

HELICOPTER SAFETY STUDY



MAIN REPORT

A/S Norske Shell



STATOIL



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Safety and Reliability

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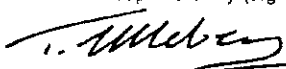
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Abstract

The report summarizes main results from the Helicopter Safety Study:

Significant risk factors associated with helicopter transportation in the North Sea area are identified and described.

A procedure for identification and evaluation of risk factors has been developed. The risk factors where risk reducing means have potential to give the highest improvements of the overall helicopter safety are identified and ranked.

Risk reducing means that derive directly from the project results are suggested.

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Helicopter Safety Study

EXECUTIVE SUMMARY

North Sea helicopter transportation has a fatal accident rate which is about ten times higher than that of scheduled airline services, in spite of a generally high standard of operations, maintenance and management. A reduction in fatalities of approximately 40% may be achieved over the next 10-15 years, through extensive efforts in research and development. Although other sources have indicated that human factors are the dominating concern in worldwide helicopter safety, this study shows that technical reliability is the most promising area for improving safety in North Sea helicopter transportation.

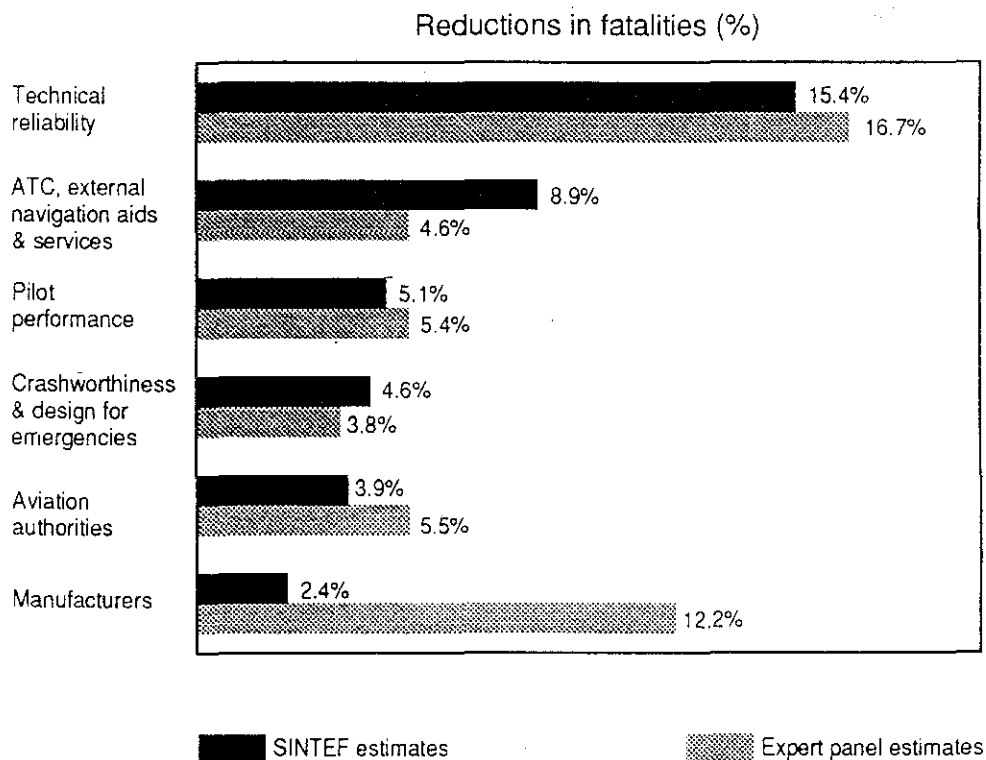


Figure 1 Reduction in fatalities, following realistic improvement of risk factors (according to SINTEF and a group of helicopter experts)

Helicopter Safety Study

EXECUTIVE SUMMARY

Background

The helicopter is indispensable for transportation of personnel in the North Sea petroleum industry. At present, there is no realistic alternative means of transportation, nor will there be in the near future.

Further research on helicopter safety was deemed necessary by Shell and Statoil to provide a basis for improving the current safety level in these operations. The existing state of knowledge for making a judgment on research priorities was considered inadequate. A study was therefore initiated to identify the areas which are most effective in improving offshore helicopter safety. The study was carried out by SINTEF Safety and Reliability, with the Cranfield Institute of Technology and the University of Leiden as sub-contractors.

The current North Sea helicopter operations are run much in the same way as other high quality aviation operations. The present safety standard depends on the high level of competence and dedication to safety of pilots, maintenance personnel and management.

The fatal accident rate for helicopter operations in the North Sea area up to 1990 has been estimated to 380 fatalities per 10^8 person flight hours. This figure is approximately 10 times that of scheduled airline services («fixed wing»). Helicopter transportation contributes significantly to the occupational risk of workers on offshore installations.

Risk factors

The study identified and assessed a number of risk factors influencing offshore helicopter transportation. A risk factor was defined as a set of conditions influencing the fatal accident risk. Risk factors are conditions that may be improved by specific actions, and changes in a risk factor can either increase or reduce the risk level by influencing accident frequencies and consequences. A total of 24 risk factors were specified and addressed within the following main categories:

- Operational functions
- Technical functions
- General management
- External factors

Helicopter Safety Study

EXECUTIVE SUMMARY

Data input

In order to assess the influence of various risk factors, the project group collected and analyzed data from the following sources, in cooperation with the five major helicopter companies operating in the North Sea area:

- Summaries of ICAO helicopter accident reports
- Company helicopter incident reports
- Company in-flight deviation reports
- Accident Investigation Branch (AIB) aircraft accident reports
- Questionnaires aimed at helicopter maintenance personnel
- Interviews with helicopter pilots
- Questionnaires aimed at helicopter pilots
- Company technical reports
- Interviews with management personnel in helicopter companies

Risk influence rating

SINTEF developed a method to identify the risk factors which could give the highest improvement of helicopter safety («risk influence rating»). The method considered the importance of each risk factor in fatal accidents, and the realistic potential for improving the risk factors. The procedure for the risk influence rating is illustrated in Figure 2.

The validity of the results from the study was addressed through a review by helicopter experts from three major helicopter companies and two oil companies.

Main results

Figure 1 shows the risk factors which, following realistic improvements, have the highest potential for reducing fatalities. Although there are some differences in the estimates by SINTEF and the helicopter experts, the most important risk factors and main conclusions are consistent.

SINTEF estimated that a 30-40% reduction of risk per person flight hour can be achieved within 10-15 years, compared to the present safety level. This requires systematic efforts in all major technical and operational areas.

Other studies of worldwide helicopter safety have indicated that the majority of all helicopter accidents were due to human error. However, the present study of North Sea operations points out technical reliability as the most important risk factor.

