period 2000-2009. When a moving average is used, the years 1998, 1999, 2010 and 2011 will also be included in the calculation for this period.

We must therefore wait a few years before we can say that the goal is fulfilled as formulated.

Even though the goal has been fulfilled as of today, it is regarded as ambitious. With the period's traffic volume, the goal corresponds to three fatalities during any five-year period. This means, e.g. that any "larger" accident with four fatalities or more would have broken the goal.

- **Secondary goal 2:** *The number of aviation accidents and serious incidents in total shall be reduced continuously. This number shall not exceed 15 per million flight hours, measured with a moving average, for any year or for any helicopter operator on the Norwegian Continental Shelf.*

  Secondary goal 2 has not been fulfilled.

  In the years 2000-2009 there has been one aviation accident, six serious aviation incidents, three serious aviation traffic incidents; which is a total of 11 accidents and serious incidents. These have been relatively evenly distributed throughout the period (cf. Figure 5.2), so one cannot claim that there has been a "continuous reduction". In the same period, approx. 440 000 flight hours have been conducted. This gives an average frequency of approx. 25 accidents or serious incidents per million flight hours for this ten-year period. The goal will most likely be fulfilled in some years and for some helicopter operators, but viewed jointly in the period, the goal is far from being fulfilled.

  This goal is also considered ambitious. With the period's traffic volume, the goal corresponds to approx. three accidents/serious incidents over any five-year period. The result of the period has been approximately one accident or serious incident per year.

- **Secondary goal 3:** *Ditching shall not lead to any fatalities due to drowning or hypothermia.*

  Secondary goal 3 is fulfilled.

  There have been no ditchings in the period 2000–2009.

- **Secondary goal 4:** *Perceived risk shall be continuously reduced and shall not lead to any serious problems for the passengers.*

  Secondary goal 4 is fulfilled.

  In the PSA's surveys in 2001, 2003 and 2005 a selection of people were asked about how great a risk they believe a helicopter accident poses for them personally. The results showed a reduction in perceived risk both in 2003 and 2005. In 2005, according to the RNNP, there was a significant reduction in perceived risk in relation to 2001 and 2003.

  As regards the formulation of personal problems for the passengers, it is both unclear and difficult to measure. It can be interpreted *no* passengers shall have *any* serious personal problems, which is regarded to be a very rigorous goal.

  Perceived risk is discussed further in Chapter 8.

8. PERCEIVED RISK

8.1 Introduction

…less simplification allows you to see more (Weick & Sutcliffe 2007:10)

"*It's time for the users to be involved.*" (Oil worker in one of the group interviews)

Helicopter-related risk constitutes a large part of the total risk a worker on the Shelf is exposed to (PSA, 2008, p.8). To further improve the safety of passengers transported to and from work offshore, increased knowledge and identification of risk reducing factors is important. In an extension of Weick & Sutcliffe's (2007) quote in their book about resilience and safety, we want to go behind the numbers to "see more", as the reality is complicated, unstable and unpredictable. The purpose of this chapter is to gain more knowledge about the passengers' views of the risk experience during helicopter transport. There is little systematic knowledge about perceived risk and how passengers experience critical incidents and near accidents in offshore helicopter transport. Helicopter transport for offshore employees has certain unique traits which make the employees a particularly interesting group for studying perceived risk (Mitchel and Braithwaite, 2008); according to this article, the employees have no other options regarding transportation to work. Pay and operating conditions are relatively good, and the sector will therefore attract some people who are more risk averse than average. As helicopter transport is a crucial factor for the entire industry, both the companies' interest organisations and the labour unions are concerned with helicopter safety. The helicopter passengers are different from average passengers because they have increased knowledge of safety as a result of safety and evacuation training, and are wearing survival suits during flight. Ten years ago in Norway, a questionnaire survey was conducted by Lie and Ringstad (1998): *Helicopter safety and working environment. Survey of anxiety and discomfort in connection with helicopter transport.* The purpose of the project was to map the passengers' perceived risk during helicopter flight, feelings of angst and anxiety and experience with the environment in the helicopter. The survey included employees on all types of facilities in the North Sea. The results indicated that the physical environment in the helicopters was a greater problem for the offshore employees than the experience of anxiety/fear. The offshore employees predominantly considered helicopters a safe way to travel. It was estimated that five per cent of the passengers were bothered by severe and continuous anxiety in connection with helicopter transport. About three-fourths of the people surveyed were unhappy with the seating conditions and the comfort level, specially in the Super Puma helicopter model. This survey contributes several interesting findings, but many changes have occurred in the last decade. The results in the quantitative survey are mainly based on the predefined categories and not the employees' own perceptions.

An objective of this survey of perceived risk was to examine what it looks like from the inside – how passengers express themselves about risk perception and their experiences with the use of helicopters as transport to and from offshore facilities. This approach is mirrored in the report, where the main emphasis is on the empirical material rather than a discussion of theories and perspectives on risk. The following main topics formed the basis for the survey:

1. Factors of significance for perceived risk related to phases in helicopter transport
2. Own and others' stories from a high-risk incident
3. Changed framework conditions such as new helicopter models, better protective equipment and organisational changes in the helicopter companies and the significance for perceived risk.

To acquire the employees' own stories and interpretations, and because this topic has not been extensively explored, we chose a qualitative approach. The analysis is based on group interviews with a strategic selection of 16 oil workers who participated in refresher courses in helicopter evacuation at FalckNutec. In addition, interviews were conducted with the instructor at the training centre and conversations were held with representatives from two labour unions. Employees from different types of companies and fixed and floating facilities are represented. A detailed review of the approach, data material, and method is provided at the end of the chapter.

For busy readers we will go straight to the discussions of the findings, and suggested measures. A more detailed presentation of the findings follows thereafter: First we present factors of significance for perceived risk. Thereafter, the oil workers' own stories from a specific incident, as well as the retelling of colleagues' experiences are analysed. In conclusion, the interpretation of the level of perceived risk tied to helicopter transport is documented.

8.2 Understanding of perceived risk and contributions to safety improvement

Perceived risk is a new topic as compared with the two previous helicopter studies. Here the employees' assessments viewed from the "inside" are the main focus, instead of the experts' judgments of the condition, and the researcher's calculations of risk level. This secondary study is also innovative because it provides new knowledge about the employees' own experiences, understandings, and interpretations about safety and perceived risk in the helicopter transport offshore through the *employees' own stories*.

8.2.1 Risk and safety influencing factors – significance of "small indicators"

To clarify the differences and similarities, we can discuss three main types of passengers: *The untroubled, the watchful and the anxious.* These types experience helicopter transport in very different ways. While the first group is relaxed and can "doze" during the helicopter ride, the other two groups are in a tense state. For the most anxious, this means that the body is in a high state of alarm, and they search for details and indicators that can be interpreted as risk influencing and/or safety promoting. None of the participants in this study suffered from lasting fear of helicopters, but many knew of someone who was bothered or had to quit the job offshore because of this. We have chosen to distinguish between airplane and helicopter fear because the data material indicates that there is no clear connection between the two types of fear of flying. Our analysis has shown that several factors, as well as "small indicators" are of great significance to perceived risk. In unusual situations such "indicators" can also lead to fear and uneasiness, even for the untroubled passengers. This shows that fear and uneasiness are not a constant for certain categories of people, but something which is created during given situations and framework conditions. Knowledge about these indicators is important, because they provide nuance for quantitative estimates of perceived risk, document the variety of factors that can contribute to insecurity, and which situations could lead to an untroubled passenger becoming an anxious passenger. It also provides input to the knowledge of how practices can change and improve throughout the entire value chain. Based on our findings in the study, the implicated interested parties should prioritise implementation of suggested measures on different levels. This does not only concern measures for vulnerable groups, but also measures that have significance for how all passengers generally perceive the helicopter transport offshore. The analysis shows that these factors can relate to anything from the contents of the videos presented before a flight (how to present the factual information without it seeming like a "last journey"), the pilot's behaviour before take-off (extra check around the helicopter) and during flight (what the co-pilot is doing), the heliguards' behaviour ("portion out" helping passengers disembark in bad weather, extra attention to first time passengers) and the other passengers' behaviour (how to relate to colleagues with a fear of helicopters, cf. for example practical jokes). Knowledge and information about what happens before and during the helicopter flight has great significance for perceived risk during helicopter transport. In unusual situations, e.g. unusual sounds, extra vibration and other technical problems, it is especially important that clear information is provided. This should occur during, but if that is not possible, factual information should be presented following the incident. In such situations, the need for information is great, and our data material uncovers several good practices, but also a need for improvement by the involved players. The need for improved information in unusual situations was also one of the main findings in the survey study from 1989 (Lie and Ringstad, 1998). Many of the employees in our selection complained that it is often difficult to hear what the pilots are saying, both because of a bad intercom, but also the way that the information was presented (technical expressions, and "air pilot English"). It is worth noting that bad sound has been a repeat offender in several official studies, but that no significant changes have been made. If there is a desire to improve perceived risk, this is an important point where efforts should be prioritised. In the pilots' training there is most likely an emphasis on the difference of communicating with the tower and communicating with the passengers. The challenge is to maintain this difference in the everyday environment.

Some employees requested more detailed information in connection with delays, cancellations, interrupted flights and emergency landings. "Technical" is now a category for a collection of different conditions, and some said that the companies should be clear if the pilots needed resting time. When all types of conditions are explained with the term "technical", this can contribute to strengthen the perception that there are a lot of problems with the helicopters, and can strengthen the unrest among anxious passengers. This is an example of how categorisation contributes to create our reality and the way we perceive it. Some requested written reports in both Norwegian and English after an incident because the reports in English are often not read. One helicopter company received praise because they came out to a facility and provided information after one of the accidents on the UK Shelf in the spring. Since this accident was closely related to the employees on the facility, it was good to have the opportunity to get more information than what was in the media. It was also reassuring for the employees to hear how the helicopter company was going to conduct further safety checks on the helicopters.

As there are many small "indicators" or details that have significance for the individual's subjective perception of risk, it will vary between persons, but also over time and space. Perceived risk is not a constant factor and does therefore not have to be in accordance with quantified figures for risk. Nor can the individual employee "calculate" the risk he/she is exposed to daily through helicopter transport. Therefore, many express that they do not experience great risk, and/or that they have a fatalistic attitude in regards to risk – you cannot keep thinking about what could potentially happen. Earlier it has been shown that there is not a simple correlation between calculation of the risk level and subjective comprehension of risk (see for example Bye and Lamvik, 2007, Rundmo, 1997). Subjective risk comprehension must therefore be put into a larger context and related to the interaction between involved players, technology and organisation. The passengers' own stories contribute to further define this and illustrate how employees attempt to create meaning in their existence.

8.2.2 What can stories of incidents tell us about perceived risk?

We have little or no systematic knowledge of critical incidents based on the employees' own stories. The analysis documents that the stories about unusual situations flourish among the oil workers – as in all other work organisations. We have analysed a total of 43 stories of a critical incident in the way they were told in the five group interviews with offshore employees. Sixty per cent of the stories were self-experienced, while the remaining were stories retold from colleagues' experiences. These stories are much more than just funny or tragic anecdotes from the field. The stories are a unique source for understanding the everyday life of oil employees seen from the inside. We gain insight into their experiences, what they talk about offshore, and not least, the employees' understanding of what they believe could be a risk. This can be in accordance with traditional risk influencing factors, but can also deviate from so-called objective indicators. The stories were categorised based on the main accident categories and Risk Influencing Factors, RIFs. The largest category stories concerns incidents in connection with landing or take-off on helicopter decks. This is the phase the passengers associate with the greatest risk in helicopter transport, especially on boats or floating facilities. In the estimated risk model in the report, which is based on expert judgments, take-off and landing on helideck is number three among the accident categories (cf. Figure 6.4). The third largest category stories was (critical) system failure during flight. This is the accident category which gives the second largest risk contribution in the estimated risk model in the report. We can therefore see that there is some, but not full, accordance between the share of stories about critical incidents from the employees divided into different categories, and which categories are regarded as the most risky in the estimated risk model. Inasmuch as very few of the informants or their colleges had experienced a collision with sea, ground or obstacles (CFIT), is not surprising that there were only a couple such stories. However, in the discussions about risk connected to helicopter transport, many informants were of the opinion that a helicopter crash or CFIT would imply great risk for loss of lives. The category "Other" makes up thirty per cent of the stories, and concerns conditions which could indirectly have significance for perceived risk such as fear of helicopter transport among fellow passengers or obesity/overweight. Some of the stories bring in new elements which are not primarily of a risk influencing character, but have more to do with consequences of perceived risk or insecurity.

The analysis of the stories provides knowledge about which incidents are retold, and what reactions the employees have during and after an unusual situation or critical incident. Even though some of these incidents occurred a few years ago, they are still important today because they are a part of the internal "conversations" about work practices and risk. Orr (1996) uses the term "war stories" about stories that deal with how demanding work operations (repair of machines) were solved. By sharing knowledge which was not in written form, the colleagues gained access to each other's experiences and developed a common knowledge base based on experience. Perceived risk is a topic which often "takes form" in examples or stories. Based on the analysis, these stories have several functions for the employees, five of which we will discuss here.

Employees share knowledge by retelling about critical incidents with helicopters

Critical incidents during helicopter transport are shared with others and are retold to colleagues. Stories work well as a transfer of experience because they are often to the point and they animate a situation. Through the story you can also gain indirect input to experiences and feelings. It is easier for the listeners to identify with the players. With this you have a basis for learning from others' experiences, and to think about what you would have done in a similar situation. The stories can therefore work as *educational stories* which prepare the employees to handle their work day in a better way. This becomes a form of emergency preparedness training, but it is important that this knowledge is in accordance with the established standards. Stories can function as *development tools* where employees jointly reflect over their own work situation and further organisational learning (Forseth 2001).

Unusual incidents with helicopters are incorporated into the "rumour mill"

In the offshore industry, many employees spend both work and free time within a limited area far out at sea when they are at work. When employees meet on the facilities, the stories function as a sort of "glue" between them, and contributes to strengthen the sense of community and identity. Stories about non-conformities and critical incidents also have another function as a contribution to the rumour mill. Some point out, if something happens, the rumours easily start spreading. The participants used expressions like *"made a mountain out of a molehill"*, *"rumours are made to be spread and exaggerated"*. Especially after incidents, near accidents, and accidents, there is much talk and speculation among the employees. Therefore stories can also, in some circumstances, contribute to strengthen and, at worst, distort an incident.

Oil workers seek control by retelling about critical incidents with helicopters

Even though the participants say that helicopter flights are not a problem and most do not experience anxiety, their stories and retellings are filled with emotions. Some of these emotions are about joy and relief, but many are about fear, unrest, and anxiety. It is human to feel a spectrum of emotions after being exposed to what one would consider a risky incident, regardless of whether the incident was objectively associated with risk or not. The stories about what they consider to be a critical incident take us under the rational surface to the darker sides of existence, with fear, anxiety and unrest. By retelling and sharing experiences from critical incidents the players can, individually or collectively, achieve a kind of "purification" (catharsis). By reviewing the incident and its causes, it is easier to put the incident behind you. The analysis confirms that the more fact-based knowledge that is communicated during or following the incident, the less room there is for fantasy. The stories are therefore crucial for employees and their formation of perspectives, to re-establish the balance and feeling of control and meaning.

Informal channel to communicate difficult and taboo topics within the oil industry

The stories in the data material also worked well as an informal channel for topics that are difficult or taboo for the employees in the petroleum industry. This was made particularly clear in relation to the topic of obesity and overweight. In this instance, the employees used stories from their every day work situation, but also scenarios where they dramatised different actions and possible consequences. Use of humour and satire as a tool can be interpreted as a way to disarm, if you cannot get through via the regular channels.

Non-conformities and critical incidents are communicated through stories

Stories are well-suited to communicate experiences from unique situations like unusual situations, critical incidents and accidents. Through the story, the experience is "coloured" and the setting, as described by the individual oil worker, provides a richer picture than fact-based rattling off of incidents. Also, the underlying causes, "heroes" and "bad-guys" and their significance for the outcome can be identified. The oil workers use different tools like exaggeration, repetition, humour and satire to emphasise the main point in their stories. In this way, the unexpected or exceptional becomes comprehensible to both themselves and their colleagues. This can be a strategy to recreate a sense of order when something unexpected has happened, and to counter unrest and fear.

The stories about what the employees describe as critical incidents are an important source of knowledge and fill many functions, five of which are discussed here. In the next chapter we will briefly discuss the phenomenon of perceived risk.

8.2.3 Perceived risk varies and is context and situation dependent

The participants have very different approaches when quantifying the risk level during helicopter transport. The tendency in the data material is that helicopter transport is experienced as more risky than airliners, but there were also some that came to the opposite conclusion. There was therefore a lot of discussion about these numbers in the groups. The analysis illustrates that such scales are not objective quantities, but are human made. Therefore they are dependant on how you measure the phenomenon and how the participants interpret the question. The number can initially be a reasonable basis for further searching: What is the reason for setting a specific number? What factors are drawn in – occurrence of incidents, occurrence of fatal consequences of an incident? Another important main point is that knowledge and assessments are context specific – we relate our knowledge to specific situation-based incidents and our framework conditions. This was illustrated when one of the participants told us that immediately after the three helicopter accidents during the spring, he would have chosen a number one or two notches higher on the scale for perceived risk than he did today. When it became clear that the same type of helicopter was going to be grounded for a review, he gave a lower number in relation to perceived risk. *From these analyses we can determine that one-to-one correlations between estimates for safety level and perceived risk do not exist, but that discrepancy is more probable.* Even though there have been no fatal situations in connection with helicopter transport on the Norwegian Shelf in the last ten-year period, it is not given that this has contributed to a reduction in perceived risk. (cf. Secondary goal 4 Annual report for Committee for helicopter safety on the Norwegian Continental Shelf, 2008). This is related to the fact that the employees do not act as a calculating player or homo economicus, continuously calculating the risk level based on the occurrence of accidents. Our analyses show that the *quantification of risk level varies, and that there are several different conditions and small indicators that have a determining significance for the individual's perception of risk.* Perceived risk is multifaceted and involves interaction between humans, organisations, framework conditions, culture, and work practices. How the individual employee "takes" it and "feels" it in relation to perceived risk is therefore multifaceted and involves much more than a number on a scale for perceived risk (cf. Bye and Lamvik, 2007).

8.2.4 Suggested measures

"We want a walkway/bridge out", said one of the participants jokingly as his answer to the question of wanted measures. If, in the future, there is prioritisation of the design of helicopter types with reduced noise level, less vibration and increased comfort, the feeling of being "*transported like cattle"* would be reduced. This is not just about possibilities, but also costs and profitability. Based on the findings of which factors and mechanisms influence the passengers' perceived risk, we will suggest the following areas for implementation of measures:

- Make the safety videos less 'serious' (scaring) and stimulate the passengers to support each other socially, in particular those travelling for the first time and feeling uneasy
- Consider choice of seat in relation to specific needs as perceived risk varies with seating location
- Consider a possible weight limit for offshore workers in order to facilitate evacuation in emergency situations
- Improve the communication equipment in the helicopters and train the pilots to give clear and evident information (Passenger Announcement; PA)
- Fasten loose equipment in the cockpit (pilot's suitcase, manuals etc.)
- Increase awareness of the heliguards as to their behaviour; notably to pay specific attention to those travelling for the first time, plus assisting passengers embarking/
disembarking in bad weather condition (wind, helideck movements)
- Minimize exemptions from recurrent training for helicopter ditching
- Improve communication of credible information after incidents. (Correct information will reduce insecurity among the passengers.)
- Extend the project "Risk level in Norwegian petroleum industry" (RNNP) with new questions related to quantitative mapping (see the proposal in Chapter 8.2.5)
- Expand the next editions of RNNP with a specific qualitative part on helicopters.

In relation to the significance of incidents for perceived risk, it is important to have extensive training for the most risky operations, such as landing on floating facilities. Measures regarding this field are discussed elsewhere in the report.

The background for the list of measures and more detailed results are reviewed in the following pages.

8.2.5 Suggestions for new questions about perceived risk

From the analyses and the findings about perceived risk, we have formulated suggestions for new questions for the quantitative measurement in Risk level on the Norwegian Shelf (RNNP). To ensure the possibility of comparisons and time series data we have chosen to reuse some of the question formulations which were used earlier in the project "Helicopter safety and work practices" from 1989 (Lie and Ringstad):

	Completely agree	**Partly agree**	**Neither agree nor disagree**	**Partly disagree**	**Completely disagree**
1. Helicopters are a safe travel method	☐	☐	☐	☐	☐
2. I feel safe when taking a helicopter to or from a facility	☐	☐	☐	☐	☐
3. Helicopter safety on the Norwegian Shelf has increased in the last five years	☐	☐	☐	☐	☐

4. Today's demands for cost efficiency are at the expense of helicopter safety ☐ ☐ ☐ ☐ ☐

5. There are more delays than before in the helicopter traffic offshore ☐ ☐ ☐ ☐ ☐

6. Have you been involved in an incident as a helicopter passenger that you perceived to be serious?

No ☐ Yes ☐ If yes, when (year of last incident if you have been involved in several) ☐☐☐☐

8. Below is a list of several different means of transport. With which mode of transport do you think a passenger is exposed to the least risk if he/she uses each mode of transport for 100 hours over the course of a year. Complete the assessment by putting a number in each box (1 = least accident risk, 6 = greatest accident risk).

Car ☐ Airplane ☐ Helicopter ☐ Ferry ☐ Speedboat ☐ Motorcycle ☐

8.3 Significant conditions for perceived risk

The focus group interviews indicate that risk in connection with helicopter transport is a topic the oil workers are concerned with. Initially, all the participants expressed that they had a relaxed attitude in connection with flying in a helicopter – it was regarded as part of the work conditions. It was said that using helicopter transport to and from work was a decision they had made when choosing to work in the oil industry. In the conversations, several interesting elements came up, which provided increased knowledge about the passengers' experiences and behaviour linked to risk and helicopter transport. *The risk perception is tied to context or setting, and small indicators or signals can have great significance.* This can involve completely specific conditions, but also seemingly insignificant or invisible details and observations. In the following, there are several examples, and these are tied to the different phases in helicopter transport or specific episodes.

The heliport

Before departure there is often a somewhat "tense mood" because there is a lot of practical information to remember and there is a fight to get the "best" seats onboard. Many described how adults suddenly act like "wild animals" and "wild sheep". Here is the impression from the female participant in the material:

Normal customs and courtesy have long since passed, because there are no women and children first. The best seat goes to the biggest and strongest person who stands right by the door and storms out to the helicopter. I don't travel often and am not used to this, and always end up sitting uncomfortably next to a 120 kg person.

Such descriptions of the "race" to secure the best seat illustrated some of the uniqueness of this type of work. A person who does not participate in this race, risks having an uncomfortable journey to the facility.

We who travel on helicopters have damn good peripheral vision. When you go out to the helicopter everyone walks at their own tempo and makes sure no one gets by. You have a plan of action for when you get in the helicopter – you're getting the best seat…
And one of the other persons adds: *And there are many reasons for why you want the seat you've been thinking of…*

For many it is important to obtain what they regard as "the best seat", for example a single seat in the front, closest to the window or the closest seat to the door. This is in part due to habit ("*we are creatures of habit"*), but some also experience an increased feeling of safety if they obtain "their" regular seat. Some stated that they like to be able to look out the window. Others explained their preferences differently: some would rather sit near the exit so that it would be easier to get out in case of an emergency situation. Others said that, due to body size, they preferred to sit near a door instead of a window. There are therefore different reasons and preferences for seat choice. Some said that they sit on the first available seat.
It was said that for some, the helicopter ride can be experienced as uncomfortable and unsafe because they did not acquire "their" seat. There were references to an email which has circulated with the title *"North Sea workers – strange animals"*, where details such as choice of seat has great significance. This email hits many situations on the head – almost to the point of being embarrassing, according to one of the participants.