Helicopter Safety Study

EXECUTIVE SUMMARY

Technical reliability

Helicopters are complex aircraft with several non-redundant critical systems. Technical failures in critical systems are a dominating cause of fatal accidents with North Sea helicopters, reflecting the fact that these aircraft are subject to adverse environmental conditions, heavy vibrations and a high degree of utilization. Major areas for improvement include systems for collection and utilization of performance data and further development of Health and Usage Monitoring Systems (HUMS), providing early warning of imminent failures.

ATC, external navigation aids & services

Lack of Air Traffic Control services and inaccurate navigation aids represent a significant risk in present helicopter operations, even though no fatal accidents have yet been attributed to this cause. Effort should be concentrated on new navigation systems, coordination of helicopter traffic with military traffic and improved offshore regulation.

Pilot performance

Offshore helicopter operations place great demands on pilots, in an environment where the consequences of errors may be catastrophic. The study identified problems related to pilot work schedules, physical work environment, emergency preparedness, operating procedures and the crew concept. Measures should be directed towards improvements in these areas.

Crashworthiness & design for emergencies

The climatic conditions in the North Sea and the design characteristics of helicopters in use affect the consequences of a helicopter crash or ditching. Areas for improvement include aircraft stability on sea, energy absorption properties, interior design and evacuation possibilities.

Aviation authorities

Problems regarding the practice of national and international regulating bodies include incomplete regulations for offshore helicopter transportation and inadequate control systems. The role of aviation authorities should therefore be examined.

Helicopter Safety Study

EXECUTIVE SUMMARY

Manufacturers

The influence of manufacturers on safety is indirect through design, which in turn influences technical reliability. Since most aircraft types flown in the North Sea today were originally designed for military use, the severe environment and high degree utilization of the helicopters in this area represent a significant change in operational conditions. Important areas to consider are testing of components under realistic conditions, certification and information exchange between manufacturers and helicopter companies.

Management factors

Management factors influence safety indirectly and may lie behind a range of specific safety problems in the companies. A difficult market situation or austere contracts with the oil companies can create conditions which may influence safety in an adverse manner. The overall goal structure of the companies, and in particular the relation between safety and other goals, need to be stated clearly, e.g. through the adoption of an overall quality assurance program. A more systematic approach with regard to information systems, the hazard analysis process and safety improvement is required. Finally, lack of experienced pilots and maintenance personnel may become a serious problem in the future.

Areas for further research and development

The study has pointed out the following areas for research and development as the most important in improving North Sea helicopter safety:

- Effective use of operational experience for helicopters.
- Guidelines and tools for safety management.
- North Sea helicopter operator safety data exchange.
- Factors influencing maintenance performance.
- Long term health effects for offshore helicopter pilots.
- Recruiting and retention of maintenance engineers for North Sea helicopter operations.
- Problems and solutions associated with Air Traffic Control in the North Sea area.
- Design specification of a helicopter optimized for North Sea petroleum support operations.
- North Sea helicopter pilots cockpit environment.

Helicopter Safety Study

EXECUTIVE SUMMARY

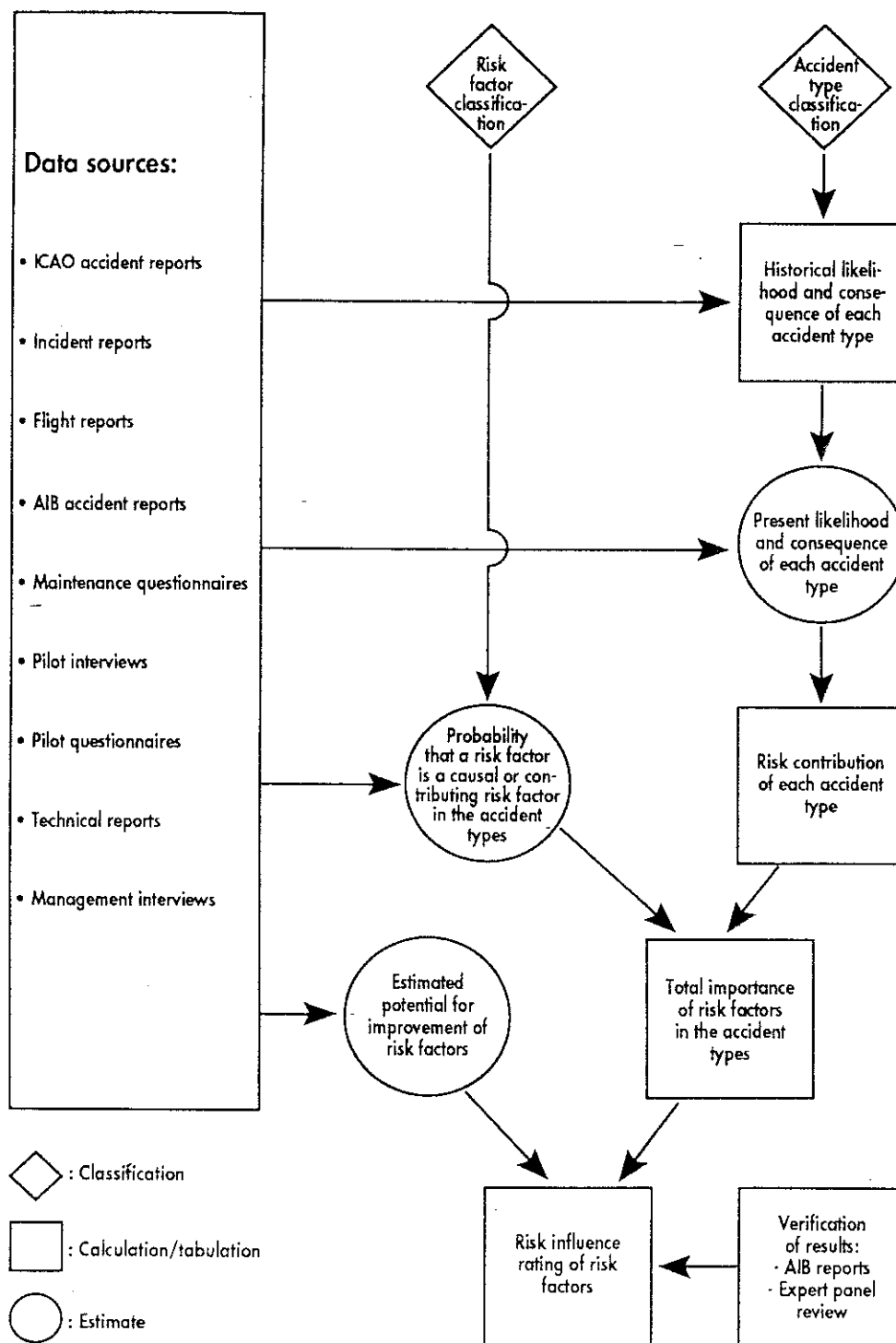


Figure 2 Procedure for risk influence rating

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PREFACE

This report summarizes main results from the research project «Helicopter Safety Study». The project was made possible through funding from A/S Norske Shell and Statoil.

The project was carried out through joint efforts from SINTEF Division of Safety and Reliability, as main contractor, with the Cranfield Institute of Technology (UK) and University of Leiden (the Netherlands) as contractors to SINTEF.

The project group wishes to extend a special thanks to the following members of the Technical Advisory Group (TAG) for active participation and creative contributions:

- E. Wiig (A/S Norske Shell), TAG Chairman
- G. C. van der Graaf (SIPM)
- R. V. Holley (Shell Aircraft Ltd.)
- J. Taarland (Statoil)
- B. Steen (Statoil)

H. Hollingsbee (Shell Expro) and R. Reynolds (NAM) have been project advisors. T. Sande (A/S Norske Shell) has given valuable comments throughout the project.

The following persons participated in the expert panel review:

- S. G. Birt (British International Helicopters Ltd.)
- H. Hollingsbee (Shell Expro)
- R. V. Holley (Shell Aircraft Ltd.)
- H. G. Goos (KLM helicopters)
- A. Hovland (Helikopter Sercive)
- R. Reynolds (NAM)
- J. Taarland (Statoil)
- C. Zeegers (KLM Helicopters)

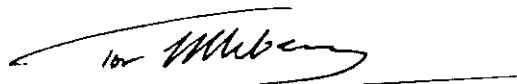
The project would not be possible without access to data and personnel in the following companies and agencies:

- Helikopter Service A/S
- British International Helicopters Ltd.
- Bristow Helicopters Ltd.
- Bond Helicopters Ltd.
- KLM Helikopters B.V.
- Safety Data and Analysis Unit, UK CAA

Thanks to the companies and the CAA for their cooperative attitude and assistance.

It is our ambition and hope that this study will, as intended, form the basis for improving safety in North Sea helicopter transportation.

Trondheim, 1990-11-01

A handwritten signature in black ink, appearing to read 'Tor Ulleberg', with a long horizontal line extending to the right.

Tor Ulleberg

Project Manager

DISCLAIMER

The data forming the basis for the Helicopter Safety Study has been collected through the joint efforts of personnel from SINTEF, the Applied Psychology Unit at the Cranfield Institute of Technology and the Hudson Group at the University of Leiden. Data were provided from the following five helicopter companies operating in the North Sea area:

- Helikopter Service A/S
- Bristow Helicopters Ltd
- Bond Helicopters Ltd
- BIH Helicopters Ltd
- KLM Helikopters B.V.

SINTEF was responsible for implementing the data into databases, the quality assurance and pooling of the data. Pooling implies that the general conclusions may not be applicable to a single helicopter company, oil company or sector of the North Sea.

The conclusions in this report, drawn on the basis of the project databases, are subject to a number of assumptions and limitations stated in the report.

SINTEF will accept no liability for conclusions being deducted by readers of the project reports. Caution should always be taken when using the results in the reports, such that decisions are not taken on an erroneous or incomplete basis.

1. INTRODUCTION

1.1 Readers guide

Section 1 of the report presents important background information, limitations and definitions guiding the project, and the risk factor classification which has been developed.

The study approach is outlined in section 2.

In section 3, results and conclusions from individual data collection studies which have been conducted as part of the project are summarized.

Section 4 gives an overview over accident scenarios in helicopter transportation and corresponding accident data from the North Sea area.

In section 5, the methodology used for rating of the risk factors based on the available data is presented. Results from each step of the procedure are presented and discussed in detail.

The most important risk factors identified through the study are discussed in section 6. Minor risk factors are discussed briefly.

A verification of the results in the report is given in section 7, through a review of official accident reports, and in section 8, through an expert panel review.

Finally, proposals for further research and development are given in section 9. A list of references is also provided.

1.2 Background

Petroleum production in the North Sea has been accompanied by a large expansion in civil helicopter transportation. Accident statistics show that this transport has given rise to a number of fatal accidents, and that the helicopter transportation is one of the main contributors to the overall accident risk connected to offshore oil and gas activities. At present, there is no feasible alternative to personnel transport by helicopter to offshore installations.

Accident Statistics

The fatal accident rate, FAR (No. of fatalities per 10^8 person flight hour) for helicopter transportation in the North Sea petroleum activity is presented in table 1.1. Figures are given for each sector of the North Sea during the time period 1966-89.

Table 1.1 Fatal accident rate for helicopter transportation in the North Sea petroleum activity.

Sector	Fatalities	Accumulated person flight hours ($\times 10^6$)	FAR (Fatalities per 10^8 person flight hours)
Norway	34	8.3	410
UK	68	18.4	370
Netherlands	6	1.6	380
Denmark	3	1.1	270
All	111	29.1	380

The exact number of person flight hours is not available. The numbers above have been estimated, based on some data supplied with judgments. The relative uncertainty in these numbers are judged to be 10% - 20% for Norway and UK, and 20% - 30% for the Netherlands and Denmark. The uncertainty in the overall figure (380 fatalities per 10^8 person flight hour) is judged to be about 10% - 15%.

The overall figure of $380 \cdot 10^{-8}$ fatalities per person flight hour approximately equal to the figure of $430 \cdot 10^{-8}$ reported in Lydersen (1982) for Norway and UK up to August 1982. Thus, there has been no change in average experienced FAR.

On the other hand, it should be noted that 45 of the 50 fatalities recorded in September 1982 - November 1989 are due the accident with the Chinook helicopter on 1986-11-06. Another interesting observation is that there have been no fatal accidents in the area since the Chinook accident. This is by far the longest accident-free period since 1973. However, there is not enough evidence to state that there is an underlying, improved safety trend.

For comparison, scheduled airplane services in 1983 - 1987 experienced a fatal accident rate of 35 fatalities per 10^8 passenger flight hours, i.e. 10 times lower than that of North Sea helicopters.

The calculated FAR may be considered as an estimate of the expected number of fatalities per person flight hour. These estimates, together with approximate 90% confidence intervals, are shown in figure 1.1. Although the experienced FAR differs somewhat between the 4 sectors of the North Sea, there are *no indications of difference in safety level*. However, it is evident that the expected number of fatalities per person flight hour is significantly higher for helicopter transportation, than for fixed wing.