Safety videos

The safety videos shown before departure were also commented on by someone who had experience from the safety delegate service. Some complained because they thought that one of the videos contributed to fear and anxiety because it had a "*last journey"* character – bad weather, emergency landing and ominous music. Others found the video informative and useful in relation to repetition of emergency procedures. A third group pointed to the many errors and inaccuracies in the safety videos used. They also requested more variation so that people will want to pay attention, because it is easy to start thinking about other things when it's just that "*old thing"* being shown. As a curiosity, it was mentioned that some used to put the video on 1.5 speed to *"spice it up a little bit"* on the way home. That way they got a good laugh – and it was equally amusing each time. It is interesting to note that this occurred on the way home as a form of celebration over the end of a work period.

Weather conditions, sounds, and vibrations

The weather conditions have great significance for helicopter transport. Good weather and good light contributes to a positive helicopter ride experience, as opposed to bad weather and darkness. Sounds and extra powerful vibration are conditions which bring people out of the ordinary "travel mode" characterised by reading, relaxing and resting. It was also pointed out that such conditions can have extra significance for first time travellers, and those with a fear of flying. The participants told of how passengers had speculated on *"When will the door fall into the sea?"* on the latest Sikorsky (S-92) because there were such powerful vibrations. Deviations, such as turbulence or irregular noises, can give people a start and they might seek eye contact with the other passengers – what is happening? Some said that they studied the surroundings in detail before and after the trip: behaviour and appearance of the flight mechanics and the pilots, the equipment in the helicopter, etc. When everything is as expected, the feeling of safety is elevated. One person told of how he, through the observation of loose plates, and screws that were not screwed tight inside the helicopter during a job overseas, had begun to wonder about the maintenance of the helicopter: If everything visible is not completely ok and well-maintained, then what about the things that are not visible to the passengers?

Pilot behaviour and information

The behaviour of the pilots can also be determining for how the flight is experienced. It is reassuring for the passengers when they see that the pilot takes an extra trip outside to check the helicopter before take-off. A co-pilot reading the paper when the helicopter is at cruising altitude, was also mentioned as a reassuring sign: everything is going as planned, everything is under control – you can just relax. Clear information from the pilot is also appreciated by the passengers. One challenge is making sure the information reached the receivers. *Ninety per cent of what the pilots are saying you cannot grasp. There is scraping, it's loud, it's too low…* According to the passengers this is due to the poor quality of the sound system. It is claimed that this topic has been brought up before without any significant changes having been made. If messages from the pilot during the flight get drowned out in noise on the intercom, the result could be counter-productive – the passengers do not understand the message, and some wonder whether something unusual is about to happen. This can spread unrest and worry, especially among those who are somewhat anxious to begin with. Some also claimed that the message can get lost in what they call "*flight captain English"* and technical terminology. Many told of how all the passengers look at each other – what did they say? – especially when this happens in the middle of the flight. After turbulence, people often look at each other to get confirming looks from others – is this ok? *There was agreement that it is especially important to receive information in connection with unusual or risky incidents, preferably before and during (if there is time), but at least after.*

Heliguard behaviour on the facilities

The heliguards on the facilities play a central role: during bad weather it is important that the heliguards portion out a certain number of people and escort them safely down from the helicopter deck. An example was given of a small person who was almost carried away by the wind when she went out of the helicopter and across the helicopter deck. Others had experienced similar episodes with the baggage. The heliguards should pay extra attention to those who are "first time" travellers, visibly anxious or have fear of flying, and help them to get (for them) a safe seat in the helicopter.

Overweight and obesity

Through the conversations with employees it became clear that many were concerned with how certain types of passengers can constitute a greater risk for themselves and others. The participants in one of the groups said they appreciated having a channel to communicate a topic they were very concerned with: obesity among the passengers. This was a topic that was hard to discuss in other channels, in part because it deals with colleagues.
Obesity is what scares me most in the helicopter scenario. When I go in, I assess who I am sitting with, on both sides – to make sure that I have an alternative. If I end up sitting with a large person who goes out before me, it is not certain that I will get out.

One of the participants imagined the following scenario in an emergency situation:

It is not just yourself that goes, it's the others too. What are we going to do if we have to go in a raft from the helicopter – we're at sea – most are aboard the raft and maybe you chose wrong, maybe you didn't get to the raft when you went through the window – you drifted off.

Then you have a man standing on the raft who is 160 kg – I do not think he is the world's most flexible and I am hoping that he will save me. And what are we going to do if he is the one in the water – and we have to get him back in the raft? Do we just have to hook him on a rope and tow him? [Laughter]. Another participant*: Use him as an anchor?* Third participant*: Hit him in the head and use him as an anchor?*

In addition to the safety aspects, the comfort aspects were also emphasised:

I had a flight with a really large guy next to me – the trip took 1.5 hours. I didn't have half of my body on the seat and I was really stiff when I came out.

Further questions were asked regarding what would happen to your back in case of a hard emergency landing and the straps are twisted. Overweight and obesity is not just a topic concerning individuals, but also has consequences for the co-passengers:

The rules are way too relaxed… Honestly – people weighing 140-160 kg do not have any business out there as long as we are being transported in those helicopters. This has to do with me being a family man and I'm thinking that I need to make sure I get back home.

In addition it is also pointed out that large people represent a danger to themselves and others if something should happen to them on the facility (e.g. carrying stretchers).

Passengers with exemption from classes

According to the current arrangement, an oil worker can ask for exemption from the exercises in helicopters tipping over if they have a doctor's certificate on the refresher course. This means that they get a stamp in their certificate which says that they can only travel on the Norwegian Shelf.

What about the people who are afraid of water and receive exemptions? What if you end up with ten passengers like that and you ditch? Then you have a problem – I do not understand why they get exemptions because of a doctor's certificate.

None of the people we talked to were bothered by a fear of helicopters, and mainly thought that flying was not a problem. The safety aspect of helicopter transport concerns the passengers and is something they talk about amongst themselves. Several Risk Influencing Factors emerged that have significance for their perception of safety. At the same time, several of the participants said that they usually did not spend much time thinking about such things, and that they had a fatalistic attitude towards flying. However, the interviews functioned as an arena where normally taboo topics were discussed. It was uncovered that *small details or indicators can have great significance for the passengers' experience of safety aboard the helicopter.* The significance of these indicators will vary depending on "time of service".

First time travellers versus experienced

The trip as a first time traveller is different from the journey as an experienced passenger. As everything is new and unusual, it is natural to be a little excited on the first trips, and there are a lot of practical things to keep in mind. One person mentioned that it was fascinating to fly by helicopter, but he also admitted that he was a little scared the first few times. Another said that he let himself be affected by the fuel smell onboard before he was made aware that this was normal. Others told how they were extra wary of sounds and vibrations on the first trips. But, with time, you know what to expect, and most achieve an unstrained attitude towards sitting in a helicopter. For some, it is unfortunately the opposite: the employees knew colleagues who had developed trauma and a fear of helicopters over time. For some this is due to specific incidents, while others developed a fear of helicopters despite not having experienced any trauma. Others pointed out that they thought it was more uncomfortable to fly as they got older because they become more tired, their bodies were stiffer and it was tiring to sit fastened in a seat over longer periods of time.

Three passenger groups

None of the passengers had a fear of helicopters, but many knew of colleagues or had heard of people who suffered from this. Based on the interviews, we can group the passengers into three main categories:

- The *untroubled* who like to fly, feel safe, and are fascinated by helicopters
- The *watchful* who think it is ok, but who are on alert (especially in unusual situations)
- The *anxious*: This can range from those who are nervous ahead of time and feel some fear and unrest, to those who have trouble with a fear of helicopters and/or fear of flying.

All of the three groups can be influenced by the factors we have discussed, but the ones with the greatest significance are the last two groups, because they are to a greater degree in physical alarm mode more than the first group. This especially concerns the people with a fear of flying or helicopters. Deviations and absence of reassurance and safety promoting indicators can be enough to crack the façade for the other category – those who have to work actively to be balanced and relaxed. For passengers with a fear of helicopters, such factors can be crucial for the experience of safety and their own ability to cope. Some told of colleagues who had developed a fear of helicopters over time, and many knew of individuals who had to leave the industry because the helicopter flights became a burden. This most likely does not make up a large group, but it is serious for the people who are affected. Which passenger category you belong in – the untroubled, the watchful or the anxious – has great significance for how you experience risk. You cannot know what others think – also not in relation to perceived risk during helicopter transport. Different risk influencing factors, including small indicators which are described here, can have great significance because they ensure that individuals can create a safe “pocket” in a situation where they themselves do not have absolute control.

8.4 Employees’ own stories

8.4.1 Stories from a critical incident

A main topic in the focus group interviews was if they or their colleagues had experienced a critical incident which they perceived to be risky as a helicopter passenger. They could define themselves what the term critical incident meant. There were no problems getting offshore employees to retell their own and other colleagues’ experiences. Stories of the type of activities which are repeated were not included in the further analysis. Some incidents from foreign shelves are included, but the majority of the stories come from the Norwegian Shelf.

The stories can be grouped in several ways. For our purposes we have chosen to take a starting point in the eight main categories of accidents (A1-A8, cf. Chapter 1.4). The data material also consists of stories that include factors or incidents of a more indirect character, but which can contribute to influencing the perceived risk. The distribution of the different categories emerges from Table 8.1. The table distinguishes between *self-experienced* and *colleague-experienced* stories to examine whether employees primarily remember and retell their own experiences, and to what degree they remember and retell others' stories. The expression retell instead of repeat, underlines that stories have a characteristic of being a construction – stories are recreated, but not as a blueprint. The stories begin to live their own life when they start to travel. Even though some of the incidents occurred a while ago, and measures may have been implemented, the stories are still important because they are still circulating and spreading knowledge.

Table 8.1. Self-experienced and colleague stories from a critical incident.

Accident category (Number)	Self-experienced (26 = 60 %)	Colleague story (17 = 40 %)	Comments
A1: Take-off/landing heliport/airport (3 = 6.9%)	2	1	Turbulence + technical
A2: Take-off/landing helideck (15 = 34,8%)	10	5	Landing offshore most critical
A3: (Critical) system failure during flight (7 = 17.5%)	2	5	”Technical”: from indicator lamp to engine failure
A4: Collision with another aircraft: 0	-	-	
A5. Collision with ground terrain/sea/obstacle (1 = 0.4%)	1	-	Collision with gas tower
A6: Person inside helicopter (4 = 9.3%)	3	1	Loose objects pilot, illness passengers
A7: Person outside helicopter	-	-	Se ”other”
A8. Other/unknown (13 = 30.2%)			
Fear of helicopters	4	1	
Obesity/overweight	1	3	
Exotic regions	3	1	

In total, 43 stories from the group interviews are a part of the analysis, where 60 per cent are self-experienced, and 40 per cent are retellings of others' experiences. Some of the stories are new, while others occurred in the 1990s. Nearly all of the categories are represented in our data material with the exception of category A4 "Collision with another aircraft" and category A7 "Person outside helicopter". If we disregard the last compiled category, there are most stories about take-off and landing offshore – especially incidents in connection with landing. These stories are to a great degree self-experienced. This is also the phase in helicopter flight which is considered the most risky in the interviews. A large portion of the stories also deal with technical problems during flight, such as emergency landings, aborting the trip and turning back, etc. Technical problems is a composite category that can contain very different incidents. Some stories obviously relate to technical problems such as engine failure and metallic chips in the gear box. In other stories, the degree of severity is more unclear, or even unknown. Some claimed that "technical problems" were also cited in cases where the pilot was entitled to resting time. They thought this was unfortunate because it gives the impression that there are more errors and technical failures than what really occurs. In Table 8.1 the "critical" system failure is put in parentheses because the cause of the problems and the degree of severity is not known in all of the incidents. The category can therefore include anything from indicator error to serious technical problems. The composite category A8 "Other/unknown", is the second largest group. Here we have collected different types of incidents, and these are categorised in three sub-groups: Fear of helicopters, obesity/overweight, and incidents from exotic regions abroad. We initially chose to place stories about weather conditions and wind limits on helicopter decks in the category "Other/unknown", but we ultimately chose to put these stories in category A2 "Take-off/landing helideck". In addition, there are funny stories from other countries, like the story about when they had to stop on an unmanned platform at sea to fill fuel, but they were not able to open the lock to the fuel tank. A few stories about accidents and near accidents from abroad have been grouped in the above categories if they were easily placed. The category "Other/unknown" is an interesting category because it adds new aspects that go beyond traditional Risk Influencing Factors, and brings in underlying factors which can influence the safety in a given situation.

Most of the stories are short and were retold in a matter-of-fact way. Other stories were gripping and emotional. Given the setting and timeframe for the group interviews, there was not time to dwell on and discuss every detail thoroughly. In many of the stories, an evaluation or concluding comment is added to the story. This is often an important part of the story because this is the essence of what the storyteller wants to communicate to others. In the following a small selection of *typical* stories from the largest categories is presented.

8.4.2 Incident or accident during take-off or landing on helicopter decks

Many of the stories are about incidents associated with landing and take-off from helicopter decks – the most critical factors in a flight according to the participants. Landing was decidedly the most critical because you get close to the facility and there could be movement (ship). The content in the stories varies, but most often involves conditions at the facility and the helideck or technical conditions related to the helicopter. Weather, wind and waves along with organisational conditions and the human factor (pilot, heliguard and passenger behaviour) are central ingredients in these types of stories, such as this one:

I have been involved in a near accident. We were going to land on platform X where I work, and they had probably stretched the limits a little bit for movement and wave height. We were almost down, and then they had to hurry up again because it started slamming under the wheels – so they couldn't get the helicopter down. So we got the message that we had to prepare for an emergency landing, but it went well, they got up again – and then they got away. We went back to land again and spent the night in Y and had a little beer to calm down. You were very – you started talking on the trip in – it wasn't just… When we landed there were people standing there who explained the situation. The pilots said that they had full control when they noticed that they couldn't get down, and they just had to snap their fingers, and then we were up again. The pilot actually said that on the way down – that it could go so far that we had to go up again – because then they were right on the limit. (E-27)

This is an interesting story in several ways. It can defiantly be regarded as dramatic because the passengers received the message to prepare for an emergency landing, the helicopter was almost able to land, but the landing attempt was aborted. The experience and emotions of the storyteller and the other passengers were reflected on in the following understatement – *"it wasn't just…"* There can be many and strong emotions involved in such situations, but individuals can react very differently. This was also discussed in the interviews. It was obvious that the passengers had a need to work through the incident then and there through conversations between themselves on the way back in. The way the pilots related to the passengers, makes this a *positive educational story*. The pilot made a controlled attempt, and made sure to inform the passengers before and after the incident. The message to the passengers was that the pilots had complete control. This is a factor that contributes to the incident not being too traumatic, and makes it easier for the passengers to put the incident behind them.

The next story is about a critical incident which resulted in a successful landing on the helicopter deck:

I have been a part of "shutting" a helicopter on the rig. I was going to America in connection with work. We're sitting onboard the helicopter – it smells a little weird and then the helicopter "shuttles" down. When that happens, the helicopter is usually not carrying passengers. This time they couldn't do that – and it was like James Bond: The next day or evening a mechanic was hoisted down to the rig and changed a part in the helicopter. I had some mixed feelings – it was a little weird. I was irritated that I couldn't come in so that I could make the trip to America. At the same time I was glad that it was discovered then and there, and not in the middle of the air. (E-37)

This story describes the emotional reactions that can occur after a critical incident. Conflicting feelings afterwards are not unusual – passengers are glad and relieved, but also irritated or frustrated. The story also provides a key to understanding the uniqueness of this type of work and the specific framework conditions. In the story, parallels are drawn to James Bond – where the players often balance on the edge of what is feasible. The oil industry is in many ways a pioneer industry where people have challenged the forces of nature and developed advanced technology to secure the extraction of oil and gas at large depths. The self-image of the industry as something completely exceptional which needs its own rules and regulations, is also a part of this. This is also made evident in the book Olien & Olien (2000), which discusses the growth of the American oil activity up to 1945. In short, it describes how the people involved compared themselves with the pioneers who had "tamed the wild west" in the USA. To be a part of such a rich pioneer culture is exciting and challenging, but can also lead to strains like the ones described in the next story. A dramatic incident had implications for at least one of the people involved:

I have a colleague who was a part of an accident on X, a drill ship, near Z. The helicopter tipped over on the helideck between the loading of passengers and fuelling. The ship turned because of strong wind and sea and the pilot was not observant enough. People were on their way up and had luckily not boarded. The helicopter tipped over and was smashed into bits – and was spread all over the boat in a radius of a couple hundred metres. It was fortunate that people had not gotten in the helicopter at that point. The heliguard was actually standing down there on a lower deck under the helideck and watched. Fortunately, they were not hit by any parts. The rotor blade was drilled into a steel structure. The pilot managed to save himself, but was seriously injured. It was just a coincidence that it went well – ten or fifteen seconds later, there might have been ten people in there. The person that was working on that rig and was part of this experience and saw it, he is one of my heliguards today. I look very closely at him when we are landing or sending a helicopter: He is very nervous, walks and paces a lot – I can *see that he is trying to focus on what he is supposed to do, but he is very nervous, even today – even though this was a few years ago. He had a lot of trouble with it – he says it himself and he is glad that he can still travel offshore. An ugly case – but luckily no lives were lost – it is just luck that it went so well.* (K-12).

This retelling of a traumatic incident gives a small impression of how a colleague is influenced by having been part of an accident. In the story, the interaction of Risk Influencing Factors is documented, and how random occurrences can have significance for the result. If the accident had occurred a little later after boarding, the outcome would have been more dramatic for the passengers. The story does not tell us anything about how the incident was handled by the involved parties, but that at least one person had lasting emotional injury. The person concerned is in a situation were the equivalent activity reminds them of the original incident. Openness about this and support from colleagues and supervisors can contribute to making the job easier to handle.

8.4.3 Critical system error

The data material also includes several stories about serious technical problems, such as the ones described in this story:

This occurred right after the Norne accident – it almost went bad 20 minutes after departure from the heliport and we had to go back. We were received and steered right into a room where we received information, but I don't know – the information we received – I cannot exactly say that "thanks this was good"… . We were told that it was something technical. It turned out to be metallic chips in the gear box. (E-19).

This story illustrates that providing sufficient and good enough information is challenging and requires capable communicators. In line with established procedures, the passengers were taken care of and informed immediately after the incident. The storyteller under-communicates, but he is clearly dissatisfied. This could be because the information was insufficient, and it could be because it was not determined what the reason for the technical problem was. It could also be that the recipients were not able to comprehend what was said because they were still influenced by the incident. As this incident occurred right after the fatal accident on the Norne field, there was probably an even greater need for debriefing and thorough information. It is therefore important to adjust situations and information to the current relevant situation and the framework conditions around it. As it was said in one of the other groups – *"a little information is better then no information"* because then your imagination is not running wild. It was pointed out that the *"dry and brief information"* is best directly after an incident, and you can wait for the facts after a potential investigation. There was agreement that there is often a lot of imagination in the periods in between and speculation and stories circulate among the employees. Therefore it was greatly appreciated that one of the helicopter companies came out after one of the latest helicopter accidents on the British Shelf and called in oil workers by groups to an open meeting. Here facts about the accidents and what measures the helicopter company was going to implement were communicated. With this, the employees had a feeling of being taken seriously and had the opportunity to ask questions. They also received assurances that the company was doing what it could to prevent similar accidents. Others had not received this information after the accident, and it was concluded that it was most likely a question of time, resources and economy.

8.4.4 Personnel incident in the helicopter

There are strict rules for the handling of loose objects in helicopters, and this is the topic of the next story:

A pilot brought his own thermos and made the helideck crew get him coffee. He dropped it right down on his control panel during flight. We do not know if a report was written because we were on the way home. This is a bad thing – you don't need hot dogs, potato cake and coffee on such a short trip. Especially as you do not have time to secure loose objects during an emergency landing, for example. This also regards the pilots' briefcases that are left unsecured in the aisle with thick binders – what if they float out in the water and in the worst case block the face of a man or an emergency exit… a large binder and a briefcase floating around. The thermos was, by the way, commented on the five next trips – "hope this isn't the coffee flight!" (E-17).

The stories illustrate that the passengers closely follow what the pilots are doing – in this case the pilot's handling of his thermos. This falls under the category small indicators which was discussed earlier, and can have great significance for the passengers' experiences and feelings of safety or anxiety. The storyteller reacts to the rules for loose objects being enforced differently for pilots and passengers. *Satire* is used to make a point here: *"You don't need hot dogs, potato cakes and coffee"*. The passengers are no longer served chocolate and coffee during longer flights. The pilot's binders and briefcases were also noted as a potential danger for the passengers' safety because it can contribute to making an evacuation of the helicopter more difficult. The story is therefore a way to communicate differences in status and power between pilots and passengers and different interpretation of rules relating to loose objects. This story also shows that extraordinary incidents are shared with others, they circulate and are retold several times. The story of the *"Coffee flight"* was retold in the coffee bar and was also a *"talking point"* before departure: *Wonder if they have cleaned up the coffee spill?* In this case the processing and communication took place with the help of humour and jokes.

8.4.5 Fear of helicopters

The data material contains six stories about strong feelings and unusual behaviour on the part of colleagues who suffer from fear of helicopters, fear, anxiety, and unrest. We have chosen to use the term fear of helicopters because it has been made evident in the data material that fear of flying and fear of helicopters are not necessarily congruent.

The man was past fifty years old and had a managerial position. He was determined to have his regular seat, but not the single seats which are normal – he wanted to sit closest to the door of the Puma – the outermost seat closest to the door. He was therefore always up first. This was during the time we used the cabin card for tickets, and this was used as a boarding card. If the spark was gone, everyone was up. He (the fifty year old) who then stood up first had not gotten the right colour code, and nobody would help him. He had to go get a new card himself. When he come back, he was blocked out. What the man then did, was to get down on all fours, and crawl between people's legs. Then people moved out of the way so that he could board first. (E-33)

At first the passengers described how some are very concerned with getting their favourite seat in the helicopter. This is one among several stories about different types of "practical jokes" among colleagues before departure from the facility. This can be giving people the wrong directions, or tying the baggage to the people who stand first in line and other "jokes". The joke can, however, turn embarrassing and have unknown consequences such as here – when an older adult leader is "stripped" of his dignity and authority and behaves like a scared child who crawls around on the floor. What starts as an innocent joke can turn into bullying and harassment. Certainly, offshore is a tough work environment with robust men and women, but under the surface, vulnerable individuals can be hiding. In this story, like in many others, you can track the change in emotion, as the story builds towards a climax. In some of the stories about fear of flying among colleagues, you can also trace a development from initial surprise, astonishment, wonder, and then discomfort, pity and respect. In this way, stories become a medium to illustrate the diversity in experienced feelings and expression of feelings in a given situation.