Estimate and Approximate 90% confidence intervals

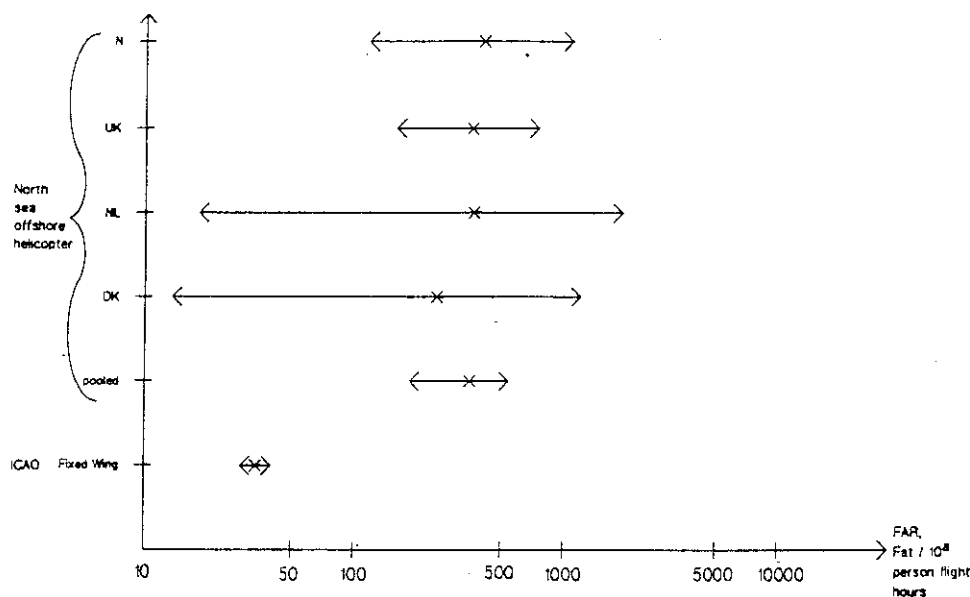


Figure 1.1 Estimates and approximate 90% confidence intervals for the expected number of fatalities per 10^8 flight hours.

1.3 Project objectives

The overall scope of the Helicopter Safety Study was:

- To provide a decision basis to A/S Norske Shell and Statoil for allocation of funds to helicopter safety research.

The specific objectives of the study were:

- Identify and describe the significant risk factors associated with helicopter transportation in the North Sea area and on the Northern Norwegian Shelf.
- Identify the risk factors where risk reducing means have potential to give the highest improvements of the overall helicopter safety, and suggest risk reducing means that derive directly from the project results.
- Develop models and methodology for data recording and analysis corresponding to objectives above.
- Develop a PC-based accident/incident recording and analysis system capable of accepting the data collected during the study, albeit in a simplified form, and allowing future updating («Helicopter Safety Study: Helicopter Safety Data Base»).

1.4 Boundary conditions and limitations

North Sea operations

The study covers helicopter transportation in the North Sea area (including the Northern Norwegian Continental Shelf). This is a highly regulated operation, with well qualified and experienced pilots and maintenance crew. The natural environment is rough compared to operations in other areas or operations covered by other studies (e.g. the US report «...Root Causes of Helicopter Accidents»).

Offshore operations in other areas in the world (e.g. the Gulf of Mexico). are not included in this study, due to the large difference in operating conditions such as, e.g., weather conditions and navigation facilities.

It should be noted that the aircraft involved are not originally designed for this type of operation, but rather for military operations.

Alternatives to helicopter transportation are not considered.

Validity issues with respect to data sources and methodology are discussed in section 5.11.

Fatal accidents

The risk influence evaluation focuses on accident risk with respect to fatal accidents.

The study considers both measures directed at the prevention of accidents and measures intended to reduce consequences if an accident should occur.

Operational limitations

The study covers the following areas of North Sea helicopter operations:

- Personnel transport to and from offshore installations
- Shuttle between installations
- Activities on heliport/helideck related to helicopter operations
- Search and rescue (SAR)
- Helicopter maintenance activities
- Company management
- Oil company and authority requirements

1.5 Definitions

Risk Factors

A main objective of the study is to identify and describe the significant risk factors associated to helicopter transportation. A risk factor, for the purpose of this project, is defined as:

- A set of conditions influencing the fatal accident risk.

Some examples of risk factors are:

- Crashworthiness
- Maintenance planning and tools
- Emergency preparedness
- Operating procedures
- Pilot working conditions

A risk factor is a relatively stable condition, not an event or a transient state. Risk factors are thus conditions that may be influenced/improved by specific actions.

Change in a risk factor can either increase or reduce the risk level. Both accident frequencies and consequences may be influenced by risk factors.

Risk factors can influence all phases of the accident process, from the first deviation from the normal state till the rescue operation.

Risk Influence

Risk influence is defined as:

- The reduction of total risk in helicopter transportation that would occur if a given risk factor were changed from the present (typical) state to a specified (optimal) state.¹

A rigorous assessment of risk influence has to take into account the following factors:

- In most accidents, the risk factor in question is one of many factors affecting the outcome. The effect of optimizing the risk factor might be to reduce, but not eliminate, the class of accidents influenced by the risk factor.
- A risk factor may influence the fatal risk level both through an impact on the frequency of fatal accidents and through an impact on accident severity (i.e. number of fatalities per fatal accident). Both impacts should be taken into account.

¹ The definition of risk influence has a clear analogy to Birnbaum's measure of importance in fault tree analysis (Lambert, 1975).

- In many cases, a change in one risk factor would lead to changes in other risk factors. Reducing gear box failures might lead to modification of emergency procedures, emergency training, maintenance procedures etc. Such modifications could in their turn influence the risk level. The risk influence rating should take such indirect influences into account. The rating is limited to fatalities, which is in accordance with the focus of the study.
- It should be assumed that conditions not influenced by the risk factor in question are kept constant.

1.6 Risk factor classification

To be able to identify and rank the most significant risk factors associated with helicopter transportation, a classification system of risk factors is required. A risk factor classification may be established in many ways and with varying level of detail. Among the requirements of a risk factor classification are:

- The classification should be exhaustive, i.e. it should include all relevant conditions.
- Categories should be mutually exclusive.
- Important terms should have operational definitions related to available data sources.

The number of categories in the classification should furthermore be limited.

The risk factor taxonomy presented below has been established in a pragmatic way. The various risk factors have been grouped in four categories:

- Operational functions
- Technical functions
- General management
- External factors

It has not been possible to make a classification where all factors are mutually exclusive. To enhance exclusivity some of the risk factors are specified by the phrase «The class does not include . . . »

It has also been difficult to define risk factors on a common level in a causal hierarchy. Some of the risk factors e.g. like «Economy & Budget» are on a higher level in the causal hierarchy than the factor «Spare Parts». This fact is, however, taken care of in the risk influence rating method.

OPERATIONAL FUNCTIONS

O1 Operating Conditions

External physical conditions in which the helicopter operates, which are not feasible to control by the helicopter operators.

O2 Heliports & Helidecks

Factors related to location, layout, equipment, heliport/helideck personnel etc. while the aircraft is on the heliport/helideck.

O3 PILOT PERFORMANCE

The degree to which the pilot(s) can be depended on to act in a manner required. This class also includes psychological factors such as attitudes etc. Note that in addition to e.g. pilot inattention, violations, etc., this category includes all factors affecting pilot performance, i.e. Operating Procedures (O4), Pilot Working Conditions (O5) and Emergency Preparedness (O6).

O4 Operating Procedures

The helicopter operators' written procedures, standards, requirements, etc. regulating operating practice. Note that emergency procedures are considered under a separate heading («Emergency Preparedness»).

O5 Pilot Working Conditions

Conditions related to the pilot's working situation, except helicopter ergonomic design and physical work environment, which may influence his performance.

O6 Emergency Preparedness

Equipment and organizational preparations (e.g. training) directed at the handling of emergencies. The class does not include factors directly related to helicopter design, e.g. stability on sea. Emergency procedures are included in this class.

TECHNICAL FUNCTIONS

T1 TECHNICAL RELIABILITY

This category includes all technical failures causing or contributing to fatal accidents, i.e. categories T2- T5.

T2 Inadequate Design

The actual design of the aircraft, e.g. failure inducing design, including selection of materials. This class does not cover ergonomic design and physical work environment in the aircraft (ref T8).

TECHNICAL FUNCTIONS, cont.

T3 Maintenance Planning & Tools

Conditions related to:

- Testing and inspection of the aircraft, identification of degradations e.g. through condition monitoring,
- Maintenance planning
- Actual maintenance and tools and facilities used during maintenance.

This class does not include supervision and human factors in maintenance (ref T4).

T4 Human Performance in Maintenance

The degree to which maintenance personnel can be depended on to carry out the required maintenance actions without errors. This class also includes psychological factors such as attitudes, etc.

T5 Spare Parts

All conditions related to availability and quality of spare parts, including spare part management, correctness of type, quality verification, etc.

T6 Equipment & Provisions

The capability and quality of equipment in the helicopter, e.g. navigation aids, autopilot. It does not cover the technical reliability of such equipment (ref T1).

T7 Crashworthiness & Design for Emergencies

Design characteristics of the aircraft which directly influence the opportunities for emergency handling and the consequences of a crash or ditching. This also includes, e.g. single engine performance.

T8 Ergonomic Design & Physical Work Environment

Design aspects of the helicopter and its equipment which influence pilot performance.

GENERAL MANAGEMENT

M1 Policy

Formulation and dissemination of operator safety policy and goals, including the way it is related to other and possibly conflicting goals.

M2 Organization and Responsibility

Factors related to the organizational structure of the operating company, including the distribution of responsibility and authority.

M3 Economy and Budget

The total economic resources within the helicopter company, the economic conditions in which the company is operating, and the way in which resources are allocated within the company.

GENERAL MANAGEMENT, cont.

M4 Personnel Management

All management activities directed at attaining a sufficient, well qualified and motivated staff. This includes e.g. the creation of a positive atmosphere for near-miss reporting.

M5 QA and Safety Management

Management activities which are specifically directed at safety assurance and conformance with requirements and standards. Includes e.g. safety and contingency training/motivation.

M6 Communication and Information Flow

Dissemination of safety relevant information in the helicopter operating company and between operating companies. Includes e.g. alert notes, systematic information on reliability.

EXTERNAL FACTORS

E1 Oil Companies

Conditions related to the interaction of oil companies with the helicopter operators, excluding the provision of helicopter facilities and services.

E2 Aviation Authorities

The policy and practice of national and international regulating bodies.

E3 ATC (Air Traffic Control), External Navigation Aids & Services

Factors related to regulations, procedures, resources and practice of air traffic control (ATC), flight information service (FIS & HFIS), navigation aids (VOR, ILS, NDB, etc.), meteorological service, etc.

E4 Manufacturers

Conditions related to the activities of helicopter manufacturers, excluding those directly covered by the risk factors «Inadequate Design» and «Spare Parts».

OTHER/UNKNOWN

U1 Untitled

Provisional category for items which are not possible to place in an above defined category.

2. APPROACH

2.1 Ambitions and challenges

The approach chosen for the present study reflects both the ambitions of the clients and the project group and the challenges encountered, e.g. scarcity of historical data.

The ambitions, as reflected in the objectives of the study, are elaborated in the following:

- *The approach should be capable of detecting and evaluating causal and contributing factors at the system or pathogen level.* The study should go beyond technical failures and erroneous actions and identify malfunctions in the planning, performance and control of transportation, including those related to agents external to the operators (e.g. aviation authorities, oil companies).
- *Risk influences should be quantified, at least at an ordinal level, i.e. a ranking of risk factors should be given.* It is however, recognized that such quantifications may be associated with considerable uncertainty.
- *The estimates and judgments involved in data analysis should be made explicit and justified.*
- *The validity of the results should extend beyond a single operator or a single country.*

The concept of *pathogens* is used in accordance with the *Tripod* conceptual framework developed by the Universities of Leiden and Manchester (Reason et al., 1988): «All man-made systems contain potentially damaging agencies, like pathogens within the human body. At any one time, each complex system will have within it a certain number of latent failures, whose effects are not immediately apparent but which can serve both to promote unsafe acts and to weaken its defense mechanisms. For the most part, they are tolerated, detected and corrected, or kept in check by protective measures. But every now and again, a set of external circumstances -- called here *local triggers* -- arises which combines with these resident pathogens in subtle and often unlikely ways to thwart the system's defenses and to bring about its catastrophic destruction. ... Resident pathogens include the effects of bad decisions made by policy makers, designers, managers, supervisors; latent maintenance errors; and routine violations. Local triggers comprise component failures, atypical systems states, environmental conditions, active operator errors and exceptional violations.»

The risk factors identified in the present study mainly refer to pathogens. We have, however, included a few risk factors which are close to the level of local triggers, e.g. technical reliability and pilot performance. The reason for this is that historical data sources often provide more information on triggers than on pathogens. Information on triggers may thus contribute to the understanding of how resident pathogens affect helicopter safety.

Important challenges were related to the availability of information:

- *Only 12 representative fatal accidents have occurred in the North Sea area.*¹ This number is too small to establish statistically significant trends.
- *Reporting criteria for occurrences are in many cases ambiguous.* It is consequently difficult to establish trends, as changes in the actual frequency of a class of incidents may be confounded with changes in the reporting practice. Reporting practice may also depend on the type of occurrence. Pilots may, e.g., be more reluctant to report their own errors than to report technical problems of similar severity.
- *Most occurrence reports and technical reports contain little information regarding system causes (pathogens).* The implication is that other data sources have to be utilized in order to identify pathogens.
- *A considerable degree of subjective judgement is involved in the investigation of accidents, and, in particular, in the identification of system or root causes.* Again, the implication is that even when historical sources contain some information regarding system causes, other information sources should be employed to elaborate the picture.

The approach chosen would thus have to cope with severe limitations in the information basis, and still be in agreement with the ambitions mentioned at the outset of this paragraph.

¹This number excludes training accidents where no passengers were involved, and where the operations or operating conditions deviated from normal personnel transportation.