8.4.6 Weather, technology and supervision

As weather and waves have such great significance for if helicopters can land or take-off, it is important that the measuring instruments for this can be trusted. This is the topic of the next story:

We got one of those "beacon" stations out on the rigs that they can read off both on land and in the helicopter – the conditions especially on the floating rigs and the movement on the rig, "pitch & roll", and the wind conditions. Now these can be read, which we couldn't do two years ago. Then it was discovered on my rig two years ago that the "pitch & roll" metre was placed incorrectly – on the centre of the rig – but it is not supposed to be there – but out on the helideck, on that side or one of the sides. So you got a lot less movement – we had read this wrong for 6-7 years and made mistakes. The pilots said time and time again: "That can't be right". One time it was so bad, and I remember that the pilot wanted to come in and see the metre – ok – the rig was right – that's what it said. How much control do we have? It's up to the rigs and that was a problem we had for 7-8 years before we finally got the metre placed where it was supposed to be. We have never had as many cancelled helicopters and delayed flights… someone here has not paid attention in class…could there be more rigs that don't have the equipment placed properly?... One time when we were going down, we could see that the helicopter stopped and hovered for a long time – are we going down on that? We don't see that anymore because now we have the right measurements. (E-15)

This is a story full of astonishment – astonishment that this weather metre was not correctly placed and installed, and that so many years can pass before anyone discovers it – what about inspections of this type of technology? (*"here is somebody who hasn't paid attention in class"),* that people react during the flight (both passengers and pilots), that you trust the measurements more than your own experience-based data (*"the rig was right"*), that nobody asks questions when there are repeated cancellations. In conclusion the storyteller asks if this situation could be happening on other rigs. Such cases do not contribute to building trust, but make the person concerned ask direct and indirect questions about control, safety, supervision and responsibility.

The next chapter is about another player who also produces stories about risk tied to helicopter transport.

8.4.7 The media's role as an information source and a producer of stories

The need for information among the employees is great in connection with incidents or accidents tied to helicopter transport. The chosen stories and other data documents that many companies and individual players are professional and ensure good follow-up and information. Unfortunately, there are also several cases where information is deficient or lacking. Then speculations easily occur and imaginations can run wild, as it was said. A central source of information for the oil workers is therefore the media – especially television, and the tabloid and web newspapers. Since the conversations with the oil workers occurred right after three helicopter accidents on foreign shelves, there was much discussion about this topic. One told that there were foreign colleagues from a neighbouring field on the UK Shelf who were involved in one of the accidents. Many sought more information, and said that both themselves and their colleagues did not hesitate to look in the online newspapers. That way, they at least got some information. If the media becomes the only source for information it is important to remember that the media has several agendas: They aim to inform the general public, but they are also selling a product. To make a good story, the media uses emotion – generally strong emotions. They also make sure that special, dramatic, and negative incidents get a lot of coverage and large headlines. The special and dramatic incidents sell, but when everything is working well there is no "story" to write about. One of the instructors of the class commented how the media over-dramatises incidents and calls everything an emergency landing: *"In reality it could be an aborted flight due to indicator error (where according to standard procedure you must turn back), or a real emergency landing due to serious system error."* With inaccurate use of different categories and the merger of small incidents to a large collected category ("emergency landing"), the media can construct a reality which exaggerates the occurrence of technical problems. This is not the type of information that contributes to calm people who are already watchful or insecure. Therefore it is important to supply information that can provide a more nuanced picture than the media-created stories (see also Renn 2008:127 about the media's significance for perceived risk).

8.5 Scale for perceived risk and changes in risk experience

In the focus group interviews we asked each participant to quantify and rank perceived risk connected to the use of helicopters. In addition, they were asked to compare it with a related activity – airliners – where they are also not in the driver's seat. The participants were asked to use a scale from 1 to 10, where "1" is the lowest risk and "10" is the highest risk. The results show a large variation in the answers and a variation band from 1 to 7 for helicopters and from 1 to 4 for airliners. These numbers are used to illustrate some tendencies and important points. Since the data material is so small, it is important to not generalise on the basis of these numbers. The tendency in the data material points to helicopter transport being considered as more risky than airliners by most, but there were also some that came to the opposite conclusion. Most of the participants did not think that there were any particular dangers associated with flying either helicopters or airliners, with some exceptions (the few who answered 7 on the scale). It can also seem as if there was greater disagreement on how safe it is to be transported by helicopter instead of airliners, since the variation band was larger. In the Lie and Ringstad (1998) study, helicopters were considered less risky than cars, but more risky than airliners.

The participants were also asked to state the reason why they chose exactly these numbers when they gave their answer. In this connection, this is just as, or more interesting as the exact numbers. In the reasoning for why they chose a given number on the scale, it became clear that the participants have very different reasons. Some gave their answer based on the *statistical risk* of being in an accident. Others gave their reason based on the *chance of surviving* in case of an emergency landing or plane crash. Others brought up the difference of emergency landings in "warm regions" and emergency landings in the North Sea with large waves, bad weather and cold water. Others were concerned with the *scope of technical error indications and problems on the helicopters*, (cf. the use of the compiled category "technical" during cancellations and aborted flights). A last group based their answer on *specific situation-dependent factors.* As an example, there was one person who said that, because in recent years there had been several helicopter accidents abroad have gone up a number or two on the scale in the days immediately after, as compared with before these accidents. Since the same helicopter type was now being checked for this type of error, he chose a lower number on the scale. This illustrates that quantification of perceived risk is situation and context dependent and is not a constant number. In interpretations of scales for accident risk, it is therefore important to be aware of the diversity in how the question can be interpreted and what the scale comprises.

We asked the participants if their perception of risk had changed in recent years since both the helicopter fleet has been renewed and the protective equipment has improved. To direct questions, the participants answered that they perceive being transported in helicopters on the Norwegian Shelf as *"relatively safe"*. Some pointed out that very much has happened since the beginning of the oil adventure, where the conditions were more characterised by the *"wild west". " Then we were more or less stuffed into a helicopter and that was that"*. It is said that, today, there is systematic work with safety in all segments. This has contributed to increase the feeling of safety. Many are satisfied with the improvements that have come in recent years, and mention factors such as better information, regular classes in helicopters tipping over, improved survival suits, and more room in the new helicopter models, music and radio to listen to during transport (and for some, personal headsets). The survival suits have been steadily improved and are now very good, in contrast to what some had experienced other places in the world: *"The survival suits were made of thin material and it looked like they had bought them cheap from Smart Club."* This is yet another example of small indicators that have significance for the perception of risk.

Even though helicopter transport on the Norwegian Shelf is perceived as being safe, one person pointed out that increased safety is an important goal, but the "safety first" mentality is a utopian idea. There will always be a weighing between costs, quality and efficiency. Therefore a certain risk is always calculated – also in helicopter transport. He illustrated this in the following way: "*Then every man would have had his own window in the helicopter..".* Another said it like this: *"When there are always technical problems, you start asking yourself: What are they [helicopter operators] flying with? Why can't they just tell us if the pilot needs resting time?* This illustrates that, even though employees say that they believe flying with a helicopter is safe, there are also a lot of questions hiding under the surface. Another participant commented on paradoxes and mixed messages from the management: *They claim that it is so dangerous to fly shuttle between the platforms (especially take-off and landing), and instead us workers have to walk between platforms that are connected.* Others had made their reflections after the last period's helicopter accidents on other shelves: *"What about all the safety measures? Or is it really bad luck each time? We just have to hope that it (the helicopter) doesn't go down!".* This shows that employees start to ask questions and ponder about safety after incidents or accidents. Some pointed out that there have been quite a lot of issues with the new helicopters (technical problems, things coming loose, unintentional release of floatation gear). It was said that these issues contribute to uncertainty as to whether they really were safer.

The data material illustrates in this way that there is a double standard in relation to the term perceived risk: On one hand it is something the employees discuss among themselves, and this has been illustrated through the analysis of stories that are told and retold. On the other hand, there are specific topics connected to risk that they do not normally discuss. This is, in part, due to it being a part of the working conditions, but also a form of coping. As one said: *"You shouldn't think about or make a problem out of everything, because it will just create unnecessary fear"*. As long as everything goes well, this topic does not receive much attention. Critical incidents or accidents work as a catalyst to bring such topics to light. Some concluded that you can never be a hundred per cent safe, neither in planes nor helicopters. Risk and Risk Influencing Factors can therefore become a "silent" topic because it "threatens" the employees' experience of control and coping.

The employees were also very concerned with changes of significance for perceived comfort in helicopter transport. Overall, there are a lot of things that are good and have been improved, but there are still details that contribute to less than optimal comfort. This can also be connected to expectations not being fulfilled. The straight seat back ("church chair") in the latest Sikorsky (S-92) is an example. Sitting in the back of the Superpuma is uncomfortable because it is cramped, and there is little air. Many think that the helicopter ride is a noisy experience, and wonder why it is so difficult to make a helicopter with less vibration that is more comfortable to sit in. The different helicopter models are also given names: Sikorsky S-61 was called the "*King"* because there was a lot of room, good ceiling height, and the passengers were seated like in a bus – *"a super helicopter"*. The newest model, S-92 is called the *"Hangar Queen"* because there were so many issues with getting the bugs out and "*technical trifles"* during the phase-in. The Superpuma is slim and elegant, but very cramped – originally a military aircraft designed to watch over French trains, it was said. The pilots might notice that the new Super Puma is better, but *"there are no benefits for us in the back"*. Some therefore call the helicopter transport "*cattle transport"* where the passengers are "stowed together" in a small area.

Safety is highly prioritised in Norway, and the participants comment that this is connected with both the Norwegian culture, the historical development of the oil industry, regulatory authorities and how the Norwegian model for employer/employee relations has been practiced within the oil industry. It was also underlined that it is in the entire industry's interest that the image of security and safety is maintained. However, there are forces that put this under pressure. In a situation with tightening budgets, and cost efficiency measures and constant pressure on prices, there are some that express a certain fear and anxiety. Employees are worried that, in a situation like the current one, with too few helicopters and problems with a shortage of pilots, there is too much time pressure. They also fear that the time perspective for mechanics that perform maintenance will be too tight because it costs too much to keep a helicopter grounded and results in penalties. It is therefore important that the authorities and companies follow up this development.

8.6 Data and method

As this part of the HSS-3 project is about the oil worker's experiences and how they reflect on risk and helicopter safety, a quantitative approach was appropriate.

8.6.1 Approach

A qualitative method is used to investigate humans' knowledge and experiences. In an exploring and qualitative research design, meaning and interpretation are crucial. An important point is to get to the "inside" and get the subject's own assessments, seen from their viewpoint. This differs from the more distanced situation where the expert's/researcher's understanding and categories are examined. In a qualitative research design, totality and depth are important in a search for connections, as well as research of phenomenon in light of the framework conditions that apply. Flexibility is another important trait because the situation and data collection can be adjusted along the way, as new aspects emerge. These can be completely different things than what the researcher had in their interview guide. Approach and method are not just a means to describe a reality, they also contribute to create it. In qualitative research, the data material emerges in a dialog with the researcher. Part of the strength of qualitative research is in-depth knowledge, but also to uncover multiple meanings, contradictions, and the complexity of a phenomenon.

8.6.2 Implementation, data collection and selection

Observation, interviews, stories and document analysis are central data collection techniques in qualitative studies. In the beginning of the study, document studies were carried out of available material (official documents, reports, media publicity) as well as some simple literature searches.

Interviews
Two telephone interviews with representatives from the labour unions LO/IndustriEnergi and SAFE were conducted to acquire a greater background for what they and their members are concerned with as regards helicopter safety offshore. One of the instructors in the helicopter evacuation course was interviewed about helicopter safety, the underlying philosophy, and the structure in the course setup, the participant's reactions and the occurrence of fear of flying.

Focus groups
A focus group is a group interview with a limited number of people that meet to discuss a smaller number of topics, and where the researcher's role is to guide the process. The method derives its strength by inviting the participants to share their experiences, and answer questions of the type "how" and "why". To achieve a god dialogue, it is most suitable to gather persons that are on the same organisational level. The dialogue between the participants helps generate new data and joint learning. The topics for group interviews were tested in a pilot study among three colleagues that travel offshore from time to time. The analysis of this data material contributed useful insight into some specific topics that were followed up in the group interviews.

Stories
Stories are a data source that, to a lesser degree than many other techniques, is influenced by the researcher's collection techniques. This is a growing research field within several disciplines. Here we have used this type of data material to achieve a broader intake of how and what employees talk about regarding the topic perceived risk. Stories communicate knowledge differently than short, fact-based descriptions. All the stories were written in a short version in a table format. In the table, the stories were numbered, and the short version was written (what happened, who and what was involved and what the result was, and a separate column with the storyteller's comments and end evaluation).

Strategic selection
The target group for the study of perceived risk is employees on facilities offshore, and we have a strategic selection of persons. To ensure variation in the selection, we wanted participants from different types of occupational groups that work on fixed and floating facilities. To limit time and use of resources, we contacted a department at FalckNutec, which conducts classes in helicopters tipping over. We were met with great enthusiasm and received permission to recruit among the participants of a refresher class in helicopters tipping over. The setup of the perceived risk study is approved by the data protection delegate, Norwegian Social Science Data Services (NSD). A letter containing information about the project and a consent declaration were distributed to potential participants at the start of the course. Those who wished to participate notified the course management, and the participation occurred during the breaks on the course day. Everyone who signed up was able to participate and were assured they would remain anonymous.

The length of the interviews lasted from 40 to 90 minutes depending on the length of the breaks. There were two researchers who participated as observers of the pool exercises during the first visit. One of the researchers was responsible for carrying out all the focus group interviews. In addition, we conducted one interview with a course instructor and had informal conversations with several of the other instructors. During the third visit at the course centre, the researcher participated in the theory part of the course and the practical exercises in a pool. This contributed to insight through informal conversations with the participants. A detailed overview of the background data for the participants is presented in Table 8.2.

Table 8.2. Background information about the participants in the focus groups.

Gender	Age	Position	Number of trips per year	Type of facility	Type of company
25-03-09		***Focus group 1***			
1. Man	51	Independent	Varies	Ship	Consultant
2. Man	48	Deck Supervisor	8–9	Fixed	Drilling
3. Man	38	Process technician	8–9	Fixed	Operator
25-03-09		***Focus group 2***			
4. Man	39	Crane operator	-	Floating rig	Drilling
5. Man	44	Subsea engineer	-	Floating rig	Drilling
6. Man	38	Mechanic	-	Fixed	Operator
22-04-09		***Focus group 3***			
7. Man	45	Work leader deck	10	Production ship	Production
8. Man	53	Crane operator	9	Floating rig	Drilling
22-04-09		***Focus group 4***			
9. Man	55	Surface treatment technician	6	Fixed	Supplier
10. Man	33	Mate	6	Floating rig	Drilling
11. Man	50	Rigger/turret	10	Production ship	Production
22-04-09		***Focus group 5***			
12. Man	41	Chef	8	Production ship	Operator
13. Man	36	Rig mechanic	12	Fixed	Drilling
14. Woman	38	Engineer	3–4	All	Operator
15. Man	46	Operations manager	4	Fixed	Operator
16. Man	46	Chief electrician	8–9	Floating rig	Drilling

The data material satisfies several demands for variation: The age of the oil workers in the focus groups varied from 36 to 55 years, with an average of 44 years. There is only one woman represented, and this is as expected from the gender division in the industry and in the courses. There is a good distribution of types of occupations, and the table shows that management is also represented. Most frequently fly by helicopter, with the exception of one person who only visited facilities sporadically. All had long terms of service offshore. Here the variation was from 8 to 25 years, with an average of 13 years. This is a pretty even distribution between type of facility, and fixed facilities, floating rigs, and production ships are all represented. Different types of companies are also represented: Operator (two different companies), drilling (six different companies), production (1), supplier (1) and consultant companies (1). As the data material contains retellings of incidents that colleagues have experienced, the study covers stories from a larger selection of oil workers than the 16 persons that participated.

8.6.3 Analysis and generalisation

In a qualitative method, the data collection and analysis do not occur in two separate phases, but the analysis is conducted along the way. This gives rise to new questions, new acknowledgements and enables changes in the setup along the way. All the interviews were digitally registered, and main points were noted during the conversations. All the stories were written verbatim as they were told. In the analysis the following have been used 1) A systematic strategy based on coding and grouping of the data material, and 2) A more pure interpreting strategy, with emphasis on the players' own experiences and how they interpret a situation and relate to it. The collected data material is rich, and covers a large spectrum of topics. The analysis was time-consuming and was conducted in several rounds. In this report, we have highlighted central themes in relation to the problems. Therefore, there are themes we have not analysed, e.g. viewpoints on culture differences between Norwegian and international conditions, and the value of helicopter safety courses. The employees own stories have been important in the analysis work. First, the main topic of the stories was written in a table. Then the stories were coded and grouped in main categories. These stories have been analysed in several rounds over a period of time. Distance to the material is important to synthesise and discuss the findings. Quotes were used to personify the account and lend voices to the subjects. Also, a selection of the stories are retold as they were told, and central main traits are analysed: The analysis concerns who was involved, what the players did, what was the outcome, which emotions were involved and how they were expressed. The stories are marked *S* for self-experienced stories, or *C* for colleague stories. The number behind states the placement in the overview of all the stories. With regard to data protection and anonymity, other personal traits of the storyteller are omitted. Also, not all the stories can be related to a specific person when they were told in a group interview. In cases regarding colleague stories, detailed personal information was not always provided.

The goal of qualitative research is to not substantiate that the findings can be generalised to the whole population, in this case all offshore employees. In essence, how many people have experienced a given situation is not a determining factor, but rather that this type of experience or knowledge exists. Such analyses can, however, contribute to increased in-depth knowledge and to provide nuance in existing knowledge about the topic perceived risk.

8.7 Conclusion and recommendation

The analysis of perceived risk has contributed to increased insight about the passengers' experience of the risk during helicopter transport, and documented that this is a complex and complicated phenomenon. The interviews with the oil workers and their stories illustrate that there are several factors and what we have called "small indicators" that have great significance for perceived risk. The topic of risk in relation to helicopter transport is, on one hand, not something that bothers them daily, at the same time as the stories from their own and others' experiences of critical incidents show that this is something that concerns them. These stories are retold and fill several functions. They are an important source of coping and knowledge sharing, as well as providing input to what can be improved. The analysis shows that quantification of perceived risk is context and situation-dependent: Most of the participants did not think that there was great danger associated with helicopter or airplane flight. The results show a large distribution and a variation span on an assigned scale, from 1 to 7 for helicopters and from 1 to 4 for airliners. Several areas for effort are identified, from practical help for first time travellers to more extensive measures and investments, cf. Chapter 8.2.4. It is recommended that these suggestions are thoroughly considered. In SINTEF's assessment, this regards the following suggestions:

- Make the safety videos less 'serious' (scaring) and stimulate the passengers to support each other socially, in particular those travelling for the first time and feeling uneasy
- Consider choice of seat in relation to specific needs as perceived risk varies with seating location
- Consider a possible weight limit for offshore workers in order to facilitate evacuation in emergency situations
- Improve the communication equipment in the helicopters and train the pilots to give clear and evident information (Passenger Announcement; PA)
- Fasten loose equipment in the cockpit (pilot's suitcase, manuals etc.)
- Increase awareness of the heliguards as to their behaviour; notably to pay specific attention to those travelling for the first time, plus assisting passengers embarking/
  disembarking in bad weather condition (wind, helideck movements)
- Minimize exemptions from recurrent training for helicopter ditching
- Improve communication of credible information after incidents. (Correct information will reduce insecurity among the passengers.)
- Extend the project "Risk level in Norwegian petroleum industry" (RNNP) with new questions related to quantitative mapping (see the proposal in Chapter 8.2.5)
- Expand the next editions of RNNP with a specific qualitative part on helicopters.

9. INDICATORS FOR HELICOPTER SAFETY

9.1 Safety philosophy and safety indicators

There has been a development in the safety philosophy over the course of several decades, and this will also influence the goals that are formulated, and therefore also which indicators are defined. With a point of departure in the latest edition of ICAO's "*Safety Management Manual"* (SMS, 2008), Hale and Hovden (1998) and Reiman and Odewall (2009) describe a development in safety management from the 1950s until today. In different time periods there have been different focuses regarding the most important measures for improving and monitoring safety.

- **From 1950: "Technical era"**
  Focus on technology development, "en-route" aviation becomes safer (measured in the number of accidents). The main question in the period: Are all technical barriers in place to maintain technical reliability to prevent accidents? In this period the main interest was on the reporting of technical factors associated with accidents.
- **From 1970: "Human factors era"**
  Focus on the human factors in accidents led to, among other things, the implementation of *Crew Resource Management* (CRM) and *Line-Oriented Flight Training* (LOFT). The main question in the period: Are the necessary measures in place to identify, prevent and reduce the effect of human errors?
- **From 1990: "Organisational era"**
  Focus on how the operational context can influence performance. Aviation becomes more open to the concept "organisational accident", and you can see the start of a barrier philosophy that includes technological, human and organisational barriers against accidents[10]. Main question in the period: Are the necessary measures in place to identify and prevent organisational errors and to promote a good safety culture?
- **From 2000: "Systemic era"**
  In this period *Resilience Engineering* is suggested, which is influenced by *Normal Accidents Theory* and *High Reliability Organisations*. In *Resilience Engineering* you look at both what is wrong, and also what is going well. This will provide a more realistic approach, with a system philosophy where interaction between humans, technology and organisation occurs in a dynamic context (not necessarily linear relations). The main question is: Does the industry have understanding of complex connections that cannot be based on linear connections and include technical, human and organisational "era".

For all periods ("era") it will generally be the case that formulations of safety goals is influenced by prevailing views of what are the most important risk contributions. Traditionally, safety measuring in aviation has been based on lagging indicators, e.g. the number of accidents per million flight hours or the number of non-conformities (technical or operational). The accident rate is divided into different categories, to identify safety measures. Examples of categories are CFIT (*Controlled Flight Into Terrain)* or LOC-I *(Loss of Control In flight)* or accident categories stated in Chapter 1.5. This categorisation has enabled us to focus on possible safety improvements. The current systems and organisations must operate with a

[10] Among other things, public report NOU 2001: 21 points out how organisation of official agencies influences helicopter safety.

context that is under constant change and increasing vulnerability (e.g. changes in framework conditions described in Chapter 4.2 and the conclusion in Chapter 4.2.7.). In this setting there is a need to find indicators that will help the organisation to identify changes that influence risk, and implement risk reducing measures to act before something occurs. Therefore there is an increasing concern that an approach only based on lagging indicators, does not provide a sufficient basis to avoid future accidents. There is a need to identify indicators that provide a more comprehensive picture of the current situation. In addition, there is a need for indicators that provide information about changes of significance for future conditions, i.e. *leading* indicators.

The absence of accidents and unwanted incidents is not necessarily a sign of good safety development. Many companies have introduced the use of lagging and leading indicators to monitor the safety condition. The International Civil Aviation Organisation (ICAO) recommends the establishment of a Safety Management System (SMS). Even though SMS contains both lagging and leading safety management, aviation is still characterised by a focus on the lagging indicators. This could be because the leading indicators can not always be shown to have a direct connection with the safety level, while for the lagging indicators the connection is obvious.

Therefore, as a part of the HSS-3 project, there will be a need to define goals based on "new" goal indicators, not just counting all the incidents/errors. The objective here is to suggest leading indicators to monitor safety and identify possible trends in the development of the risk/safety level. This will comprise the following topics:

- Assessment of the current incident and activity indicators used in RNNP and public report NOU 2002: 17, Chapter 4.2.
- Description of methods for identification of safety indicators
- Suggested indicators
- Conclusions

The work is limited to indicators that are connected to major accident risk. Risk of work accidents is only covered to the extent that the working environment and psycho-social conditions are related to the major accident risk.

9.2 Resilience Engineering (complement to linear models)

In a resilience engineering perspective, safety is not just about reduction or elimination of negative outcomes. Resilience engineering views safety as the ability to succeed during continuous changes in framework conditions. Resilience is defined as the ability to handle risk. It views the system's ability to maintain operability before, during and after changes and disturbances in relation to expected and unexpected factors. Resilience engineering is particularly important for development of principles, models and methods as support in organisations that set high demands for safety performance.