2.2 Main features of the approach

Based on the considerations outlined in the preceding paragraph, the project group in agreement with the clients chose an approach having the following main features:

- *The historical information available in e.g. accident reports, flight reports and technical reports was supplemented with information and evaluations collected through interviews and questionnaires directed at pilots, technical personnel and managers in helicopter companies. The latter class of information was necessary to obtain a comprehensive and up to date picture of current safety standards in North Sea helicopter operations.*
- *Information was collected in five different helicopter companies in three different countries in order to broaden the information base and achieve validity across operators and countries. The study evaluated North Sea helicopter transportation in general. In some cases, the existence of substantial differences between companies or countries was pointed out. It was, however, necessary to pool the data set and avoid presentation of information which could be related to a specific company, in order to protect the interests of the participating companies.*
- *A classification system for risk factors (risk factor classification) was developed to ensure that a comprehensive set of causal and contributing factors were taken into account. The risk factor classification was checked against previous studies and our own data sources to ensure completeness.*
- *The project group identified eight different accident types and estimated the contribution of each risk factor to the potential for loss of life for each accident type. The risk influence estimates take into account (1) that the influence of each risk factor is dependent on accident type, and (2) that the distribution of accidents according to the accident types given current technical and operational standards may differ from the historical distributions.*
- *The risk influence ratings were based on subjective judgments made by the project group on the basis of the available information. This approach was chosen because the historical data were limited in scope and did not permit valid statistical projections. The project group has furthermore arranged an expert seminar to review and supplement the estimates involved in the risk influence ratings.*
- *The risk factors related to general management were discussed, but not rated in the same manner as other risk factors. The effects of these factors on accidents are indirect and often poorly documented. It was thus not considered feasible to attach numbers to these factors with a reasonable degree of confidence.*

The approach chosen is thus based on a broad and varied information basis, and involves use of subjective judgments.

2.3 Overview

Figure 2.1 shows the main steps of the approach and the interconnections between the different steps. The figure can be summarized as follows:

1. *Data collection.* Information relevant to the analysis was collected from the following data sources:
 - 74 ICAO accident summaries
 - 30 incident reports
 - 2120 flight reports
 - 22 AIB aircraft accident reports
 - 329 technical reports
 - Interviews with 35 pilots
 - 225 pilot questionnaires
 - 270 maintenance questionnaires
 - Interviews with 21 managers
2. *Risk factor classification.* A risk factor classification system was developed on the basis of the data sources and results from earlier studies. This classification was used as a basis for analysis of historical accident data.
3. *Accident classification scheme.* Eight different fatal accident types were distinguished. The occurrences in the accident reports and incident reports were classified according to this scheme.
4. *Contribution of accident types to fatalities.* The project group estimated the relative contribution of each accident type to fatalities in North Sea helicopter transportation, given the present technical and operational quality. This estimate is based on historical data (4a), and an adjustment based on the information reviewed (4b).
5. *Likelihood ratings.* For each risk factor and each accident type the project group estimated the likelihood that the risk factor in question is a causal or contributing factor, given that a fatal accident of the type in question has occurred.
6. *Total importance estimates.* The total importance of each risk factor, i.e. its total contribution to fatalities across all accident types, was estimated by combining the outputs from steps 4 and 5.
7. *Potential for improvement.* The project group estimated the potential for improvement (in percent) of each risk factor within a period of 10-15 years.
8. *Reduction in fatalities.* The relative reduction in fatalities which can be achieved through improvements of each risk factor was estimated on the basis of outputs from steps 6 and 7.
9. *Verification of results.* The results from the project were compared to results from a review of official accident reports. In addition, key figures were subject to an expert panel review.

10. *Discussion.* The individual risk factors were discussed and improvements suggested with emphasis on the four factors with the highest risk influence ratings.

This summarizes the tasks involved in risk influence rating. The validity of the approach is discussed in section 5.11.

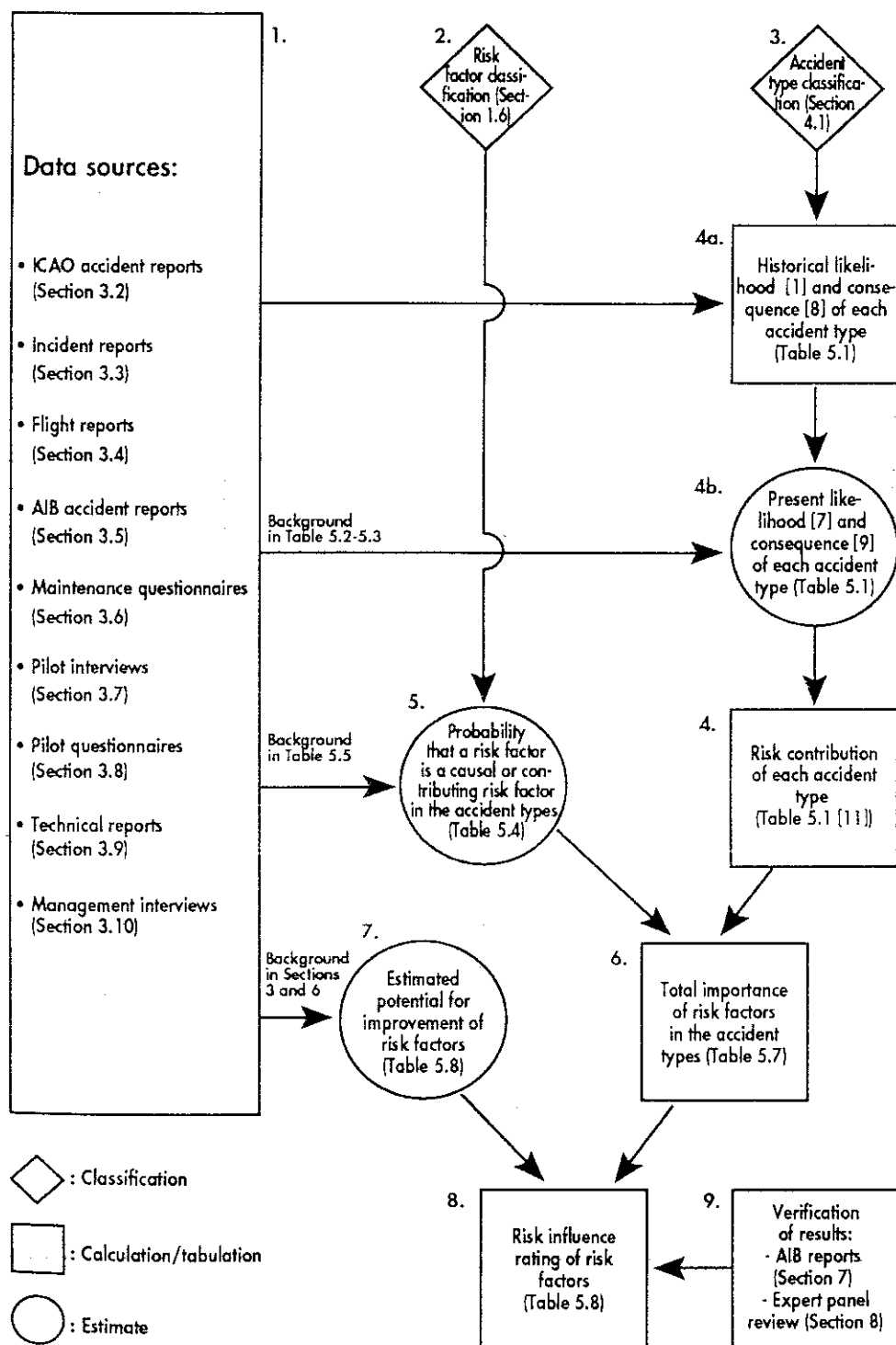


Figure 2.1 Overview of the Helicopter Safety Study approach

3. DATA SOURCES & RESULTS

3.1 Overview

The following data sources have provided input to the project:

- Accident report summaries of ICAO accidents
- Incident reports from helicopter operators
- Flight reports for helicopter operators
- Accidents Investigation Branch (AIB) aircraft accident reports
- Maintenance personnel questionnaires
- Pilot interviews
- Pilot questionnaires
- Technical reports from helicopter operators
- Management survey

Each data source is described briefly below, including the study objective, method used for collection and analysis, and results and conclusions. The complete results are given in «Helicopter Safety Study: Detailed Results».

Risk factor weight

The term risk factor weight is used to characterize risk factors in accident-, incident, flight- and AIB reports (sections 3.2-3.5). Each accident, incident or report was assigned one or two risk factors and corresponding risk factor weights. The sum of risk factor weights for each record was always 100, reflecting 100 %. If two risk factors were assigned, the sum of the weights is 100, e.g. 90-10, 50-50. The importance of each risk factor was calculated by summarizing risk factor weights.

3.2 Accident reports

Objective

The objective of the survey of accident reports was to provide an overview over main risk factors involved in offshore helicopter accidents in the North Sea area.

Results and conclusions

Reference is made to table 3.1. The survey was based on the brief descriptions of ICAO helicopter accidents in «Personnel Transportation Offshore» (1984) and CAA SDAU Offshore Helicopter Operations Statistical Reports. The data cover the period 1968-88, and includes a total of 74 accidents.

Technical failures are the most dominant cause of the accidents reviewed (55%). Detailed causes of technical failures (e.g. maintenance errors, design, etc.) are however not indicated in the brief accident descriptions.

Crashworthiness is found to have a risk factor weight of 5%.

Operational functions have a risk factor weight of 35%. This includes mainly Pilot performance (14%), Heliports & helidecks (12%) and Operating conditions (9%).

About 50% of the fatal accidents were caused by failures in critical aircraft systems, see table 4.2. Sudden crash into sea or terrain (25%) was another important accident type causing fatalities.

Note that 39% of all the ICAO accidents (i.e. fatal and non-fatal accidents) occurred on take-off or landing on heliport/helideck. However, only 1 of these accidents was fatal, see table 4.1.

3.3 Incident reports

Objective

The objective of the analysis of incident reports was to deduce risk factors from available detailed information concerning near-accidents in North Sea helicopter transportation.

The source is judged to be of particular interest, as in-depth causal and contributing factors have been investigated.

Results and conclusions

Reference is made to table 3.1.

The major risk factor categories are «Technical functions» with 70% and «Operative functions» with 28%. The risk picture is thus comparable to the results from the analyses of ICAO defined accidents (60% / 35%) and flight reports (68% / 15%). The fact that the incident reports contain in-depth information supports the assumption the actual «Technical function» contribution is 60-70%.

Within technical functions, «Inadequate design» is the major risk factor with approximately 40% of total weight, pointing in the direction of manufacturers. The second largest risk factor is «Maintenance planning» with 13%, pointing at the operating company and in particular inspection procedures/intervals. «Human performance in maintenance» equals 8%.

Within operational functions, the main contributor is «Pilot performance» with 10% (inattention/violations).

3.4 Flight reports

Objective

The objective of the survey of flight reports was to provide an overview over risk factors in North Sea helicopter transportation that are encountered during flight.

Results and conclusions

Reference is made to table 3.1.

The majority of reports involving specific aircraft systems reflect a high proportion of technical problems, e.g. faulty manufacture, human errors in maintenance, maintenance routines and procedures. Risk factor contribution of technical factors is 68%. This figure varies, depending on system involved. Critical, non-redundant systems (i.e. rotor drives, rotors, rotors flight control, tail rotor, tail rotor drive) have a higher technical risk factor contribution (83%) than the average for the data material (68%).

Data on detailed causes of technical problems, e.g. whether failures are caused by faulty manufacture or maintenance errors, is frequently inadequate (depending on system involved). In such cases, events are classified as unknown technical factors.

Factors related to helidecks & heliports contribute to risk in offshore helicopter transport (risk factor weight: 6%). Factors identified are location, facilities, activities nearby, ground/deck crew, housekeeping and procedures.

A smaller number of problems in pilot performance are indicated, mainly pilot errors such as non-compliance with procedures and inadequate check-out of aircraft before take-off (risk factor weight: 5%). Note that reporting of pilot errors may be incomplete, due to reluctance to report ones own errors.

Risk due to lack of controlled airspace offshore and heavy traffic in certain fields is reflected in the data material. Problems are increased by other helicopters flying at wrong altitude, unknown military aircraft, inadequate radio communication and inaccurate weather information (risk factor weight: 4%).

There was no consequence/importance rating of reports. It is consequently difficult to distinguish between potentially hazardous and trivial events.

Table 3.1 compares the results from Accident reports, Incident reports and Flight reports, and indicates the same important trends.

3.5 AIB Aircraft accident reports

Objective

The objective of the survey of the UK Accidents Investigation Branch (AIB) aircraft accident reports was to provide an overview over main risk factors involved in offshore helicopter accidents in the North Sea area, based on in-depth accounts of accident causes and contributing factors. The survey was carried out after the other data sources had been collected, and was intended to be a verification of these results.

Results and conclusions

Reference is made to table 3.1.

Although the figures for risk factor weights in the AIB reports differ from those in the accident-, incident- and flight reports, no major change of the risk picture was indicated.

Pilot performance

The risk factor weights for «Pilot performance» in the accident-, incident- and flight reports were in the interval 5%-17%. The corresponding risk factor weight for AIB reports was 19%, which is outside the interval, and 5% higher than the result from the ICAO accident reports (14%). The AIB reports therefore indicate a somewhat higher risk factor contribution of «Pilot performance», compared to the other data sources.