Several renowned researchers discuss that linear accident and risk models have greater limitations in representing complex dynamic factors found in today's socio-technical systems (Amalberti, 2001; Dekker, 2004; Leveson, 2001; Woods & Cook, 2002; Hollnagel, 2004). Lately, systematic models and methods are being developed to take into consideration the non-linear interaction between functional elements. An attempt is made in HSS-3 to identify indicators that provide a picture of the current situation. Therefore, a functional risk model is taken into consideration that also looks at non-linear interactions for a socio-technical system. The system is described with the aid of functions. This is built upon a functional model that describes normal operations (things that go well). And when the model describes how things are going well, it can also be used to understand why things go awry. A classic risk model focuses on things that can go wrong, while a functional model focuses on normal variability in the system and takes variations in the execution of daily operations into consideration.

In HSS-3, the functional modelling and the resulting identification of indicators is based on Functional Resonance Analysis Method (FRAM, Hollnagel, 2004). The goal of identified indicators is to evaluate the current situation and work to improve safety. A FRAM modelling of functions in relation to the RIF-model in HSS-2/HSS-3 was carried out. Furthermore, the scenario "landing on helideck" was chosen to identify indicators.

The objective of FRAM is to describe the dynamic and non-linear interaction. A FRAM analysis is carried out in five steps:

Step 1. Defining the objective of the analysis. FRAM can be used as risk analysis (assessment of future events) and as an accident investigation method (assessment of past events).

Step 2. Identify and describe relevant functions. A *function* in FRAM terminology is an activity or a task which has important or necessary consequences for the state or properties of another activity. The result of this step is the model itself. Every function is described with the help of six aspects, Figure 9.1; *"Input"* (I, what the function uses or changes), "*Output"* (O, what is produced in the function), "*Preconditions*" (P, conditions that must be fulfilled to carry out a function), "*Resources*" (R, resources that are necessary to carry out a function), "*Time*" (T, time that influences the function's availability), and "*Control*" (C, monitoring and controlling the function).

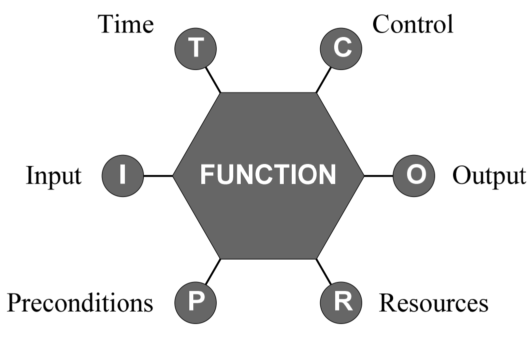

Figure 9.1. The six aspects of a FRAM function

Step 3. Determine and assess the potential for variability for each function. FRAM differs from the background and foreground factors that can influence the variability of a function. Foreground factors are directly associated with a function (for example the input to a function), while background factors refer to factors that can influence one or more functions over a period of time (for example competence).

Step 4. Identify dependences and possibility for functional resonance. Based on Steps 1-3 we can describe how functions influence each other. In a dynamic modelling you put together functions that are "active" in a specific interval with the use of instantiation in a specific time interval. For each instantiation/time interval, dependences are defined, as well as which dependences are critical for a successful operation. It is possible to see how variability in a function is transmitted further in the system. Functional resonance occurs when a combination of variability can lead to the system losing control. In FRAM, functional resonance can contribute to an unintentional operation that can lead to the system losing control, or to a prepared unintentional operation. An example of an instantiation in HSS-3 is the planning of landing which is carried out one hour before departure, see Figure 9.2.

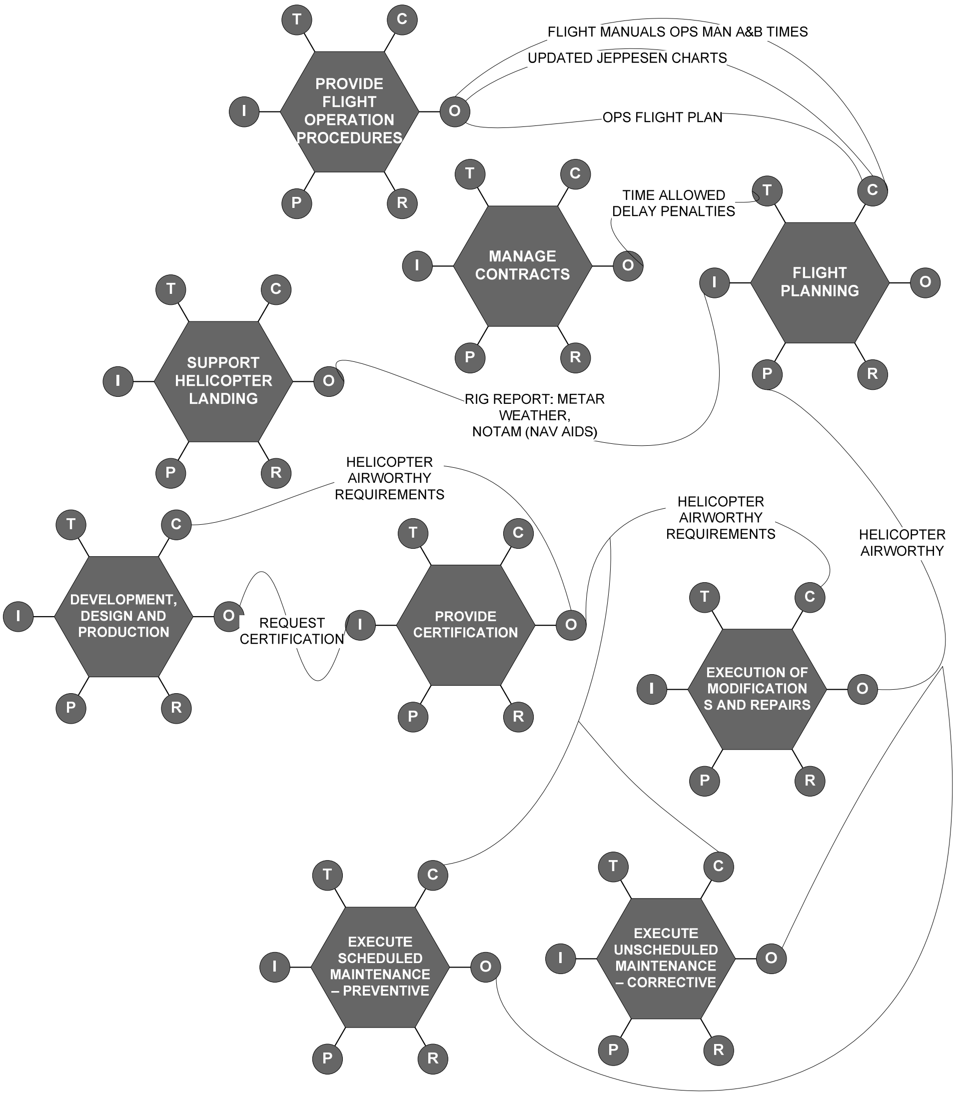

Figure 9.2. Selected elements of FRAM for scenario landing on helideck.

Step 5. Suggest improvements. In this step, barriers are suggested that can dampen variability that results in unwanted functional resonance and therefore loss of control. Measures that can contribute to improved performance are also suggested. In FRAM, one of the measures can be to suggest indicators to monitor the system's performance and variability, and with that, receive early signals of changes that can influence risk. This will contribute to identifying unwanted variability and how it influences the system's performance. The helicopter study will focus on critical dependences, and indicators to monitor the variability are suggested. In this connection, indicators that influence the performance of functions are identified. Interpretation of indicators can provide information about future performance. Therefore, the indicators can be regarded as leading.

9.3 Assessment of the current indicators that are used in RNNP and public report NOU 2002: 17

The annual RNNP report presents the development in three incident indicators and two activity indicators for offshore helicopter transport. These indicators have been registered annually, starting from the year 1999, and they are presented and assessed below.

- Event indicator 1[11] includes "most serious events" that are defined based on the incident type and the degree of severity. The most serious events include the categories *aviation accident* with a severity degree of high, medium and low, *aviation incident* with a severity degree of high, medium and low, and *operations occurrences* with a high severity degree. Events with a severity degree of *minimal* and events where the helicopter is in a parked phase have not been included.

- Event indicator 2[12] includes the same as in Event indicator 1, as well as *occurrence* with a severity degree of medium and low, and incidents where the helicopter is in the *parked* phase. Incidents with a minimal severity degree have not been included.

- Event indicator 3[13]. The severity degree in the incidents included in Incident indicator 3 are the same as in Incident indicator 1, the only difference being that incidents related to the *parked* phase are included here, while they were excluded in Incident category 1.

- Activity indicator 1 concerns the volume of ground transport service per year.

- Activity indicator 2 concerns the volume of shuttle traffic per year.

RNNP 2009, does not consider these indicators as being sufficient to monitor helicopter safety. Among other things, they do not reflect much upon the improvements related to redundancy and robustness provided by the new helicopters. Further work will therefore be conducted to improve the indicators. It is also pointed out that incidents connected with removing the technical nuisance alerts with the implementation of new helicopter types (S-92) tend to be categorised as relatively serious incidents, and that an increase in the number of incidents is therefore not necessarily a reflection of increased risk.

In each edition of RNNP, an attempt is made to explain the cause of trends and deviations (for the number of incidents given in these indicators). No limit values are used to indicate that the risk level may be too high. In SINTEF's judgment, the indicators in RNNP work well regarding looking at trends and developments in the past. However, the indicators are not very proactive, and they are less suited to evaluate trends in the future. It must also be mentioned that the indicators provide limited information, and questions can be asked as to how representative the incident indicators are for the accident risk. The indicators present a rather one-dimensional picture of the safety/risk and they do not consider the framework conditions and influences from the operational context.

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[11] Incident indicator 1 includes, according to RNNP, on average 10 incidents per year in the period 1999–2006.
[12] Incident indicator 2 includes, according to RNNP, on average 158 incidents per year in the period 1999–2006.
[13] Incident indicator 3 includes, according to RNNP, on average 13 incidents per year in the period 1999–2006.

In public report NOU 2002: 17, Chapter 4.2 has the following suggestions for indicators:

a) The number of fatalities per million person flight hours.
b) The number of aviation accidents per million flight hours.
c) The number of fatalities per year in connection with helicopter traffic.
d) The number of registered serious aviation incidents and aviation incidents per year or per million person flight hours.
e) The number of occurrences per year or per million flight hours.
f) The number of registered technical and operative deviations per year or per million flight hours.
g) Subjective (perceived) risk.

Indicators a), b) and c) essentially measure the same thing (given fairly steady annual traffic). Indicators d), e) and f) can build upon a large number of reports. But the reporting routines will change with time. It is also a challenge to choose the reports that are *relevant* enough to be included in an indicator basis. Indicator g) is based on questionnaires (e.g. scale 1-5) with questions like: More dangerous than before? Helicopter versus airplane? Here HSS-3 has suggested other questions with consideration to perceived risk (see Chapter 8.2.5).

As regards the indicators e) and f), it can be asked whether the number of occurrences and the number of registered deviations are good risk indicators for helicopter transport, when the risk is measured in the number of fatalities per million person flight hours. These lagging indicators will provide information about the result of helicopter activity, but not sufficient information to help organisations that are undergoing change to act before something happens. Along these lines, we have to use these lagging indicators as signals of areas that need improvement. Therefore our helicopter study will continue to use one set of lagging indicators to determine the current situation, but will also use leading indicators.

9.4 Approach to identify and assess safety indicators

The suggestion for indicators has resulted from a mapping of existing literature, research in progress, interviews and a seminar with people from the helicopter industry. The current indicators are, as mentioned, often based on the number of undesirable incidents, and is not considered to be satisfactory.

Based on experience with the use of safety indicators from other industries and through a study of literature, a lack of consistency has been found between the definition of lagging and leading indicators and their use. There is therefore a need for a more precise definition and use of different indicator terms in any context, (Hopkins, 2007). HSS-3 suggests the use of two categories:

- *Lagging indicators;* measure the result of undesirable incidents in the form of damage or loss
- *Leading indicators;* show the current condition, where interpretation of some of them can be used to predict future safety performance (safety level).

There are several *criteria* for what is considered to be a good safety indicator, cf. extensive discussion about indicators in literature (e.g. Safety Science, 2009). In HSS-3 there is a need for a pragmatic choice of criteria for the evaluation of indicators. The choice of criteria is based on the literature study, discussion with researchers from different environments and presentations in national and international forums. There is not necessarily an indicator that will fulfil all such criteria, but it is at least expected that a joint set of good safety indicators fulfil the following criteria:

- Relevance (meaning): The value is presumed to be (strongly) correlated with either accident frequency, or consequence; potentially with (important) RIFs (Risk Influencing Factors in the risk model for accidents/incidents) or with FRAM functions, variability (risk model for normal operations)
- Availability: Data can be acquired at a reasonable cost.
- Reliability: Data is regarded as being objective and without significant sources of error.
- Operability: The indicator can be used to identify concrete measures in an operational context
- Ownership: They are "owned" by the players that the indicators are used to measure (for example pilots, maintenance personnel or air traffic controllers).

A number of interviews have been conducted with individuals/experts to evaluate the suggested indicators with consideration to these criteria.

With the basis in the discussion above, we have come to several suggestions for leading and lagging indicators for helicopter safety with the use of different techniques:

1. Existing suggestions stated in literature / previous studies, particularly
   a. The then Accident Investigation Board for civil aviation and railroad (herein referred to as the HSLB study); currently the Accident Investigation Board Norway (for transport), AIBN, 2005)
2. Suggestions based on risk modelling (the RIF model in HSS-3).
3. Suggestions based on modelling of normal operations with the use of a case study (i.e. based on a resilience engineering perspective), several meetings.
4. Seminar/work-shop with operative, technical, air traffic service and customer personnel
5. A number of interviews have been conducted with individuals/experts to evaluate the suggested indicators in relation to the criteria.

In the HSBL study (2005), suggestions are provided for different performance indicators for aviation safety. Here, indicators are chosen based on the existing data. There are suggestions for 43 different performance indicators for aviation safety, divided into five lagging indicators (called result indicators in the HSLB study) and 38 leading indicators (called activity indicators in the HSLB study). In the HSLB study, a review of the indicators was carried out together with the Swedish Civil Aviation Authority to identify indicators that are relevant for major accidents. The indicators were used to arrive at a comment about the safety development in Norwegian commercial aviation from 2000 to 2004. One of the conclusions from the study is that indicators based on considerable quantitative information should be complemented with qualitative information.

Furthermore the risk indicators can be based on an RIF (which has considerable influence on risk). Important RIFs on an operational level are related to technical and operational factors, helideck and Air Traffic Management (ATM). Relevant indicators can be based on the number of incidents that can provide information about the condition of an RIF; primarily an RIF on an operational level, see the influence diagrams for frequency and consequence respectively. Some examples:

- Technical RIFs; the indicator can be based on, e.g. the number of times you have:
    - Windshield cracking
    - Chip warning
    - Door open warning
    - Oil leakage detected by walk-around
- Operational RIFs; the indicator can be based on, e.g. the number of times you have:
    - Overload of cargo
    - Incorrect marking or improper handling of dangerous goods in cargo
    - Fuelling event
    - Flight planning, e.g. wrong/missing charts in flight folder
    - Go-around / Missed approach / Aborted landing due to weather
- Operational – Helideck RIFs; indicators can be based on e.g. the number of times you have:
    - Crane or other obstacles on rig near helideck
    - Incorrect helideck position
    - Incorrect information of pitch/roll/heave rates from moving helidecks
- Weather and other RIFs; the indicator can be based on e.g. the number of times you have:
    - Incorrect weather information or weather forecast
    - Bird strike

A third possibility is to take a point of departure in a resilience engineering philosophy, based on Functional Resonance Analysis Method (FRAM, Hollnagel, 2004). As an example of the use of these principles, we have analysed normal operations with landing on helidecks with the goal of preparing alternative indicators. This approach will help us understand how safety is created through normal activities. Through the FRAM analysis, we established that the following functions are relevant for landing on helidecks:

- Development, design and production
- Execution of modifications and repairs
- Certification
- Execute scheduled maintenance - preventive
- Execute unscheduled maintenance - corrective
- Provide flight operation procedures
- Manage contracts
- Manage competence
- Perform weight & balance calculations
- Manage procedures
- Approach planning
- Fix approach on GPS
- Do prelanding preparations
- Arrive to minimum descend
- Approach near by obstruction
- Establish visual
- Decide approach type
- Verify position
- Land
- Perform landing check list
- Support helicopter landing

Using FRAM modelling, it has been possible to produce a dynamic representation and identify significant indicators for a successful operation. Dynamic representation is based on several selected elements of landing on helidecks ("*instantiation*"), which is shown in Figure 9.3.

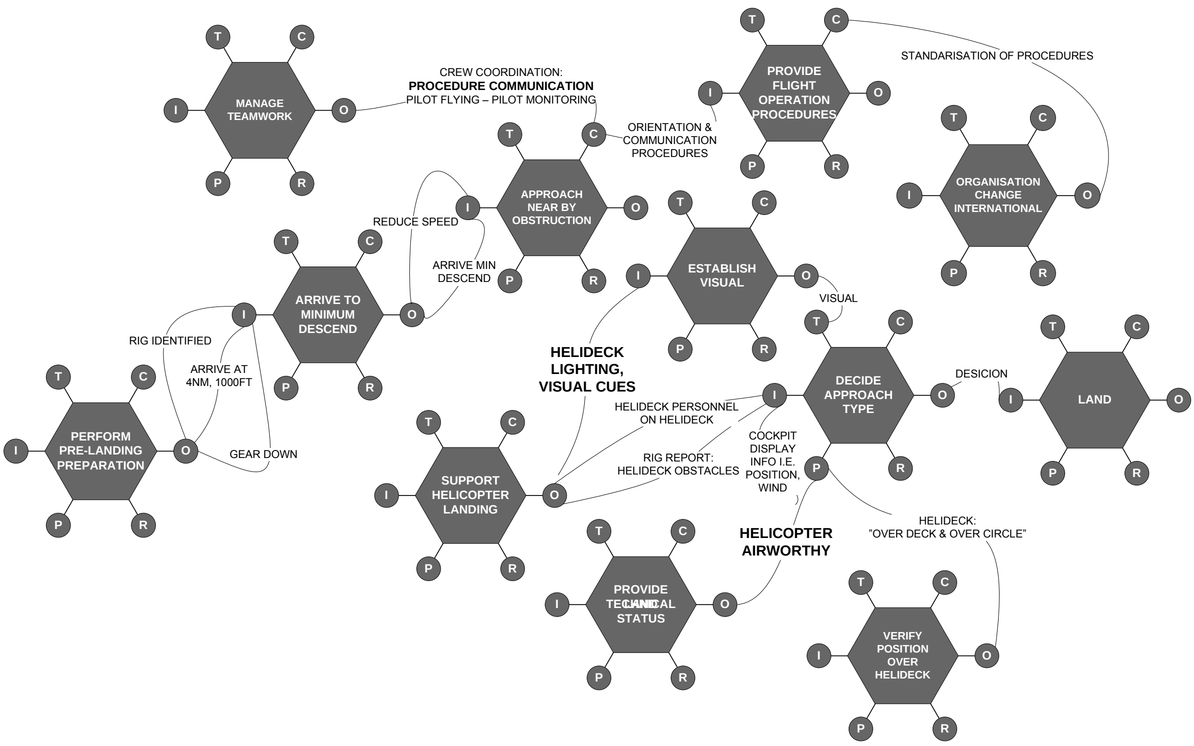

Figure 9.3. Selected elements of FRAM for landing on helidecks during night-time conditions.

Landing on helidecks is modelled for landing on fixed and floating facilities during daytime and night-time conditions. In this way, indicators have been identified which are relevant and tied to the performance of functions in an operational context. These indicators provide information about future performance that can be interpreted with the use of the FRAM model. Therefore, the indicators can be regarded as leading. Identified indicators are related to a more qualitative approach which complements other identified indicators. To operationalise identified indicators, a review has been conducted together with relevant organisations. The following indicators are identified in this scenario, Table 9.1:

Table 9.1 Basis for indicators for landing on helidecks.

Indicators	Operationalising
Airworthiness of helicopter (quality of technical condition)	• **Minimum Equipment List (MEL)**: The status of critical systems. MEL can be an indicator which says something about to what extent the organisation maintains continuous airworthiness. • Data from continuous use of Health Usage Monitoring System (**HUMS**) data for early identification of errors • Indicators related to **performance of maintenance work**
Quality of rig/facility report	• Quality assurance of personnel that make reports. **Training of weather observers**
Quality of information, technical equipment on helidecks	• Indicators tied to status of technical systems, **reports from facility**
Quality of updated procedures, which describe practices according to the helicopter type	• Conducted through audits or observations of normal operation of the Helicopter operators, ATM/ANS and helidecks. **Procedures, audits and compliance** • Active use of **Flight Data Monitoring (FDM)**

Indicators	Operationalising
Quality of communication between helicopter and helideck personnel; procedures and practice	• Here there are individual differences as regards the use of language, and helicopter-related phraseology (especially for small floating facilities). Language knowledge varies on different facilities, particularly those with floating helidecks (ships). • **Observations** to provide a qualitative assessment of the development in regard to communication. • **OLF MANUAL/regulations update**. The number of changes in revisions. Harmonising of data provided to pilots, use of radio frequency (in some areas there is increased use of VHF). Passenger manifest is provided with METAR and TAF
Quality of team work (*CRM - Crew Resource Management*)	• Quantitative goals are difficult. **Observations** more important than interviews, but both can be used, see what works well and what does not work well
Competence to operate on the Norwegian Shelf	• **Observations** of normal operations. Use line check proactively. **Observations** in Line check are conducted once a year, with a simulator twice a year.
Quality of safety management in connection with organisation changes	• Implemented **analysis of safety related consequences** of change
Contract conditions – ”*penalties*”	• If penalties are experienced during delays. **Deviations in time** from the operations centre; the number of bought days off per year, use of overtime
For floating helidecks, the occurrence of visual clues	• Status on helideck, according to CAP 437, OLF guidelines

9.5 Suggested indicators

With a basis in the processes described above, candidates for lagging and leading indicators have been suggested for helicopter operators, ATS/ANS, heliports/airports and helidecks. These were grouped as seven lagging indicators, eight leading indicators relevant for all organisations, 26 leading indicators relevant for the helicopter operators, five leading indicators relevant for the air traffic service, and eight leading indicators for the helideck operators. A work seminar assessed which of these indicators had the greatest relevance for helicopter operations. A rough assessment identified six activity indicators that are relevant for all organisations, ten which are relevant for the helicopter operators, five related to air traffic service, and two related to helidecks. There has been a need to carry out simple interviews with operative, technical, air traffic service, helideck personnel, and personnel from quality departments. These interviews have contributed to process a limited set of indicators in relation to the criteria. This was further processed/evaluated, and a complete list of possible indicators with evaluation criteria and supplementary comments were carried out in the project, Table 9.2.

Table 9.2 Prioritised indicators sorted by relevant organisation.

Indicator	
Topic	**Name/definition**
Helicopter operators – technical condition	
Health Usage Monitoring System (HUMS) data	**Continuous use of HUMS data** for early identification of errors

Indicator	
Topic	**Name/definition**
Helicopter technical condition: *Deferred Defect List* (DDL) & *Minimum Equipment List* (MEL)	**Number of DDLs** is a better indicator than MEL in relation to sufficient resources to uphold maintenance **Number of MEL** reports per year. Number of deviations/errors on systems that can influence safety. Flying with an MEL mark is possible and the helicopter is considered airworthy. If MEL increases or decreases, this can indicate something about parts and accessories, shortage of components, ability to correct faults
Predeparture check	**Quality of predeparture check**, competence, experience
Procedure compliance	**Number of deviations from procedure**. **Audits and observations** reveal whether there are deviations between procedure and practice.
Revision of procedures	**Number of updated revisions of procedure in the last period**
Maintenance program, updating	**The number of updates per year**, is seen together with information sent to the technician, e.g. technical information with updating. The number does not say anything about quality; therefore it is necessary to view this together with other indicators for procedure revision and compliance.
Change in maintenance program	**Number of changes in important programs and for tasks with short intervals**
Back-log	**Average back-log in maintenance tasks** per company per year. An alternative indicator is repair times in relation to MEL.
Maintenance, crew, scope	**Planned crew versus real crew per station per shift. The number of maintenance hours per flight hour**
Cooperation	**Quality of cooperation.** Quantitative goals are difficult. **Interviews** better cover the status of the cooperation.
Communication	**Quality of communication.** Quantitative goals are difficult. **Interview** better covers the condition of the cooperation.
Workload Sufficient resources and slack	**Average work time (hours per day) for employees per year.** Use of overtime is seen in relation to exemptions and in relation to crew
Helicopter operators – flight operative condition	
Revision of procedures	**Number of "*notice to pilots*"** or **"*information to crew*"** (revision of procedure)
Procedure compliance	**Active use of FDM analyses.** Audits and observations reveal if there are deviations between procedure and practice.
Training, cooperation and communication	Proactive use of ***Line Check*** in relation to observations of "normal operations". Simulator training, number of hours and training in beyond regulatory requirements.
Crew, sufficient and shortfall in resources	Number of purchased days off per year.
Penalties	Follow up of the penalty regime, and how this influences the organisation. If there are penalties associated with delays and stress in the organisation to maintain regularity.
Exemptions	**Average number of applications for exemption related to aviation safety** per company per year (i.e. in relation to maintenance interval and DDL)
Helicopter lagging indicators	
Aviation incidents	**Number of serious aviation incidents per 100 000 flight hours.** If there are serious incidents the organisation must act.

Indicator	
Topic	**Name/definition**
ATA-code (*Air Transport Association, code to classify systems within aviation) reports.*	**The number of repeating deviations per ATA per period.** This is analysed in the Maintenance Review Board meetings. Analysis includes when the same deviations (deviation within the same ATA chapter) occur on two or more flights within a time period. Systems that can be regarded as critical are related to communication (ATA 23), navigation (ATA 34) and rotor (ATA 65-70) The number of technical errors per system. i.e. • *Windshield cracking* • *Chip warning* • *Door open warning* • *Oil leakage detected by walk-around* • Error involving main rotor, gearbox (UK, based on accident, 2009)
Pilot reports	**Number of pilot reports per year.** This is analysed in the Maintenance Review Board meetings
Air Traffic Service (ATS/ANS)	
Radar/ADS-B coverage; surveillance coverage, controlled airspace	**Percentage of the area with radar coverage** (Ekofisk, Ula, Sleipner, Heimdal, Statfjord CTA, Haltenbanken, Norne and the Barents Sea)
Radio communication	**Number of/per cent redundant communication systems per area** (Ekofisk, Ula, Sleipner, Heimdal, Statfjord CTA, Haltenbanken, Norne and the Barents Sea)
Exemptions	**Percent exemptions.** Many flights with exemptions result in a negative impact on the work situation (Avinor has the best overview of exemptions granted directly on an ad hoc basis)
Procedure inquiry	Audits reveal potential deviations between procedure and practice. Can be acquired from feedback (interview) from pilot – user survey – focus on standardisation. This can be seen in connection with the use of FDM (Flight Data Monitoring).
Cooperation, phraseology, communication	Observations are more important than interviews, but both can be used, must see what works well and what does not work well.
Crew	Average work time per position per unit per year, seen in relation to exemptions. The number of persons per control unit in relation to sector. Can analyse if the development in the on call duty lists is expedient and if there is a possibility for improvement.
Lagging indicators	
Aviation incidents in MESYS (Confidential fault reporting, Avinor)	**Number of serious aviation incidents per 100 000 flight hours.**
Trend in reporting to MESYS	**Number of reported incidents in MESYS.** (People are not as careful with reporting errors in technical systems, as they are with incidents)
Helideck	

Indicator	
Topic	**Name/definition**
Revision procedure	**The number of facilities with a logbook/system which tracks that people sign off that they have read the** revisions. It is important to have a system and an active use of the distribution list. The challenge lies in shift work and ensuring that everyone has the same information. Experience transfer and handover are IMPORTANT in relation to changes of procedure on shifts. **OLF MANUAL; regulations update**. The number of changes per revision. Harmonising of data which is provided for pilots, better use of frequency (in some areas there is an increased use of VHF and facilities for planning fuel). Passenger manifest is given with METAR and TAF.
Procedure compliance	**Number of deviations** (in relation to following procedures, procedure is available). Audits reveal potential deviation between procedures and practice.
Training, weather observers	**Percent persons with radio responsibility that are trained per year per facility.** BSL-G-MET is finished and will be implemented. Important to have a continuous process that keeps the personnel professionally up-to-date.
Technical condition and lighting on helideck	Here there is a need to look at the status of helidecks in relation to OLF guidelines and CAP 437
Lagging indicators	
Incidents	Number of reports of undesirable incidents per year in relation to helideck/HFIS

These indicators represent a pragmatic selection for continuous monitoring of the safety risk level. Organisations and systems are under continuous change, therefore there is a need for an update and revision of indicators to identify new aspects and indicators.

9.6 Conclusion

This part of the study has identified a set of indicators that provide information about the condition of functions that have substantial significance for helicopter safety. The use of observations of critical operations is recommended to identify changes and possible new indicators that are relevant. Suggested indicators in HSS-3 are a combination of quantitative and qualitative information. Qualitative indicators provide important information about quality in addition to the quantitative indicators.

The helicopter study regards aviation safety as a dynamic quality and collaboration between several players and functions. Helicopter safety is something that is created, not a system that is “owned”. The objective of safety indicators is to provide information about safety levels and decision support in relation to which measures should be implemented, in addition to motivating the decision-maker to implement the measures (Hale, 2009). Activity and discussions about safety indicators in HSS-3 have brought awareness and identification of relevant measures.

There are different needs and different motivations for using safety indicators. For example, the Petroleum Safety Authority has a need for a limited set of indicators for annual monitoring of the safety level, while the helicopter operators have a need for continuous monitoring as a part of their safety management. For the Petroleum Safety Authority, we recommend widening the field of interest from reported incidents from the helicopter operators, to also consider the Air Traffic Service and the helideck function. For the helicopter operators, most indicators are based on information that is available in the organisations. HSS-3 recommends that the helicopter operator considers active use of observations of normal operations for special conditions, like landing on floating helidecks or heavy maintenance. Observations will provide a better understanding of what works well and can contribute to identify changes that can have significance for safety.

Aviation has generally been characterised by a focus on analysis and learning from lagging indicators. To be able to further develop the safety of helicopter transport, the safety monitoring should, in the future, be based on both lagging and leading indicators that focus on significant functions related to the operation of helicopters. Indicators identified in the study represent a step forward in the proactive safety work.

10. SUGGESTED MEASURES

This chapter contains suggestions for safety promoting measures which have been identified and adapted through interviews and expert meetings, and through review of relevant documents and previous incidents. Information on the latter was found in investigation reports and statistics dealing with incidents/accidents during offshore helicopter transport in the North Sea and Canada (cf. for example the review of accidents in the North Sea during the period 1999-2009, Chapter 7.3). Measures which were suggested during changed framework conditions (Chapter 4.2.8), additional Norwegian requirements (Chapter 4.3), perceived risk (Chapter 8) and indicators (Chapter 9), respectively, are also reviewed in this chapter.

For the most part, we have identified frequency-reducing measures (Chapter 10.2), but we also provide some consequence-reducing measures (Chapter 10.3) on the part of organisations, authorities and customers (Chapter 10.4). For every suggested measure, a comprehensive assessment has been carried out in relation to expected feasibility and anticipated risk reduction (i.e. useful effect) in the coming ten-year period (2010–2019). The most favourable measures following the assessment will then be selected (prioritised) for a closer estimation of the cost/benefit relationship. Rough cost assessments have been made for these measures, and are included under the measure's description in Chapters 10.2-10.4. Measures assigned a low priority are not included further in connection with cost/benefit. Even if the measures have been given a low priority, this does not mean they do not have a safety promoting effect, but that they are not presumed to be among the measures which would provide the most risk reduction in the coming period.

Cost/benefit assessments of the selected measures are provided in Chapter 10.6. The final recommendations are presented in Chapter 11.9, mostly based on which measures would most benefit safety and are cost-effective, i.e. they have a low cost per cent of risk reduction. The approach is illustrated in Figure 10.1.

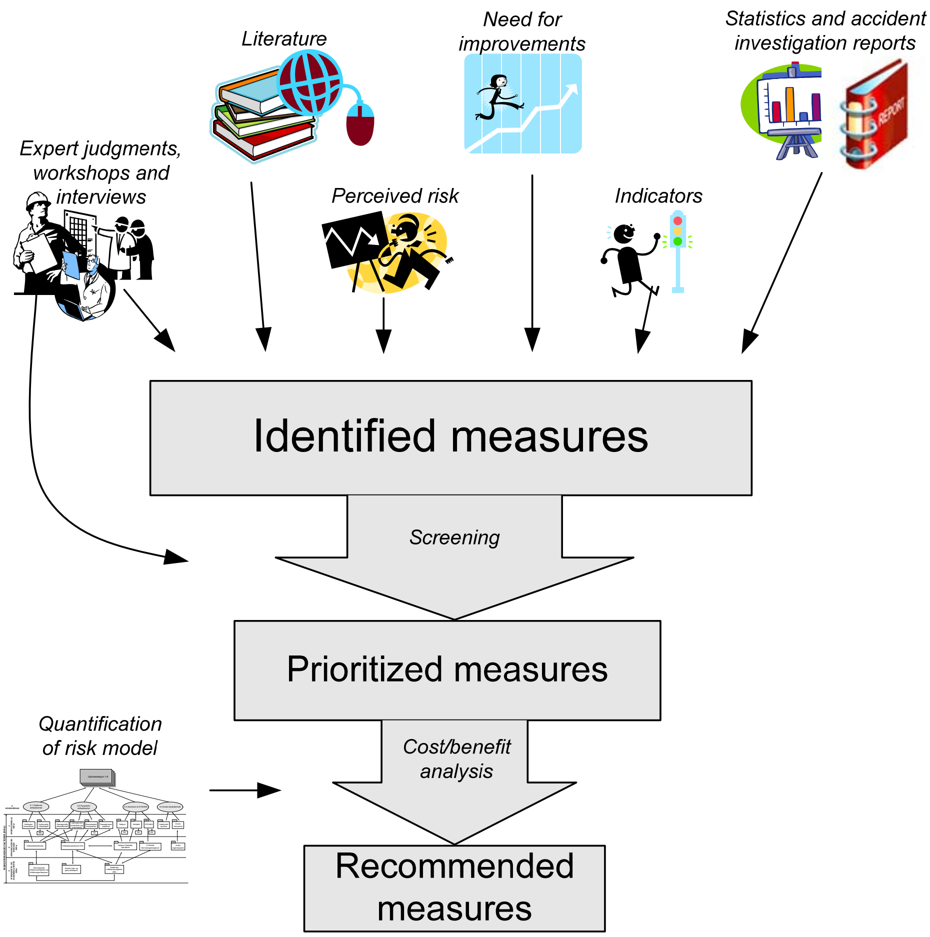

Figure 10.1. Approach for identifying measures and recommendation of measures.

10.1 Assumptions and limitations

Note that by *measure,* in this case, we mean measures which have neither been introduced nor planned as of today, and which would be realistic to introduce within a reasonable amount of time (up to 10 years). This includes further developing already existing systems as planned/expected changes in the time to come, and these will not be part of the recommendations. *In other word, we assume that already planned or expected changes will be implemented, and that the measures suggested in this chapter will be* *<u>in addition to</u>* *the recommendations to execute the presumed changes in Chapter 4. The most important assumptions are:*

- Maintaining today's regulatory requirements. (Including maintaining additional Norwegian requirements and maintaining the requirement for a Norwegian *Air Operative Certificate; AOC*)
- Installation of *Traffic Advisory* (minimum TCAS I) in most helicopters
- Further development and use of HUMS
- Further development and use of FDM
- More use and better reliability of anti-icing equipment on the new helicopter models
- Better cooperation between helicopter operators and helicopter manufacturers
- Further development of *Crew Resource Management* (CRM)
- Introduction of PC2e

- ADS-B on Ekofisk
- Improved flying weather service and *Automated Weather Observing System* (AWOS)
- Weather observation course for helideck personnel in accordance with BSL G 7-1. Regulations relating to flying weather service
- Further development and harmonising of operational limitations based on measurements with the "*Helideck Monitoring System*".

10.2 Frequency reducing measures

Below we present several frequency reducing measures. These are categorised under the following topics (Risk Influencing Factor (RIF) for frequency in parenthesis, see Figure 2.2):

1. Helicopter design (RIF 1.1)
2. Continuous airworthiness (RIF 1.2)
3. Operational work conditions (RIF 1.3)
4. Operational procedures (RIF 1.4)
5. Pilot's competence (RIF 1.5)
6. Heliport/airport (RIF 1.7)
7. Helideck (RIF 1.8)
8. ATS/ANS (RIF 1.9)

Here we list the measures which were identified through interviews, expert meetings and relevant document review. *Measures selected (prioritized) for a more detailed estimate of the cost/benefit ratio, are labelled with a star (*) and are addressed further in Chapter 10.6 (cf. also Chapter 10.5). Unless otherwise noted, the measures are given in random order. Note that several of the measures are connected, and that introducing one measure can be contingent upon the introduction of another.*

RIF 1.1 Helicopter design

M01 – Requirement for TCAS I in all helicopters
TCAS I provides a warning for the danger of collision with another aircraft.
Assessment: Low priority. Currently, TCAS is installed in about 90% of the helicopters used for personnel transport, and most have this as a customer requirement. In the remaining helicopters, "Skywatch" is used, a system which predates TCAS.

M02 – Requirement for TCAS II in all helicopters
TCAS II provides, in addition to collision danger alert, advice on how to avoid a collision, using a *Resolution Advisory* (RA). A voice will either say *"descend, descend"* or *"climb, climb"*.
Assessment: Low priority. In 2011, all EC225 machines will be delivered with TCAS II as standard equipment. Compared to TCAS I, TCAS II provides an additional reduction of the frequency for accident category A4 (collision with another aircraft), but the risk reduction is estimated to be low per NOK invested for the coming ten-year period.
Cost: Low, if TCAS I is already installed in the helicopter. If not; more costly than TCAS I.

M03 – Research project: Lightning protection*
Lightning strike incidents take place, on average, about one to three times per year, and some say the lightning has gained strength over the years. In the UK sector, during the period 1999–2009, three accidents have been registered as caused by a lightning strike. So far, lightning has only caused material damage to the helicopters. After every lightning strike, a thorough

inspection must be performed to identify visible and possible hidden damage, possibly leading to costly repairs. Helicopters should be able to withstand lightning strikes better than they currently do. During the design and certification processes, the possible intensity of lightning is not known. The energy discharge could possibly be several times greater than what is currently assumed. As of today, there are no practical means of registering static electricity (HSRMC, 2009).

Our UK counterparts are also concerned with the risk connected with triggering lighting, and a research project has been started through the “Helicopter Safety Research Management Committee” (HSRMC), including the ability to give notice about lightning and active lightning areas. Representatives from the CAA-N and OLF are also on the committee.

To achieve improved protection against lightning strikes and triggering, this measure (T03) is suggested as a research project, which must be founded on the discoveries from the current project in the UK and performed in collaboration with the UK. Such a project should include the following topics:

- Testing technology and the helicopter’s resistance to lightning strikes, to test the limits and certification possibilities for the latest generation of helicopters. Possible development of new technology to ensure adequate lighting protection.
- A system to detect lightning activity, so as to avoid flying into hazardous airspace, thus reducing the probability of triggering lightning. This includes the development of joint procedures for all helicopter operators concerning when and how flights shall be cancelled due to lightning activity.
- Cooperation between helicopter operators to reduce the exposure of helicopters in active lightning areas. *Please note that this recommendation relates to organisations, authorities and clients.*
- Assess if the technical inspection currently performed following lightning strikes is adequate. *Please note that this recommendation relates to continuous airworthiness.*

<u>Assessment:</u> Triggering lightning and lighting strikes are risk elements which have caused several incidents and accidents on the North Sea in recent years. Even though none of these led to fatalities, lightning is considered an uncertain risk factor, which needs to be further controlled.
<u>Cost:</u> Depends upon scope.

M04 – Requirement of latest generation of proven helicopter technology for all helicopters performing personnel transport *

All helicopters performing commercial personnel transport offshore should, as a minimum, be maintained and updated in accordance with given updates of FAR 29 / EASA CS 29, so as to satisfy the latest generation of helicopter technology without non-conformities. Satisfying such a demand requires customer participation. In practical terms, this means only utilising the latest generation of proven helicopter technology.
<u>Assessment:</u> High priority. Use of the latest generation of proven helicopter technology would lead to a considerable risk reduction, compared to older technology. For instance, newer technology incorporates considerably more redundancy, improved impact absorption and improved fire protection (design and location of fuel tanks etc.).
<u>Cost:</u> Practically speaking, implementation of the latest generation of proven helicopter technology is about to be introduced. This implementation requires considerable investment costs, both in the technology itself and with unforeseen costs, due to new and “less familiar” technology. The operating costs are expected to be lower for the latest generation of proven helicopter technology than continuing use of the existing/old technology. Others claim that

new technology is more expensive and will lead to increased operation costs due to, among other things, unexpected costs and price increases from the suppliers.

M05 – Continual transfer of status data from helicopter and infrastructure

The measure deals with the continuous transfer of status data via satellite, from helicopter and infrastructure to land. This concerns both the helicopter (HUMS data, status of critical elements etc.) and the rest of the infrastructure (helideck measurements, weather conditions, logistical conditions etc.)
Assessment: This system is expected to reduce the probability of several accident types by detecting dangers at an early stage and avoiding development into an accident.

RIF 1.2 Continuous airworthiness

M06 – Stricter regime for independent inspections offshore and on land bases*

Independent inspection, in connection with maintenance of critical components, must be performed by two independent and qualified persons, both offshore and on land bases. Today, interpretations of the Norwegian regulations allow the technician performing the work to conduct the "independent" inspection. This is not acceptable from a safety standpoint. Current requirements under EASA are more restrictive and non-conformities from M.A.402 relating to independent inspection should be avoided, despite the fact that EASA 145.A.65(b)3 provides opportunities for non-conformities. Exemptions should only be given in exceptional cases.
Assessment: Will reduce the risk contribution from RIF 1.2 Continuous airworthiness for cases where technicians have performed work offshore and on land bases.
Cost: Investment costs between NOK 1–10 million; operating costs between NOK 10 million and 100 million (mainly due to one extra person on offshore bases and land bases where there is currently only one).

M07 – Improved training for technical personnel*

Current technicians express that both basic training and retraining are not comprehensive enough and do not put enough focus on specific equipment. Current machinery includes more accessories and is more complex than before, especially as regards avionics. To maintain competence, there is a need for increased focus on training content. The following improvements are suggested for basic training and retraining, respectively:

- *Basic training / Type courses:* There is a need for both increasing and "focusing" the training (more relevant content) to be able to train on relevant machines / specific equipment the technicians work with, not just the "base case". There is also need for training which provides an overall system understanding; which connects the different components both as concerns operation and troubleshooting. The type courses must provide the students with an understanding of the system's purpose, operation and error indications. Furthermore, the courses should provide training in navigating, reading and understanding manuals, forms, tables and procedures. The type course instructor must have daily contact with the operative work day.
- *Retraining / Periodic training:* There is a need for systemising retraining where the training is quality-assured before and during training, where goal is developing the technician staff. The training should contain both theory and practice (e.g. classroom teaching, CBT – *Computer Based Training*, simulator). This is in contrast with current practices, which mostly consist of "filling out simple forms". The measure also sets requirements for instructors concerning their breadth of knowledge and in-depth competence, practical application and the ability to provide the students with system understanding. Basic training and retraining must also be integrated.

<u>Assessment:</u> Will reduce the risk contribution from RIF 1.2 Continuous airworthiness.
<u>Cost:</u> Depends upon scope. Increased system understanding and sequential systematic follow-up can also contribute to more efficient maintenance.

M08 – Improved availability of spare parts*
The helicopter fleet has grown significantly, and in certain areas the spare part stock has not been able to keep up. Improved availability of spare parts primarily involves adjusting stock to which components most often need to be replaced, ensuring that spare parts will always be available when needed. This is to avoid "cannibalising", i.e. taking parts from one machine and using them in another. Cannibalising increases the workload and stress level. This can lead to increased risk. To achieve improved availability, stock management must function as a dynamic system, where the manufacturers and helicopter operators cooperate to continually ensure optimal stock levels. For the operator, this means contributing reliability data to provide the manufacturer with information on how often each component is needed. The helicopter manufacturers, on the other hand, are responsible for coordinating the information from the operators and updating the stock levels, based on the number of helicopters and traffic volume. When phasing in new helicopter models, it is especially important to, as early as possible, identify components that often fail. For example, during the phase-in of the S-92, problems were experienced with a heating element in the air intake due to the de-icing equipment. Identifying this type of problem and also an assessment of the components' reliability can be more closely analysed before phasing in new helicopter models.
<u>Assessment:</u> Will reduce the risk contribution from RIF 1.2 Continuous airworthiness.
<u>Cost:</u> The costs are mostly due to phasing in and managing a system to continually maintain optimal stock levels. The industry's operating costs can also be lowered by such a measure leading to increased maintenance work efficiency when there is no waiting for parts and "cannibalising" can be avoided.

<u>RIF 1.3 Operational work conditions</u>

M09 – Paperless cockpit*
There is need for a project exploring the possibility of making the cockpit paperless. This would eliminate the pilots' paperwork and filling out forms, including:

- *Electronic flight bag*: Electronic manuals (Approach map, Jeppesen, etc.)
- Electronic program for calculating weight and balance automatically. This would reduce the pilot's workload and reduce unnecessary communication over VHF.
- System for eliminating logistics work and superfluous radio chatter for the pilots

The work can build on the foundations already laid by Airbus for the A380 airplane.
<u>Assessment:</u> Reduced (unnecessary) pilot workload can make them more focused on safety tasks. Automation and electronic procedures will lead to less paper and fewer manuals in the cockpit, but also sets requirements for system reliability and the pilot's competence in handling the system. A reduction of loose items in the cockpit is also considered to have a positive effect on perceived risk.
<u>Cost:</u> Dependent upon scope.
Please note that this recommendation also pertains to RIF 1.4 Operational procedures.

M10 – Moving map in all helicopters
Moving map is important for machines flying over land. Moving map will be included on, among others, the SAR helicopter which will report to Hammerfest in fall 2010.
<u>Assessment:</u> Low priority for offshore flying.

RIF 1.4 Operational procedures and user support

M11 – Automatic approach procedures / standardised approach*
Of the 12 accidents which have occurred in the North Sea during the period 1999–2009, three occurred in connection with approach to the helideck during reduced visibility. Incidents have also occurred in the Norwegian sector where the helicopter flew too close to the sea during approach in comparable situations, but was saved by the 100 foot warning (GWPS). This is an incident type which is likely to occur again on the Norwegian Shelf, and steps must be taken.

The measure relates to automatic approach to a closer set distance from the facility, and then performing a safe visual approach for the last part of the flight to the helideck. Included in this measure is replacing the *Non-Directional Beacon* (NDB) with a more user-friendly system which also contributes to risk reduction. The NDB is currently required by law by the CAA-N. It is not possible to achieve completely automated approach procedures, as for airplanes, but the goal must be to introduce an optimal level of automation.

Other risk reducing measures which can be discussed in connection with this type of accident, are the pilots cooperating on reference points, visualising the glide path, a system for lighted references on the helideck which take into account the facility's placement, wind and turbulence conditions, the use of night-vision goggles, training, and training quality directly linked to landing on the helideck in the dark or reduced visibility (for example simulator training with approach to specific facilities). Furthermore, to reduce the probability of such incidents, it is important to have a culture which promotes learning about incidents and communicating to other pilots how to act in equivalent situations. In certain other countries, for example Brazil, night flying is prohibited, which would be difficult, but not impossible, to implement in Norway. *Please note that some of these recommendations will show up as separate measures or fall under other areas/recommendations.*

Both Sikorsky and Eurocopter have designed automatic approach methods for their helicopters, and Sikorsky has started selling the product. Therefore, the measure includes adapting the built-in system to Norway (i.e. getting the system approved by the Norwegian aviation authorities, accepted by Norwegian helicopter operators and implemented in the helicopters).

Assessment: High priority. Automatic approach procedures will reduce the risk contribution from human factors during approach, and will provide a considerable risk reduction for accident category A2 (Take-off/landing on helideck) and A5 (Collision with sea). A completely automated approach is not recommended, because this will lead to an increased risk of collision with the many obstacles (including the derrick and cranes) on the facility and near the helideck.
Cost: Both the investment and operating costs are estimated at less than NOK one million each.

M12 – Proactive updating of manuals
Proactive updating of manuals entails that a risk analysis is performed *before* significant changes to procedures, replacing the current practice, which is reactive in that changes are made after faults have been identified.
Assessment: Low priority, since the expected risk reduction is limited. It is also expected that the measure is already being implemented as part of SMS and the quality manual.

M13 – Reduce the number of flights to ships during night conditions and reduced visibility*
Flying at night and during reduced visibility (dense rain, snow or fog) is connected with far greater risk than flying in daylight and in good visibility. This is especially true during approach to the helideck and particularly ships (accident categories A2 and A5), cf. measure M11 concerning standardised approach procedures. Furthermore, unnecessary night flying to ships should be eliminated and as much as possible of the flying should take place in daylight. Approach to the helidecks associated with the most risk should also be performed in daylight

Two elements are emphasised as important measures toward reducing the risk associated with night flying to ships:

- The routes should be planned with consideration for lighting conditions, so that you land on smaller ships during the best lighting conditions and on larger, fixed facilities during more difficult conditions.
- Prohibition against landing on category B and B+ vessels during night conditions. As much as possible, avoid landing on category A and A+ vessels at night.[14] If landing is necessary, only the captain / most experienced pilot should be given permission to land on the vessel during night conditions.

If exceptions from the above points are necessary due to special assignments, a risk analysis should be performed in advance.

Equivalent criteria as described above for night flying should also be considered for flying to ships in reduced visibility, for example by including the criteria in manuals and that decisions are based on weather observations.

Assessment: Risk reduction mainly for the accident categories A2 and A5. Reduced night flying to ships can also reduce consequences since accidents in daylight will make rescue work easier.
Cost: Reduced night flying to ships only requires planning and is associated with low costs.

RIF 1.5 Pilot's competence

M14 – Improved training and exercises for pilots and requirements for simulators*
In general, and in the same manner as for technical personnel, there is a need for increasing both the amount of practical training and the amount of simulator training. This will make time for "developmental training" and training under specific conditions and situations beyond general basic training. Today's digital helicopters also require more training, because they demand a greater system understanding. As opposed to analogue cockpits, which were used

[14] Pursuant to OLF Helideck manual rev. 31 December 2008: "*There is no official method for classification of helideck. The classification is based on the actual floating unit's size and motion characteristics. The method is based on experience built over the years in operation between CHC Helikopter Service and Norsk Helikopter. The classes are:*

- *Category A: Large ships (including production ships) and semi-submersible rigs with measuring and monitoring equipment deviating from the OLF Helideck manual.*
- *Category A+: Cat. A with measuring and monitoring equipment installed, and functional, in accordance with the OLF Helideck manual.*
- *Category B: Small ships (diving vessels and similar) with measuring and monitoring equipment deviating from the OLF Helideck manual.*
- *Category B+: Cat. B with measuring and monitoring equipment installed, and functional, in accordance with the OLF Helideck manual.*"

earlier, the pilot of a digital helicopter now only sees the top “layer”; which requires more training to understand the underlying “layers”. A practical measure could be to increase the annual training hour requirement, where a certain amount of hours are earmarked for specific training.

In summary, we recommend improving the quality of the pilots’ basic training, specific training and retraining by spending more time on the following:

- Relevant, offshore-related training in simulator, including landing on ships.
- Training of critical phases/situations, especially landing/take-off helideck, including during night conditions.
- Specific night training (during transition from summer/fall), for example three landings/take-offs during night conditions in the fall.
- Training in light use and labelling on the helideck.
- Training in clear information exchange with passengers both before take-off and en route (where the passengers have to go when disembarking, get ready for strong winds on the helideck etc.). Proper information exchange with passengers is also important following incidents.
- Training on cooperation in the cockpit (CRM).
- Training in regulations.

To satisfy the above measure relating to increased training and more offshore-related training, requirements will be set for increased availability and quality of simulators, and also that they are adapted to Norwegian conditions and relevant situations (for example landing on a rig).

The following requirements are set for the simulators:

- Easily accessible for training when needed (beyond regulatory requirements).
- Proximity, so they can be used more often and utilise local instructor competence. However, hours in the simulator will be preferred over proximity. On the other hand, proximity and availability will provide technicians the opportunity to train in a simulator, which they do not normally do.
- Reflect the instrumentation of Norwegian helicopters.
- Reflect realistic Norwegian conditions and Norwegian facilities, with the opportunity to train on floating rigs with realistic movement patterns.
- In accordance with the companies’ procedures and instructors.

<u>Assessment:</u> High priority. The measure will lead to a risk reduction for most accident types (both frequency reducing and consequence reducing). Together with the measure concerning training and exercises, the increased requirements for simulators will contribute to further risk reduction within most accident types. Clearer exchange of information with passengers will also reduce the perceived risk (cf. Chapter 8.2.4).
<u>Cost:</u> A new simulator comes with a large investment cost. The operating costs are estimated to be between NOK 1-10 million annually.

<u>RIF 1.7 Heliport/airport</u>

M15 – Standardising procedures at the heliport/airport

The measure concerns standardising the procedures for helicopter operations at Norwegian airports, just as for airliners.
<u>Assessment</u>: Low priority.

M16 – Risk analyses for labelling at the heliport/airport
The measure concerns performing risk analyses in connection with labelling at the heliport/airport. The analyses should, in this case, involve both operative and technical helicopter personnel.
Assessment: Low priority.

RIF 1.8 Helideck

M17 – Clearer requirements for lights on the helideck*
The requirements in BSL D 5-1 should be updated and clarified in relation to CAP 437, as regards requirements for lighting and light quality.
Assessment: Improved lighting and standard lighting on/around all helidecks helps reduce risk during landing (accident category A2 and A5).
Cost: Investment costs, as represented by the installation of new lighting on most helidecks, but no changes in operating costs as compared with today.

M18 – Different lighting for prepared and unprepared helidecks
One alternative would be to operate with green lights for a prepared helideck and red lights for an unprepared helideck (would also cover large movements of floating helidecks).
Assessment: Low priority. Discussed in SF. Not easily implemented.

M19 – Handheld communication for pilots moving about the helideck*
The measure involves the pilots utilising handheld communication when located on the helideck outside the helicopter.
Assessment: High priority.
Cost: Investment costs are estimated at NOK 1-10 million for procurement and certification. Relatively low operating costs.

M20 – Training in English helideck phraseology
The measure involves the communication between pilots and helideck personnel taking place in English (the technical language). This requires offering training in English helideck terminology.
Assessment: Low priority, because there will usually be at least one Scandinavian-speaking pilot in the helicopter.

M21 – Requirements for weather observation equipment
The measure involves evaluating improved systems for more reliable recording of weather conditions, especially for facilities located at a large distance from other facilities. New equipment also requires the user to be competent in operating the equipment.
Assessment: Low priority.

M22 – Radio communication course
The measure involves requiring a radio communication course (beyond radio certification) for all HLOs, heliguards and radio guards on facilities outside HFIS zones where Avinor cannot communicate all the way down to the helideck. Additionally, there could be a need for communication between helideck personnel, both internally and across oil companies, to ensure the transfer of experience and harmonisation of procedures, see measure M38.
Assessment: Low priority.

M23 – Improved routines for reporting safety-related faults*

The reporting culture among helideck personnel is currently not satisfactory as pursuant to regulatory requirements in BSL D 5-1 Regulations relating to flying on the Continental Shelf – commercial aviation to and from helicopter decks on facilities and vessels at sea and BSL G 7-1 Regulations relating to flight weather service. This covers both technical equipment and other safety-related conditions. Currently, there are poor routines for, e.g. reporting non-functional equipment which must be sent to land for repair. Typical examples of deficient reporting are fault in navigational equipment, errors in measuring weather data and broken communication equipment. One cause of deficient reporting of such faults is that personnel on the facilities do not have adequate knowledge of the importance of the equipment being used and other conditions relevant to safety. This illustrates that there is a need for clear information as regards the importance of relevant equipment, procedures etc., including stricter routines for reporting defects and deficiencies. Such a measure also requires helicopter operators to provide the necessary information to the helideck personnel/oil company about the equipment and work they are responsible for, before starting to fly at the facility.
Assessment: Equipment faults offshore are a big problem and a high priority should be considered.
Cost: Low investment costs. Operating costs, such as training, etc. are also low.

M24 – Automatic Identification System (AIS) / Improved map database for mobile facilities
AIS is an automatic identification system used to identify ships and rigs, and can also be used in helicopters and all facilities with helidecks, enabling the pilots to identify where each facility is located.

Assessment: Installation of AIS on facilities with helidecks makes it easier to identify the right facility, and reduces the probability of landing on the wrong rig. Implementing AIS will also provide a new operative procedure for identifying the right facility. This is expected to reduce the chance of incidents and accidents in connection with landing on the wrong facility. An improved map database for mobile facilities will also reduce the chance of flying to a position where the facility is no longer located.

RIF 1.9 ATS/ANS

M25 – Introduction of ADS-B / controlled airspace, air traffic service during the complete en route phase and communication coverage*

ADS-B and controlled airspace
ADS-B on the entire Shelf (replacing radar) will provide expanded surveillance in non-controlled areas. Approved surveillance (traditionally radar, not M-ADS) is a prerequisite for controlled airspace. ADS-B is an alternative to this.
Assessment: The introduction of ADS-B / controlled airspace is expected to reduce the risk of mid-air collisions (MAC) by 50–100%.
Cost: ADS-B is considered to be the future of technology, and the costs are about 1/10 of the cost of radar. Currently, work is underway on implementing ADS-B in the Ekofisk area. The cost is estimated to be about NOK 10 million. Additional millions would be needed to also cover the rest of the Shelf off southern Norway.

Air traffic control during the complete en route phase
Establishing air traffic control for the entire en route phase will also reduce the chance of MACs, lead to more efficient air traffic control service, and also improved alarm service. The measure is connected to the introduction of ADS-B.
Assessment: Establishing air traffic control for the entire en route phase is primarily considered for the Shelf outside southern and central Norway, which makes up the most heavily travelled area.
Cost: Relatively low costs in addition to the cost for ADS-B / controlled airspace. The cost of installation in helicopters is not included.

Communications coverage
There is no satisfactory two-way communication coverage (radio) between pilots and the air traffic control service. This has been identified in, among other things, public report NOU 2002: 17 (see Chapter 5.4.5 of the study). A survey has been started, but not completed pursuant to these suggestions. Improved communications coverage would involve VHF coverage between helicopters and the air traffic control (two-way communication) everywhere helicopters are flown on the Norwegian Shelf. Currently, there is only one transmitter/receiver in the southern part of the North Sea (at Ula).
Assessment: Just as for the two measures above, this will contribute to reduced risk of MACs, but also increased traffic efficiency and improved alarm service. Together with the introduction of ADS-B and air traffic control during the entire en route phase, the MAC risk is estimated to be reduced in the area as a whole by between 90–100%.
Cost: Less than NOK one million in investment costs and about NOK one million annually in operating costs.

M26 – Continuation/replacement of M-ADS*
M-ADS is a unique system which, among other things, ensures that the helicopter can be located immediately following an accident. The chance of saving lives is therefore greater. One important advantage of M-ADS compared to, for example, ADS-B or radar, is that coverage extends down to the surface of the sea. (Cf. also Chapter 3 on M-ADS, and challenges related to delivery of replacement parts, exemptions from M-ADS, etc.) A measure aimed at tackling the M-ADS issues should therefore be implemented, either in the form of continuation or replacement of the system.

In January 2010, a solution turned up which enabled the continuation of M-ADS by producing new “boxes” (Inmarsat SATCOM) supporting the system, but no decision has yet been made on implementing the solution. Furthermore, there will still be challenges related to the use of M-ADS in the northern areas.

If M-ADS cannot be continued, a new system must replace or supplement the current M-ADS. Currently, there is no direct solution for providing the same degree of surveillance. Iridium satellite flight following / Sky-track is an “alternative” to M-ADS which provides coverage regardless of where the machine may be at any given time. Iridium satellite flight following has been installed on helicopters in Hammerfest due to the lack of M-ADS coverage. “Iridium” or an equivalent system is a redundant system for M-ADS, especially in areas with poor surveillance. Currently, the “alternative” system mentioned above has been implemented and used by the customers (oil companies), which can independently monitor their traffic. There is no superior authority over this system. For this type of system to function optimally, it must be coordinated with the air traffic control / CAA-N and the rescue service. There must also be requirements for safety analysis and certification of the system. Satellite-based ADS-B is a possible alternative, but there is less information available to date.

Assessment: High priority. *Please note that this measure is also highly relevant toward reducing the consequences of an accident.*
Cost: Dependent upon if M-ADS can be continued or must be replaced, and which, if any, system will be used to replace M-ADS. "Iridium" is a very cheap system; investment costs are about NOK 30,000 per machine, i.e. about NOK one million for the total helicopter fleet. The operating costs are estimated at NOK one million annually. Using the solution for continuing M-ADS which is currently outlined (January 2010), the costs are connected to production and installation of new "boxes" in the helicopters currently lacking M-ADS.

M27 – Air traffic service on the land bases
Land bases currently lacking air traffic service are: Florø, Brønnøysund and Hammerfest.
Assessment: Low priority. The traffic volume to and from the land bases is currently very small compared to the traffic volume to and from Sola and Flesland. The measure could be relevant in the long term and when Avinor is adequately manned.

M28 – Transfer HFIS tasks to Avinor
The measure involves transferring the HFIS unit at Tampen/Ekofisk to the Stavanger Air Traffic Control Centre, to avoid interfacing between the HFIS and the surrounding airspace, given some preconditions.
Assessment: Low priority. Tampen is satisfied with the current situation. The measure is difficult to implement in practice and less practical, due to heavy shuttle traffic in the area and the staffing situation at Avinor.

In general and beyond measures T25-T28, an improved effort is expected and recommended for the air traffic service offshore.

10.3 Consequence reducing measures

Here we have listed suggested consequence reducing measures. They are related to the top level of the influence diagram for consequence, see Figure 2.3

M29 – Quality assurance and standardising of emergency preparedness procedures between companies
It is assumed that this issue is safeguarded by the oil companies and the Petroleum Safety Authority Norway.
Assessment: Low priority.

M30 – Evacuation procedures for passengers
What is being taught at the safety courses must correspond with the procedures followed by the pilots. The teaching should also represent realistic situations. For example, there is no training on the evacuation of a helicopter landing on sea, while still floating and without capsizing.

In relation to training on helicopter capsizing, no exemptions should be allowed. Every passenger must be able to exit a capsized helicopter. If the person sitting by the window can not get out, this complicates the situation for the person sitting next to him/her. Requirements for the passengers' ability to evacuate in an emergency situation should be considered. If a passenger's ability to evacuate through the helicopter window is limited, due to physique, obesity or other physical limitations, this passenger can be a danger to themselves and others in the helicopter.
Assessment: Low priority.

M31 – Requirement for full hangar offshore for SAR helicopters*
"Full hangar" here means a permanently stationed, temperature-controlled hangar offshore which would make folding and spreading rotor blades unnecessary. A full hangar contributes to reducing risk in connection with folding and spreading. Aging mechanisms are also reduced, especially corrosion. In addition to a full hangar, a hangar with a repair shop for simple offshore repairs could be considered.
Assessment: Consequence reducing in connection with SAR operations.
Cost: High investment costs per hangar.

M32 – "Night vision goggles" for SAR pilots
Night vision goggles will improve the pilots' night vision.
Assessment: Low priority.
Cost: Both investment costs and operation costs are low.

M33 – Improved fire preparedness / automatic fire fighting system on unmanned facilities
Assessment: Low priority. Unmanned facilities make up a small part of the total number of facilities on the Norwegian Shelf and a small number of total take-offs/landings.

M34 – New rescue helicopters
The issue of the current aging rescue helicopters and reduced access to spare parts contributes to increased risk for any potential SAR operations.
Assessment: This issue is being handled by the authorities and will not be further discussed here.

10.4 Organisations, authorities and customers

Below we list measures connected to level 2 and level 3 in the risk influence diagrams, and which will influence the operational RIFs (Level 1) and, therefore, the risk level. For these measures, it is very difficult to estimate costs. Most measures also relate to two or more organisations and/or influence many of the operational RIFs. They also influence both frequency and consequence contributions to risk. All together, this complicates a cost/benefit assessment and prioritising based on the risk model.

M35 – More thorough criticality analyses (FMECA)*
FMECA or equivalent analyses during the engineering phase should be improved, and also have the potential to improve. Examples of possible improvements are introducing precise requirements for the analysis and its content. By performing an FMECA on a helicopter before it is put to use, you can identify faults and potential dangers which earlier would only have been discovered during operation or in connection with an incident/accident. More thorough FMECAs should also be performed for larger modifications.

In addition to more thorough FMECAs, more detailed risk analyses could be considered, especially in connection with operation of new helicopters or new operational procedures.
Assessment: This recommendation should be especially considered in connection with new helicopters. Risk is expected to be reduced over time and as more new helicopter models are used on the Norwegian Shelf. To realise this risk reduction, it is important to introduce the measure relatively soon.

M36 – Revitalising technical helicopter cooperation*

The "Committee for Helicopter Safety on the Norwegian Continental Shelf" was established pursuant to a recommendation in public report NOU 2002: 17. The purpose was for the committee to have representatives from all relevant parties in Norway and to function as the driving force for implementing those risk-reducing measures chosen to be carried out following the NOU report, and promote safety in helicopter transport on the Norwegian Shelf in general. The committee has been in operation since 2003, and has contributed to exploring and/or implementing several of the recommendations in public reports NOU 2001: 21 and NOU 2002: 17. During the interviews and expert judgments in HSS-3, there have been clear signals from several parties that the time is right for revitalising the further work on improving the safety of this type of transportation. The most concrete suggestion involves revitalising the committee through establishing a technical helicopter centre, most likely at Sola. One precondition for such a centre to function efficiently will be providing decision-making authority and continuity.

The measure will involve an increase of Avinor's offshore capacity and one or two positions / permanent representatives from the Civil Aviation Authority - Norway. The purpose of the centre will be to gather relevant competence under one roof, and thereby secure an increased, coordinated and continual focus on safety in helicopter transportation offshore. The mandate should include responsibility for implementing safety-promoting measures, including disseminating information to the helicopter operators relating to weather conditions, incidents, helicopter models etc.
<u>Assessment:</u> High priority. One alternative to replacing the Committee for Helicopter Safety on the Norwegian Continental Shelf with a technical helicopter centre could be to maintain the committee and give the centre the task of processing cases between committee meetings.
<u>Cost:</u> Low.

M37 – Improved supervisory activity*

There is a particular need for more active supervision of helicopter operators during significant changes in framework conditions (see discussion in Chapter 4.2). This also includes that the CAA-N follows up audits performed/being performed.

The increased audit activity should also include helideck inspections. More frequent inspections of helidecks is important to ensure that the quality of the helidecks and their equipment is maintained, in addition to the helideck personnel's competence and procedures. In particular, there should be increased focus on inspections of helidecks on floaters/rigs.

The CAA-N should also promote positive change processes with the helicopter operators, cf. the last part of the HSLB study (HSLB, 2005, Safety Recommendation no. 1): *"The Civil Aviation Authority should consider putting greater emphasis on systemoriented holistic and risk-based supervision and develop/recruit personnel with relevant expertise - not least in order to follow up and become aware of potentially negative safety consequences of the change measures at those they supervise."* One relevant activity could be to review procedures for reporting and classifying organisational non-conformities, i.e. highlight the non-conformities in relation to their actual risk contribution.
<u>Assessment:</u> High priority.
<u>Cost:</u> Some operational costs arising from increased supervisory activity. Will not include significant costs beyond measure M36 above ("Revitalising technical helicopter cooperation").

M38 – Increased focus on communication to learn from incidents*

The measure will involve an improvement of communication between the CAA-N and the helicopter operators (nationally and internationally) following incidents. The purpose is to learn from incidents.

The helicopter operators currently report information about incidents and accidents to the CAA-N through “Altinn”. The current system is limited to reporting, and the helicopter operators would like to receive feedback from the CAA-N. This would improve the ability to learn from accidents. The lack of feedback is, for example, caused by issues of confidentiality. It is assumed it would be too ambitious to develop a tool for quality assurance, processing and sorting of information through “Altinn”, and then to generate sensible feedback to the helicopter operators. Therefore, the improvement should not primarily take place through developing the “Altinn” tool, but rather by improving cooperation and utilising the available information. For instance, the information processed by the CAA-N for internal use, e.g. safety measurements and indicators based on reported accidents and incidents, can be forwarded to the helicopter operators via the Internet.

Feedback from the CAA-N to the operators will contribute to reducing risk over time (communication about more incidents some time after the incidents occur). But communication is also important immediately following incidents to facilitate learning from the occurrence. Furthermore, it is important for helicopter operators to exchange information amongst themselves about lightning activity, bad weather, technical faults in helicopters etc. Another element which will contribute to increased harmonisation is the transfer of experience, e.g. while introducing new helicopter models used by two or more companies.

One precondition for this to succeed, is good communication between operators and that organisational structure, roles of responsibility and reporting lines are clear for all involved parties.
Assessment: The CAA-N is positive toward working with the helicopter operators to clarify what needs to be reported in return. Improved utilisation of information from the incident reporting from the CAA-N will contribute positively in relation to future safety work and provide the opportunity for the helicopter operators to learn from their own and others’ incidents. Cross-communication and harmonisation will contribute proactively toward reducing the danger of incidents and accidents. Good internal communication and understanding between helicopter operators will also contribute toward a more uniform company culture.
Cost: Low investment costs, since the information already exists and is available. Operation costs will be connected to utilising the current system and the available information, but this is difficult to estimate.

M39 – OLF’s guidelines as recognised standard*
OLF’s guidelines are not a general requirement within flying on the Continental Shelf, but are mostly followed up as a contractual requirement, and are therefore observed by the helicopter operators. The Norwegian helicopter operators, however, feel that foreign helicopter operators do not always have the same respect for OLF’s guidelines as they have themselves. Smaller oil companies can also be assumed to have poorer buyer competence. It has been asserted that some have e.g. practised daily commuting until the PSA issued a notification of order if this practice was not changed.

Some of the smaller oil companies are also said to cause other problems, e.g. some claim they prefer to use smaller helicopters with less safety equipment and which are not on the same level as regards technical approval and equipment. Yet others claim that smaller helicopters, from a safety standpoint, are not inferior to the larger helicopters, but that the *perceived* risk can be different. This can be related to the fact that smaller machines have less optimal seating schemes, are more prone to turbulence and that newer, small helicopters are perceived, by many passengers, as new and unfamiliar.

The measure involves that the PSA and/or the industry associations should ensure that all oil and gas operators on the Norwegian Shelf require the helicopter operators to abide by OLF 066 - Recommended guidelines for helicopter flights to petroleum installations. This also presents a challenge for the PSA to motivate all other relevant parties to follow these guidelines.

In the updated OLF 066, measure M04 “Requirements for the latest generation of proven helicopter technology for all helicopters performing personnel transport” will be included as an underlying requirement.
Assessment: High priority. The measure will be more relevant as more helicopter operators operate on the Shelf, and especially if distinctive Norwegian regulatory requirements are dropped. Harmonising requirements will have a positive safety effect. The measure should have high priority.
Cost: Can be substantial for any foreign oil companies needing to update their helicopters, operational procedures and/or training schemes to what is used on the Norwegian Shelf. Costs connected to requirements for the latest generation of proven helicopter technology for all helicopters and the remaining costs must be separated, if both measures are implemented.

M40 – Review of the penalties scheme
The helicopter operators claim that some customer contracts contain penalty clauses of considerable size (fine in the event of non-fulfilment of contractual requirements, especially as regards punctuality), but no incentive elements, and that this causes considerable problems. The helicopter operators also are given less and less time to prepare their bids, and they believe the customers should allot more time in the bid process for more thorough analyses.

The measure will entail that those oil companies which practice penalties will review the scheme for fining helicopter operators when contractual requirements are not satisfied, especially for delays. Currently, fines can be given daily. The claim is that this scheme causes stress for those responsible for each operation, i.e. operations centre, pilots and maintenance personnel. Such stress can propagate in the organisation and cause errors. The measure will therefore also involve that the helicopter operator management is aware of how any critique from the customers is disseminated in their own organisation, so as not to create unnecessary stress.

Suppliers of helicopter services, must expect to be measured by their performance. One suggestion is to not issue fines on the basis of single trips, but instead based on relevant monthly statistics and indicators. It should also be possible to vary the framework from contract to contract and location to location.
Assessment: It is important to maintain a balance between what is required of the delivery from the helicopter operator (especially as regards punctuality), and the possibility to perform adequately safe operations. However, SINTEF does not have a clear enough picture of to which degree the customer contracts contain clauses relating to fines.
Cost: Relatively low.

M41 – Active inclusion in the engineering phase of helicopter personnel with experience operating in the North Sea

Helicopter personnel (pilots and technical personnel) with experience in helicopter operations in the North Sea should be involved in the engineering phase for new helicopters. There are technical challenges unique to the North Sea and the Norwegian Shelf, e.g. icing and corrosion. As regards the pilot's working conditions in the cockpit, it has been pointed out that lights, window size and ergonomical designs can be improved toward reducing the danger of fatigue. In addition to the engineering phase for new helicopters, competent operative personnel should be included in helideck design. This would contribute to optimising the design and placement of the helideck as regards take-off and landing.
Assessment: Low priority, due to the fact that we do not expect a considerable amount of new development of helicopters during the coming ten-year period.

M42 – Monitoring safety though systematic use of indicators*
Safety monitoring is part of ICAO's requirements for SMS. Chapter 9.5 identifies a set of leading and lagging indicators for monitoring safety within the helicopter operators. Active use implies not just recording observations, but also following up and implementing measures based on the information provided by the indicators. Indicators are pointless if the organisation is not capable of making decisions, acting and implementing safety improvements in time, i.e. before an accident, which could have been predicted, occurs.

The suggested indicators only reflect a limited number of the factors influencing safety. Therefore, a periodic review and reassessment of the indicators is recommended.

Monitoring the *perceived* risk for passengers flying on the Shelf can be improved through expanding the current quantitative mapping in RNNP and establishing a separate qualitative part concerning helicopters. Suggestions for new questions for RNNP are given in Chapter 8.7.

Assessment: High priority. Following up a unified set of leading and lagging indicators will contribute to focus on the safety work and monitoring the safety level, ensuring that the danger of an accident developing is registered and acted upon before the accident occurs.
Cost: Dependent upon scope. Investment costs are considered low, since most of the required information already exists within the organisation. What remains is only a matter of using the information in proactive safety work, and also following up how the work is performed in practice. Some costs are associated with establishing a system for observations and training.

10.5 Summary of prioritised measures for cost/benefit assessment

The following is a summary of suggested measures selected for a more detailed assessment of the cost/benefit ratio:

M03 – Research project: Lightning protection
M04 – Requirement for the latest generation of proven helicopter technology for all helicopters performing personnel transport
M06 – Stricter regime for independent inspections offshore and on land bases
M07 – Improved training for technical personnel
M08 – Improved availability of spare parts
M09 – Paper free cockpit
M11 – Automatic approach procedures / standardised approach
M13 – Reduce number of flights to ships during night conditions and reduced visibility
M14 – Improved training and exercises for pilots and requirements for simulators
M17 – Clearer requirements for lights on the helideck

M19 – Handheld communication for pilots moving about the helideck
M23 – Improved procedures for reporting safety-critical errors
M25 – Introduction of ADS-B / controlled airspace, air traffic control during the complete en route phase and communication coverage
M26 – Continuation/replacement of M-ADS
M27 – Requirement for full hangar offshore for SAR helicopters
M35 – More thorough criticality analyses (FMECA)
M36 – Revitalising technical helicopter cooperation
M37 – Improved supervisory activity
M38 – Increased focus on communication to learn from incidents
M39 – OLF guidelines as recognised standard
M42 – Monitoring safety through systematic use of indicators.

10.6 Rough cost/benefit assessments

Most of the suggested measures are associated with a large amount of risk as regards estimating costs. Therefore, we have chosen to use four cost classes for investment costs and annual operating costs, respectively, see Table 10.1. The operating costs include daily operations, repairs, spare parts, maintenance, salaries etc.

Table 10.1. Cost classes given in NOK million (estimated mean values in parenthesis).

Investment cost (I)			Annual operating cost (D)		
I0:	0	(0)	D0:	0	(0)
I1:	0–10	(5)	D1:	0–1	(1)
I2:	10–100	(30)	D2:	1–10	(3)
I3:	>100	(150)	D3:	>10	(13)

The estimated mean values (expected values) within cost classes I2, I3, D2 and D3 in Table 10.1 are based on the assumption that the probability distribution within each cost class is such that the expected value within the cost class is in the bottom half of the cost class.

The cost/benefit assessments are, to large extent, based on the risk model and the risk influence diagrams, and also the current (2009) risk level distribution for the different RIFs and accident categories. Each of the selected measures is related to one (or more) RIFs or accident categories. The measure's impact is estimated by assessing the improvement within the current RIF(s) and/or decline in risk for current accident categories by implementing the measure. This impact is categorised as follows:

- *Low impact (L):* 0–20% improvement in the RIF, i.e. decline in frequency/consequence for accidents within the current accident category.
- *Medium impact (M):* 20–40% improvement in the RIF, i.e. decline in frequency/consequence for accidents within the current accident category.
- *High impact (H):* 40–80% improvement in the RIF, i.e. decline in frequency/consequence for accidents within the current accident category.

Note that the impacts within frequency and consequence are assessed separately, and then used to find the impact on total risk. If the measure's impact cannot be categorised within either RIFs or accident categories, the impact is considered directly on the total risk instead.

In further estimation, the mean values for the three categories are used, 10% (L), 30% (M) and 60% (H), respectively. Consideration is also given to what extent the current RIF(s) or accident categories contribute to the total frequency/consequence/risk, based on the quantification of the RIF model from Chapter 6.

Table 10.2 demonstrates how we proceed to find a measure's contribution to *frequency*. Firstly, we review the combination of RIFs and accident categories where the measure is expected to impact the frequency. Example 1 shows that if the measure has an impact within RIF 1.2, this contribution makes up 17.7% of the total risk. Secondly, we assess if the measure has a low, medium or high impact. Assume that a mean value of RIF 1.2 (i.e. 50% reduction in frequency) is expected. The expected frequency reduction for the measure will then be 0.5 x 0.177 = 8.9%. Let us further assume that the same measure is expected to improve the consequence of accidents by 3%. The expected change by implementing the measure will then be

$$(1-0.089)\times(1-0.03)-1=-0.12$$, i.e. a risk reduction of 12%.

Table 10.2. Two examples of contribution from given RIFs and accident categories to frequency. (The table is identical to Table 6.1)

Example 1: RIF 1.2, all accident categories. The total contribution equals the sum of the contributions from RIF 1.2 for all accident categories, i.e. the total contribution equals 17.7 %.

RIF		Accident category								Total
		A1 Heliport	A2 Helideck	A3 System failure	A4 Collision air	A5 Collision terrain	A6 Person inside	A7 Person outside	A8 Other/ unknown	
1.1	Helicopter design	1.7	4.1	18.7	0.0	0.4	0.4	0.7	1.2	**27.2**
1.2	Continuous airworthiness	1.2	4.2	11.4	0.0	0.4	0.4	0.1	0.0	**17.7**
1.3	Operational working conditions	0.1	0.9	0.5	0.0	0.9	0.0	0.0	1.0	**3.4**
1.4	Operational procedures	0.6	5.9	0.0	0.0	1.6	0.0	0.7	1.0	**9.9**
1.5	Pilot competence	0.9	6.5	2.7	0.2	3.1	0.0	1.1	0.5	**15.0**
1.6	Passenger behaviour	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	**0.3**
1.7	Heliport	0.3	0.0	0.0	0.0	0.0	0.0	0.6	0.7	**1.6**
1.8	Helideck	0.0	9.0	0.0	0.0	0.0	0.0	0.6	0.7	**10.3**
1.9	ATS/ANS	0.5	0.0	0.0	0.4	1.1	0.0	0.0	0.0	**2.0**
1.10	Weather conditions and climate	1.2	2.3	4.8	0.0	1.1	0.0	1.4	0.6	**11.3**
1.11	Other activity	0.1	0.0	0.0	0.1	1.0	0.0	0.0	0.0	**1.2**
Total		**6.7**	**32.9**	**38.1**	**0.7**	**9.7**	**0.8**	**5.4**	**5.7**	**100**

Example 2: The RIFs 1.4 and 1.5 for accident category A5. The total contibution equals the sum of the contributiosn from fra RIF 1.4 and RIF 1.5 respectively, for accident category A5, i.e. the total contribution equals 4.7 %.

Please note that introducing a measure that reduces risk contribution within one area, can increase the risk contribution within another area. Additionally, the measure's impact within the RIF must be viewed in comparison with all other relevant measures within the RIF. Costs must also be considered. Therefore all measures are considered, even if they belong to RIFs (or accident categories) that are not the largest contributors to total risk.

A summary of the prioritised measures is provided in Table 10.3. See the table below for a description of the table's columns. The measures have, to the extent possible, been formulated in such a way as to make them independent of each other, although some measures are still dependent upon other measures being implemented to achieve the desired effect/risk reduction. This has been considered in our final assessments of measures within the different areas. The right column provides an evaluation of the measure's priority. One or more of the following reasons have formed the basis for prioritising a measure:

- The measure contributes to significant risk reduction
- The measure is cost-effective
- The measure covers an area which has contributed to several accidents in recent years and where the necessary measures have not been implemented
- The measure satisfies a need on which the industry expends a great deal of time and resources and which will contribute to easing the industry's work and its focus on important work tasks, thus increasing safety.

Table 10.3. Summary of prioritised measures.

Measure	RIF[1)]		A[4)]	Cost		Effect[7)]	Reduction[8)]			Relative cost/benefit as regards risk[9)]	Assessment of importance[10)]
	F[2)]	C[3)]		I[5)]	D[6)]		F	C	R		
M03 – Research project: Lightning protection	1.1, 1.2, 1.10	-	A8	I0	D2	3 (60%)	1 %	-	1 %	Low	High: Several historical accidents
M04 – Requirement for latest generation of proven helicopter technology for all helicopters performing personnel transport	1.1, 1.4	1.1, 1.2, 1.3	All	I3	D0	3 (60%)	22%	14%	33 %	Medium	High: Large risk reduction
M06 – Stricter regime for independent inspections offshore and on land bases	1.2	-	All	I0	D3	1 (10%)	2%	-	2%	Low	Low
M07 – Improved training for technical personnel	1.2	-	All	I1	D2	2 (30%)	5%	-	5%	Low	Medium
M08 – Improved availability of spare parts	1.2	-	All	I2	D1	1 (10%)	2%	-	2%	Low	Low
M09 – Paper free cockpit	1.3, 1.4, 1.5	-	All	I0	D2	1 (10%)	3%	-	3%	Low	Medium
M11 – Automatic approach procedures / standardised approach	1.4, 1.5	-	A2	I1	D1	3 (60%)	7%	-	7%	High	High: Cost-effective
M13 – Reduce number of flights to ships during night conditions and reduced visibility	1.4, 1.10	1.12	A2	I0	D1	2 (30%)	3%	1%	3%	Medium	High: Cost-effective
M14 – Improved training and exercises for pilots and requirements for simulators	1.5	-	All	I3	D2	3 (60%)	9%	-	9%	Low	High: Large risk reduction
M17 – Clearer requirements for lights on the helideck	1.8	-	A2	I2	D1	1 (10%)	1%	-	1%	Low	Low
M19 – Handheld communication for pilots moving about the helideck	1.4, 1.8	-	A7	I2	D0	1 (10%)	0%	-	0%	Low	Low
M23 – Improved procedures for reporting safety-critical errors	1.8	1.10	A2	I1	D1	1 (10%)	1%	0%	1%	Low	Low
M25 – Introduction of ADS-B / controlled airspace, air traffic control during the complete en route phase and communication coverage	1.4, 1.9	1.12	A4/All	I2	D2	2 (30%)	0%	2%	3%	Low	Low
M26 – Continuation/replacement of M-ADS	1.9	1.12	All	I2	D2	2 (30 %)	1 %	2%	3%	Low	High: Problem area which must be solved and which wastes a large amount of

Measure	RIF[1)]		A[4)]	Cost		Effect[7)]	Reduction[8)]			Relative cost/benefit as regards risk[9)]	Assessment of importance[10)]
	F[2)]	C[3)]		I[5)]	D[6)]		F	C	R		
											resources
M31 – Requirement for full hangar offshore for SAR helicopters	-	1.12	All	I3	D1	1 (10%)	-	1%	1%	Low	Low
M35 – More thorough criticality analyses (FMECA)	1.1, 1.2	1.1, 1.2, 1.3	All	I1	D0	2 (30%)	8%	7%	15%	Very high	High: Cost-effective
M36 – Revitalising technical helicopter cooperation	All	All	All	I1	D2	2%	-	-	2%	Low	Medium
M37 – Improved supervisory activity	All	All	All	I0	D1	5%	-	-	5%	High	High: Cost-effective
M38 – Increased focus on communication to learn from incidents	All	All	All	I0	D1	2%	-	-	2%	Medium	High: Cost-effective
M39 – OLF guidelines as recognised standard (beyond M04 – Requirement for latest generation of proven helicopter technology for all helicopters performing personnel transport)	All	All	All	I2	D1	10%	-	-	10%	Medium	High: Large risk reduction
M42 – Monitoring safety through systematic use of indicators	All	All	All	I1	D2	2%	-	-	2%	Low	Medium
Total reduction by implementation of all measures[11)]							50%	25%	70%		

1) Risk Influencing Factor.
2) RIF number in the influence diagram for frequency, see Figure 2.2.
3) RIF number in the influence diagram for consequence, see Figure 2.3.
4) Accident category, see Chapter 1.5.
5) Estimated investment costs, see Table 10.1.
6) Estimated operating costs, see Table 10.1.
7) Estimated impact for the current RIFs and accident categories when the measure is implemented, *Low impact (L):* 0–20% improvement of the RIF / decline in frequency/consequence for accidents, *Medium impact (M):* 20–40% improvement of the RIF / decline in frequency/consequence for accidents and *High impact (H):* 40–80% improvement of the RIF / decline in frequency/consequence for accidents.
8) Estimated risk reduction, i.e. percentage decline in frequency contribution to risk (F), in consequence contribution to risk (C) and for the total risk (R) (number of fatalities per million person flight hours). The total sums are somewhat misleading in relation to each other. This concerns frequency and consequence compared to risk, since for the five bottom measures (M36–M39 and M42) only the total expected risk reduction is given, compared to the current risk level. *Risk reduction* will here signify the expected impact of the measure in relation to the total risk, i.e. percentage decline in risk from the current risk level (2009) and until the measure is 100% implemented.
9) Relative cost/benefit yield with regard to risk, compared to the other measures in the table. Cost/benefit is measured in risk reduction per *annual* expense. In this case, the investment costs are distributed over ten years, and the annual costs are calculated for every year, starting this year (2010) and up to 2019. For simplification, we have assumed that all measures are implemented this year (2010).
10) Collected overall assessment of the importance of the measure based on risk reduction and cost/benefit yield in addition to assessments performed earlier in the report.

Figure 10.2 shows an overview of the selected measures, sorted by the relative cost/benefit yield between the measures. The figure also shows the estimated expected risk reduction when the measure is completely implemented. The result shows that the measure involving more thorough FMECA is the most effective as regards cost/benefit, and also contributes the second most to risk reduction. Other cost/benefit-effective measures include improved supervisory activity and automatic approach procedures. The measure contributing most to risk reduction, disregarding costs, is the measure involving a requirement for the latest generation of proven technology for all helicopters performing personnel transport. Furthermore, measures involving improved training and exercises for pilots, requirements for simulators and the use of OLF as the recognised standard are expected to lead to a large risk reduction.

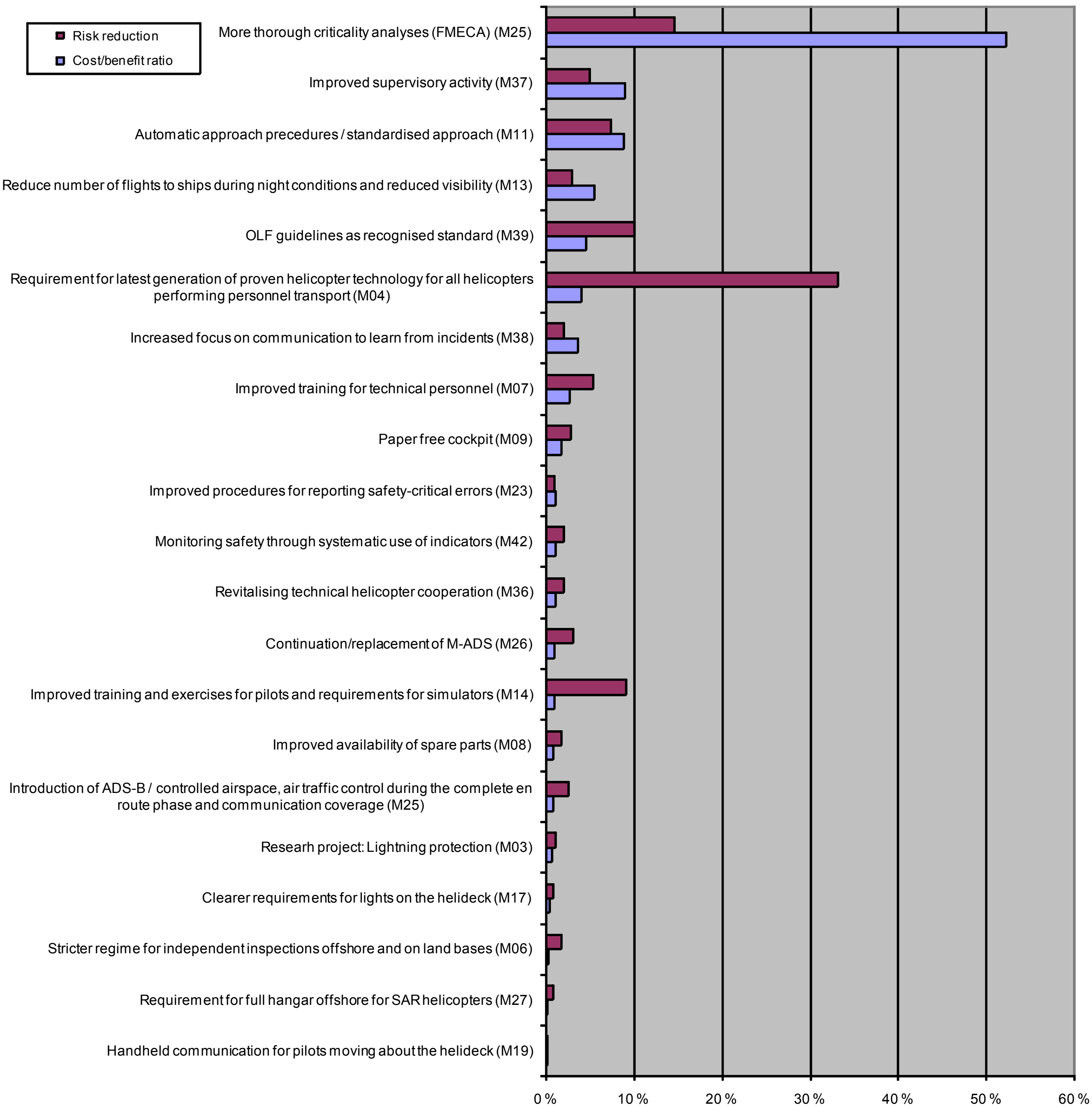

Figure 10.2. Overview of the measures, sorted by cost-efficiency (relative cost/benefit yield for a measure as compared to the other measures).

10.7 Conclusion as regards cost/benefit assessment of measures

SINTEF's calculations and recommendations presuppose that already planned and/or initiated measures will be completed within a reasonable time (cf. Chapter 10.1). The most important are:

- Maintaining today's regulatory requirements. (Including maintaining additional Norwegian requirements and the requirement for a Norwegian Air Operative Certificate; AOC)
- Installation of Traffic Advisory (minimum TCAS I) in most helicopters
- Further development and use of HUMS
- Further development and use of FDM
- More use and better reliability of anti-icing equipment on the new helicopter models
- Better cooperation between helicopter operators and helicopter manufacturers
- Further development of Crew Resource Management (CRM)
- Introduction of PC2e
- ADS-B on Ekofisk

The recommended measures should be assigned priority on the basis of an assessment of the cost/benefit relationship, estimated risk reduction, feasibility, time aspect, co-variation with other measures, etc. Furthermore, it is important to view the measures in context and assess the potential gains from implementing further measures within the different areas. If we examine each different measure and the combination of the cost/benefit relationship and the estimated risk reduction alone, the following measures stand out as the most beneficial (in order of priority, cf. Figure 10.2):

1. More thorough criticality analyses (FMECA)
2. Use of the latest generation of proven helicopter technology
3. Implementing automatic approach procedures
4. Improving supervisory activities
5. Use of OLF's recommended guidelines as the recognised standard
6. Reduce number of flights to ships during night conditions and reduced visibility, especially during approach to ships

Based on an overall evaluation, the following measures should also be considered particularly important:

- Improved training and exercises for pilots and requirements for simulators
- Improved training for technical personnel
- Continuation/replacement of M-ADS
- Increased focus on communication to learn from experience

With complete implementation of *all* of the suggested measures within a reasonable time, a 70% risk reduction of the current risk level is estimated, *given* that no changes occur which will contribute to increased risk. Risk reduction based on already planned changes (estimated at 23%) will add to this. In total, this will yield a net risk reduction of 77%. This is a rough figure, given that there are no changes added which will contribute to increased risk. There are also several other sources of uncertainty, e.g. the already planned changes and the recommended measures will overlap slightly, leaving the total risk reduction somewhat lower.

The final recommendations as regards which measures should be implemented to be able to control the potential threats and improve safety further, are summarised in Chapter 11.9.

11. MAIN CONCLUSIONS

This chapter provides answers related to the secondary goals (A–E) in the overall objective (cf. Chapter 1.3):
A. Verify that/whether the assumed reduction in risk during helicopter transport also includes perceived risk,that the reduction is genuine and is not generally due to random variations.
B. Explain any deviations (positive and negative) in relation to the goals in public report NOU 2002: 17. The goals in public report NOU 2002: 17 will also be assessed based on new developments in safety philosophy (e.g. *Resilience Engineering*).
C. Establish a "HSS-3 methodology" with risk influencing factors, safety promoting factors, and risk and safety indicators which provide a significant contribution to help explain the risk development in helicopter transport, and which gains wide acceptance in the industry.
D. Identify all trends that will be important for the risk and safety level for offshore helicopter transport of personnel in the ten-year period 2010-2019, and map out relevant effects of these trends.
E. Identify all of the most important and most relevant measures to maintain or improve safety during this type of helicopter transport. With the aid of rough cost/benefit assessments, it will also provide a foundation for prioritizing the measures in relation to each other.

11.1 Accident statistics

- During the period 1999–2009, there has only been one helicopter accident on the Norwegian Shelf and no fatalities. This represents a significant decline from the previous period (1990–1998), where 2.3 fatalities were registered per million person flight hours.
- If we include the whole 20-year period 1990–2009 on the Norwegian Shelf, there have been five accidents with a total of 12 fatalities. This equals **0.9** fatalities per million person flight hours and an accident rate of **0.4** accidents per million person flight hours.
- In comparison, during the period 1999-2009, **5.6** fatalities have been registered per million person flight hours in the UK sector.

11.2 Current risk level

- Risk reduction on the Norwegian Shelf between the previous period (1990–1998) and this period (1999–2009) is estimated at **16%,** based on expert judgments. This reduction is larger than what was estimated in HSS-2 (5%).
- The average risk level on the Norwegian Shelf during the 20-year period 1990–2009 is estimated at **1.1** fatalities per million person flight hours. The risk level during the period 1999–2009 is estimated at **1.0**, while the risk level for the previous period (1990–1998) is estimated at **1.2**.

11.3 Fulfilling goals from public report NOU 2002: 17

- The main objective relating to at least halving the total probability of fatalities during helicopter transport during the next ten-year period, compared to the period 1990–2000 is not considered to be fulfilled (cf. Chapter 7.5.1).
- Secondary goals 1, 3 and 4 have been met while secondary goal 2, has not been met (cf. Chapter 7.5.2).

11.4 Detailed risk for RIFs and accident categories

The contributions to risk from the different accident categories and Risk Influencing Factors are summarised in the following.

Contribution to accident risk
The three accident categories contributing most to risk are A5: *Controlled flight into terrain, sea or obstacle* (34%), A3: *Critical system failure during flight* (29%) and A2: *Take-off/landing helideck* (23%), cf. Figure 6.4.

- The two operational RIFs for frequency contributing most to risk are RIF 1.5 *Pilots' competence* (21%) and RIF 1.1 *Helicopter design* (20%), cf. Figure 6.5.
- None of the operational RIFs for consequence stand out as more important than others. The RIF group *Rescue safety* (comprising RIF 1.1–1.5) represents 40% of the risk "contribution". The RIF group *Aerodrome*, comprising issues related to heliport/airport and helideck (RIF 1.9–1.11), appears to be least important, "contributing" only 11% to risk, cf. Figure 6.7.
- The accident category with the clearly highest consequence is A4 *Collision with another aircraft / Mid-air collision (MAC)*.

Contribution to accident frequency

- The two most common accident categories are A3 *Critical system failure during flight* (38%) and A2 *Take-off/ landing helideck* (33%), cf. Figure 6.1.
- The two operational RIFs contributing the most to accident frequency are RIF 1.1 *Helicopter design* (27%) and RIF 1.2 *Continuous airworthiness* (18%), cf. Figure 6.2. These two RIFs make up the RIF group *aircraft technical dependability* with a total of 45% of the contribution to accident frequency.

Importance of organisational RIFs

- The two organisational RIFs most influencing risk are RIF 2.1 *Helicopter manufacturers/Design organisations* and RIF 2.2 *Helicopter operators/Maintenance organisations* (cf. Figure 6.10). Review of the changed internal framework conditions' significance for flight safety for helicopter operators confirms this.

11.5 Changes in risk during the period 1999–2009

During the ten-year period 1999–2009, we have the following estimates for change in risk:

- Estimated risk reduction during the period 1999–2009 is **20%** (cf. Figure 7.4). The estimate is based on a reduction of 11% in accident frequency due to improvements in (operational) RIFs for frequency, and a reduction of 10% of consequences from accidents due to improvements in (operational) RIFs for consequence.

- Almost all Risk Influencing Factors show improvement during the period, and thus contribute to reduced risk. A small number of RIFs contribute to a (modest) risk increase.

The most important operational factors contributing to this risk change are given in the following, together with net risk change in parentheses. Almost all numbers reflect a risk reduction, and are therefore negative. If it is evident from the text that it is a reduction, the sign is omitted. The few cases where a risk *increase* is indicated, this is emphasised by a positive sign. We also highlight larger RIF groups to emphasise their total impact. RIFs for both frequency and consequence appear together, so the letters "F" and "C" in the RIF numbers are used to differentiate between "frequency and consequence", respectively.

RIF C0.1 *Rescue safety* (-6.1%)
The most important cause of improved rescue safety is the introduction of new helicopter models on the Shelf (mainly the S-92). Seats with higher g-tolerance, better stability at sea and improved cabin design are presented as important factors. Additionally, survival suits have become safer and emergency locator equipment has become more accurate.

RIF F1.5 *Pilots' competence* (-2.1%)
Simulators are becoming more realistic, and there is increased work on *Crew Resource Management* (CRM). An increased degree of standardisation and automation reduces the workload in the cockpit.

RIF F1.8 *Helideck* (-2.0%)
Helideck safety has been in focus in recent years, which has e.g. led to the publication of a new OLF helideck manual and new requirements for designing helidecks. Competence requirements for helideck personnel have become stricter. An increased number of mobile facilities with moving helidecks contribute to increased risk. One compensating measure would be the introduction of automatic systems for monitoring helideck movement.

RIF F1.1 *Helicopter design* (-1.9%)
This risk improvement can be attributed to the introduction of new machines (mainly the S-92 and EC225), with technical improvements on several levels.

Of the very few operational RIFs not showing improvement during the period, the following is selected:

RIF C1.13 *Organisation and cooperation* (+0.5%)
The main cause for the deterioration is the increased number of mobile facilities, and the potential challenge posed by the fact that everyone involved might not have the correct (updated) information about the relevant infrastructure in the situations that arise.

11.6 Changes in risk during the period 2010–2019

For the period 2010–2019 we have the following estimates for change in risk:

- The estimated risk reduction during the next period (2010–2019) is **27%** (cf. Figure 7.4). The estimate is based on a reduction of 19% in accident frequency due to improvements in (operational) RIFs for frequency, and a reduction of 11% in the consequence of accidents due to improvements in (operational) RIFs for consequence.

- The estimated risk reduction *between* the two periods 1999–2009 and 2010–2019 is **23%** (cf. Figure 7.4).

The most important operational factors contributing to this risk change are given in the following, together with net risk change in parentheses. Almost all numbers reflect a risk reduction, and are therefore negative. If it is evident from the text that it is a reduction, the sign is omitted. In the few cases where a risk *increase* is indicated, this is emphasised by a positive sign. We also highlight larger RIF groups to emphasise their total impact. RIFs for both frequency and consequence appear together, so the letters "F" and "C" in the RIF numbers are used to differentiate between "frequency and consequence", respectively.

RIF F1.1 *Helicopter design* (-5.9 %)
The greatest technical safety benefit from the phase-in of new helicopter models (S-92 and EC225) and development of the latest generation of proven helicopter technology is expected to manifest during the next period.

RIF F1.2 *Continuous airworthiness* (-4.0%)
Systems and procedures for registering errors and deficiencies have improved, e.g. through HUMS, which is continually being improved. Risk management in general is expected to further improve. Closer cooperation between helicopter operators and helicopter manufacturers is also expected, e.g. through regular meetings. Additionally, increased experience is gained with the new helicopter models.

RIF F0.1 *Aircraft technical dependability* (-9.9%)
This RIF group includes the two above-mentioned operational RIFs. In other words, there will be considerable risk reduction within the flight-technical area, cf. RIF F1.1 *Helicopter design*.

RIF F0.2 *Aircraft operations dependability* (-6.4%)
RIF F1.5 *Pilots' competence* (-3.1 %) contributes most to this RIF group. The pilots will have increased experience with the new helicopter models, and the availability of simulators is improving.

RIF C0.1 *Rescue safety* (-6.3%)
During this period, the safety benefit of introducing new helicopter models (S-92 and EC225) is expected to also include rescue safety. RIF1.2 *Stability at sea,* especially, contributes (-2.3%) within this RIF group. This is also connected to the increased share of new helicopter models.

Of the few RIFs not showing improvement during this period, the following are highlighted:

RIF F1.10 *Weather conditions and climate* (+0.5%)
We see a tendency towards more extreme weather. As activity increases further north, weather conditions are expected to become somewhat more challenging, e.g. the danger of polar low pressure. The increased activity in the north must be met with a satisfactory development of services within heliport/airport infrastructure, rescue service, weather forecasting etc.

RIF F1.11 *Other activities* (+0.5%)
Air traffic is increasing. The use of unmanned aerial vehicles (UAV) is also cause for concern. The regulations for such flying are considered unclear. One improving factor is improved availability of cartographic data bases for mobile facilities.

RIF C1.13 *Organisation and cooperation* (+0.6%)
The main causes of increased risk contribution are the challenges associated with search and rescue when distances increase as more activities move north.

11.7 Perceived risk

The analysis of perceived risk has contributed insight into the passengers' perception of risk during helicopter transport, and has documented that this is a compound and complex phenomenon. The interviews with oil workers and their stories illustrate that there are several circumstances and what we have called "small indicators" of great importance to perceived risk. Risk in connection with helicopter transport is not something that bothers them daily, but the stories of personal and related experiences show that this is a concern. These stories are retold and serve several purposes. They are an important source of coping and transfer of experience, and they also yield suggestions for improvement. The analysis shows that quantifying risk is context and situation-dependent: Most of the participants did not feel there was significant risk connected to flying either helicopters or airliners. The results show large diversification and a range of deviation of one to seven for helicopters, and from one to four for airliners, on a scale of one to ten. Several commitment areas are identified; from practical help for first-time travellers to more extensive measures and investments, cf. Chapter 8.2.4. It is recommended that these measures are examined thoroughly, and that the least controversial measures are implemented, as a minimum. According to SINTEF's judgment, this covers the following (non-prioritised) suggestions:

- Make the safety videos less 'serious' (scaring) and stimulate the passengers to support each other socially, in particular those travelling for the first time and feeling uneasy
- Consider choice of seat in relation to specific needs as perceived risk varies with seating location
- Consider a possible weight limit for offshore workers in order to facilitate evacuation in emergency situations
- Improve the communication equipment in the helicopters and train the pilots to give clear and evident information (Passenger Announcement; PA)
- Fasten loose equipment in the cockpit (pilot's suitcase, manuals etc.)
- Increase awareness of the heliguards as to their behaviour; notably to pay specific attention to those travelling for the first time, plus assisting passengers embarking/
disembarking in bad weather condition (wind, helideck movements)
- Minimize exemptions from recurrent training for helicopter ditching

- Improve communication of credible information after incidents. (Correct information will reduce insecurity among the passengers.)
- Extend the project "Risk level in Norwegian petroleum industry" (RNNP) with new questions related to quantitative mapping (see the proposal in Chapter 8.2.5)
- Expand the next editions of RNNP with a specific qualitative part on helicopters.

11.8 Resilience and indicators

The use of resilience in the project has contributed to the ability to experience normal operations without incidents, and where the organisation's ability for continual operation is considered. This has caused expanded system knowledge. To further improve safety during helicopter transport, safety monitoring should, in the future, be based on both leading and lagging indicators, which focus on significant functions in connection with the helicopter operation. Indicators identified in the study are the next step in proactive safety work. In addition to the use of proactive indicators, we recommend the use of observations of critical operations to identify changes of importance to safety. This includes any new indicators to be considered, and that existing indicators are revalidated.

11.9 Final suggestions as regards measures

Given that the above mentioned already planned improvements are implemented, the study concludes with several suggested measures for keeping the potential threats under control and further improving safety. In non-prioritised order, the measures are broken down into the following areas:

1. Improve safety regarding approach helideck operations
2. Reduce the possibility of technical failures
3. Improve the management of organizational changes and changes in the internal framework conditions
4. Increase the use of proactive safety indicators
5. Improve interaction between the operators involved in offshore helicopter transport
6. Develop and maintain technical and operational competence
7. Reduce the risk of lightning strikes and their possible consequences on helicopters
8. Minimize exemptions from requirements and the OLF recommended guidelines
9. Evaluate measures to reduce perceived risk
10. Follow up and implement the recommendations presented in this report.

Suggested measures for each area are explored below, still not in prioritised order.

1. Improve safety regarding approach helideck operations

Proposed measures:

1.1. Implement automatic flight approach procedures up to a specific distance to the installation, thereafter a safe visual approach in the last part of the approach and landing

1.2. Improve education, training and interaction for the pilots, plus the requirements for use of simulators such that the pilots can train on realistic operations regarding approach to the offshore platforms in non-optimal conditions

1.3. Minimize flights during night conditions and in reduced visibility, particularly flights to ships.

2. Reduce the possibility of technical failures

Proposed measures:

2.1. Complete thorough criticality analyses (Failure Modes, Effects and Criticality Analysis (FMECA) or similar) before new helicopters are put in service and before the implementation of major modifications
2.2. Focus on the use of the latest generation proven helicopter technology
2.3. Maintain the Norwegian offshore helicopter requirements, among others, the use of the Health and Usage Monitoring System (HUMS) and systems for position indication of the helicopter all the way down to sea level (Modified Automatic Dependent Surveillance (M-ADS) or similar)
2.4. Consistently apply the OLF's recommended guidelines for this type of helicopter operations
2.5. Improve the routines for reporting failures in critical safety equipment on helidecks.

3. Improve the management of organizational changes and changes in the internal framework conditions

Proposed measures:

3.1. Active use of risk analyses prior to implementing changes, and utilize the experience after changes have been implemented
3.2. Improve CAA-N's mandatory inspection and surveillance programmes, notably with focus on routine follow up of the helicopter operators after major organizational changes
3.3. Ensure that Norwegian additional requirements are kept.

4. Increased use of proactive safety indicators

Proposed measures:

4.1. Improve safety management by extended use of leading indicators
4.2. Develop indicators based on observations of normal operations and better comprehension of what seems to work well (e.g. observations of landing on a moving helideck or base/heavy maintenance)
4.3. Further develop the Petroleum Safety Authority's project on "Risk level in Norwegian petroleum industry" (RNNP) to also include:
    - reported incidents from the air traffic control and the helideck function
    - a set of leading and lagging indicators as proposed
    - monitor changes in risk levels through an update of the HSS-3 model based on the risk influencing factors (RIF).

5. Improve interaction between the operators involved in offshore helicopter transport

Proposed measures:

5.1. Increase the involvement of the air traffic service for offshore operations
5.2. Improve the communication and exchange of information internally and between the players in this sector. This to elucidate reporting routines, lines of responsibility and organization, and to learn from experience

5.3. Increase feedback from the Civil Aviation Authority to the helicopter operators in order to improve organizational learning across organizations
5.4. Improve the communication within and between the helicopter manufacturers and the helicopter operators. There is a special need to increase the availability of spare parts.

Figure 11.1 illustrates the need for improvement in effort and cooperation.

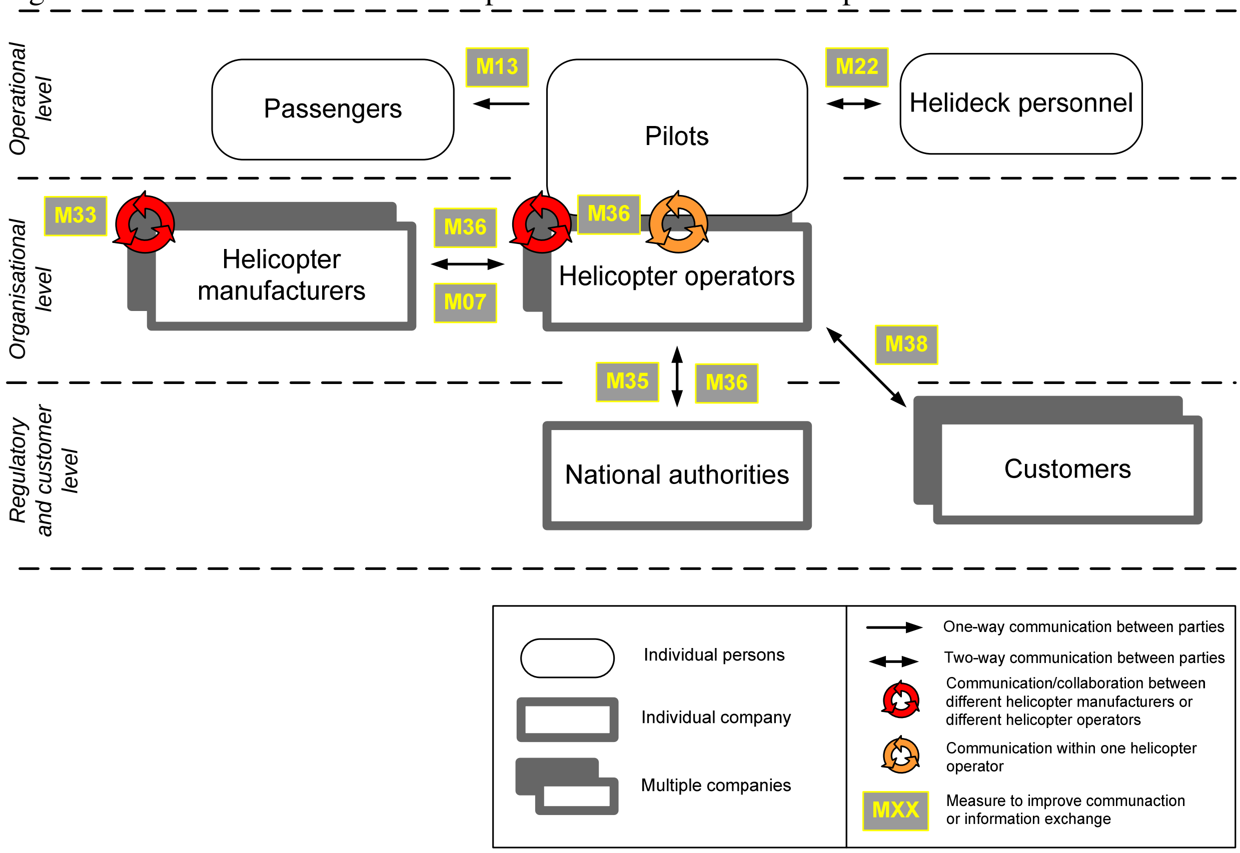

Figure 11.1. Improvement areas for cooperation between players

Four types of cooperation, communication and information exchange are identified below, in addition to areas where a need for improvement has been identified:

- between different players, e.g. between the CAA-N and the helicopter operators
- from one player to another, from the pilots to the passengers on board the helicopter
- between similar players, e.g. between different helicopter operators
- within a player (helicopter operator).

Some of the measures described in this chapter identify the need for and examples of measures designed to improve the flow of information for the four types above. Figure 11.1 illustrates some relevant measures grouped with their "communication area".

6. Develop and maintain technical and operational competence

Proposed measures:

6.1. Change the training of the technical personnel in order to increase system comprehension and more time to train on equipment that is specific for the operation of helicopters on the NCS

6.2. Extend and adapt the training of the pilots to realistic and critical situations
6.3. Initiate a project to look at the possibilities and possible safety gain of the paperless cockpit (Electronic Flight Bag or similar).

7. Reduce the risk of lightning strikes and their possible consequences on helicopters

Proposed measures:
7.1. Initiate a research project on the risk of lightning strikes on helicopters taking weather conditions and operations on the NCS into consideration.

8. Minimize exemptions from requirements and recommended guidelines

Proposed measures:
8.1. Minimize exemptions in overturn evacuation training in the requirements for refresher emergency training courses
8.2. Exempt possibilities to interpret the mandatory requirements that may lead to the lack of independent inspections of critical maintenance tasks offshore
8.3. Minimize exemptions from the Norwegian additional requirements and the special practice established for helicopter transport on the NCS (ref. item 2.3 on the use of HUMS and M-ADS).

9. Evaluate measures to reduce perceived risk

9.1.Measures to be further assessed:
- Make the safety videos less 'serious' (scaring) and stimulate the passengers to support each other socially, in particular those travelling for the first time and feeling uneasy
- Consider choice of seat in relation to specific needs as perceived risk varies with seating location
- Consider a possible weight limit for offshore workers in order to facilitate evacuation in emergency situations
- Improve the communication equipment in the helicopters and train the pilots to give clear and evident information (Passenger Announcement; PA)
- Fasten loose equipment in the cockpit (pilot's suitcase, manuals etc.)
- Increase awareness of the heliguards as to their behaviour; notably to pay specific attention to those travelling for the first time, plus assisting passengers embarking/
  disembarking in bad weather condition (wind, helideck movements)
- Minimize exemptions from recurrent training for helicopter ditching
- Improve communication of credible information after incidents. (Correct information will reduce insecurity among the passengers.)
- Extend the project "Risk level in Norwegian petroleum industry" (RNNP) with new questions related to quantitative mapping (see the proposal in Chapter 8.2.5)
- Expand the next editions of RNNP with a specific qualitative part on helicopters.

10. Follow up and implement the recommendations presented in this report

Proposed measure:

10.1. OLF and the Civil Aviation Authority - Norway must in cooperation take an initiative to form a 'body' that can ensure that the proposed measures in this report will be evaluated and followed up by concrete actions. It is recommended that the cost/benefit analyses carried out (Chapter 10.6-10.7) are used as basis for this process.

Prioritising measures

Prioritising of the suggested measures should be done on the basis of an assessment of the cost/benefit relationship, estimated risk reduction, feasibility, time aspect, co-variation with other measures etc. It is important to view the measures in context and consider the benefit of implementing several measures within the different areas. If we view the different measures separately, and the combination of the cost/benefit relationship and the estimated risk reduction alone, the following measures stand out as the most beneficial (in prioritised order, cf. Figure 10.):

1. More thorough criticality analyses (FMECA)
2. Use of the latest generation of proven helicopter technology
3. Implementing automatic approach procedures
4. Improving supervisory activities
5. Use of OLF's recommended guidelines as the recognised standard
6. Reduce number of flights during night conditions and reduced visibility, especially during approach to ships

Based on an overall evaluation, the following measures should also be considered particularly important:

- Improved training and exercises for pilots and requirements for simulators
- Improved training for technical personnel
- Continuation/replacement of M-ADS
- Increased focus on communication to learn from experience

On complete implementation of *all* of the suggested measures within a reasonable time, a 70% risk reduction of the current risk level is estimated, *given* that no changes occur which contribute to increased risk. Risk reduction based on already planned changes (estimated at 23%) will add to this. In total, this will yield a net risk reduction of 77%. This is a rough figure, given that there are no changes added that will contribute to increased risk. There are also several other sources of uncertainty, e.g. the already planned changes and the recommended measures will overlap slightly, leaving the total risk reduction somewhat lower.

11.10 Further work

SINTEF makes the following suggestions for further work:

- Perform a more thorough cost/benefit analysis of measures
- Clarify who is responsible for implementing and following up the measures
- Further consideration of measures relating to perceived risk
- Further use and follow-up of safety indicators
- Consider compensating measures for the potential of increased risk (elimination of additional Norwegian requirements, increased traffic volume, increased activity in the northern areas, larger changes in the helicopter fleet etc.)

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