Technical reliability

Similarly, the risk factor weights for «Technical reliability» in the accident-, incident- and flight reports were in the interval 55%-70%. The corresponding risk factor weight for AIB reports was 60%, which is within this interval, and 5% higher than the result from the ICAO accident reports (55%).

General management

Data on general management are lacking in the AIB reports, as in most of the original data sources.

Table 3.1 Distribution of risk factors in Accident-, Incident-, Flight- and AIB reports

Risk factors	Accident reports	Incident reports	Flight reports	AIB reports
OPERATIONAL FUNCTIONS:				
Operating conditions	8.9	4.7	4.6	6.1
Heliports & helidecks	12.2	6.0	5.9	-
Pilot performance	13.5	17.0	4.9	19.2
Subtotal	34.6	27.7	15.4	25.3
TECHNICAL FUNCTIONS:				
Technical reliability	55.3	70.4	67.9	59.7
Equipment & provisions	-	-	-	4.1
Crashworthiness & design for emergencies	4.7	-	0.1	5.4
Ergonomic design & physical work environment	-	-	-	-
Subtotal	60.0	70.4	68.0	69.2
GENERAL MANAGEMENT:				
Policy	-	1.7	-	-
Organization & responsibility	-	-	-	-
Economy & budgets	-	-	-	-
Personnel management	-	-	0.4	-
QA & safety management	-	-	0.1	-
Communication & information flow	-	-	0.6	-
Subtotal	-	1.7	1.1	-
EXTERNAL FACTORS:				
Oil companies	-	-	0.8	0.1
Aviation authorities	-	-	-	2.9
ATC, external navigation aids & services	-	0.3	3.6	-
Manufacturers	-	-	-	2.0
Subtotal	-	0.3	4.4	5.0
Untitled	5.4	-	11.2	-

3.6 Maintenance questionnaires

Objective

The objective of the maintenance survey was to obtain judgments and information concerning factors assumed to influence the quality of maintenance, and subsequently helicopter safety.

Results and conclusions

The survey was carried out in four companies, and 270 questionnaires were returned.

The over-all responses support the common perception of maintenance personnel as a dedicated and responsible group. They also give the impression that the best companies practice high maintenance standards.

The results indicate that a significant potential for improvement remains in the following areas:

- Cooperation and exchange of information between different helicopter operators.
- The extent and quality of feedback offered to maintenance personnel.
- Refreshment courses and information to maintenance personnel on current technical problems.
- Maintainability, as it is affected by aircraft design.

Slightly more than one half of the respondents agreed with a statement that «maintenance intervals prescribed by manufacturers are not always trustworthy».

Significant differences between companies were found in certain areas, indicating a potential for improvement in some companies, i.e.:

- The degree of perceived correspondence between what managers say and what they do.
- The extent to which staffing was considered sufficient.
- Work environment (e.g. noise, temperature, humidity) and availability of appropriate tools and equipment.
- The extent to which maintenance plans were judged to give sufficient time to do the maintenance work properly.

Finally, it is argued that the relationship between competition, economy, and safety merits serious attention. The impact of a strained economy may range from inferior standards of equipment and tools to deterioration of the organizational climate. This was further substantiated in the management interviews.

3.7 Pilot interviews

Objective

The objective of the pilot interviews was to establish a preliminary overview over possible accident scenarios and risk factors in North Sea helicopter operations, and to obtain a preliminary assessment of the contribution of human factors to the over-all risk of the operation.

In addition, the interviews provided information to develop a list of initiating events and describe potential accident scenarios. Based on these results, a questionnaire distributed to a large sample of pilots was prepared.

Results and conclusions

A variety of possible hazardous events and underlying risk factors were identified. The results revealed that a distinction must be made between general and specific risk factors. General factors are conditions or agents that influence the risk level in several different ways where the direct influence in a particular situation may be difficult to pinpoint or assess. Specific factors influence the risk level in a particular type of event, situation or during a specific phase of the flight.

The interview data from all the operators were combined, which implies that a case entered in the classification list below does not have to represent a problem for all sectors of the North Sea. In some instances, it may apply to only one or a few installations or helicopter operators.

Human factors

Fatigue and stress was reported by a large portion of the pilots as a general factor which influence on pilots' awareness and tendency to commit errors. Errors made inadvertently were not seen as being a big problem. Most errors pilots make are detected and corrected instantly. When in a difficult situation, e.g. having to handle several problems simultaneously or when fatigued, or in an emergency situation, even experienced personnel may have a serious reduction of awareness.

Few examples of violations of regulations or procedures were mentioned, but this finding must not be accepted on face value. The frequency of violations is not known, and is difficult to assess based on a restricted number of interviews. Some situations pilots might be faced with during a flight were not satisfactorily covered in the flight regulations or procedures. This might result in risk taking if such conduct was encouraged for other reasons, e.g. time pressures.

Flight phase related problems

Problems in the cruise phase, and especially technical failures occurring out at sea far away from a safe landing site, were what helicopter pilots feared the most. The reason being that problems at sea might make it necessary to ditch, and pilots were pessimistic with regard to the prospect of surviving a ditching in high winds and rough seas.

A large part of the operation takes place in uncontrolled air space. The risk of mid-air collision with military aircraft or with other helicopters in North Sea traffic was a frequently mentioned risk, as perceived by the pilots.

Aircraft technical aspects

On the whole, pilots did not expect that technical systems would fail during a flight, and they felt that they would be able to handle most technical failures. Critical systems are rotors, rotor drive including gearbox, where indication of serious problems would enforce immediate landing, if control was not lost immediately. Other systems are provided with redundancies which the pilots can activate or use in case of failure.

Management factors

An opinion held by many pilots was that the upper management did not always seem to realize the specific requirements involved in running an airline. Dispositions were sometimes made for short term profit which could endanger the company reputation on safety and reliability in the long run.

External factors

External factors which pilots perceived as influencing safety, were primarily the aviation authorities, air traffic services, (including meteorology), and the oil companies. In addition, the aircraft manufacturers and companies rendering services to the helicopter operators, (e.g. gear box overhaul) play a role. Factors referring to all these agents were mentioned, which demonstrates the important point that the total number of factors influencing the safety of offshore helicopter operation is large and varied.

A specific worry often mentioned was the aviation authorities' relaxed attitude regarding regulations and enforcement. It was emphasized that the main problem was that the national aviation authorities consider helicopter operations to be equivalent to fixed wing airline operations, while the differences are marked.

Another worry mentioned by several pilots was that the intense competition in the offshore helicopter transportation market might result in reduced safety, especially since CAA was perceived to play a passive role in controlling the activity.

Some pilots find oil companies' tendency to set specific requirements on the operation to be problematic, because the resulting variation in requirement between companies becomes confusing.

In addition, the operation frequently takes place in adverse weather conditions, and in an environment that in certain cases puts both personnel and equipment under considerable strain.

3.8 Pilot questionnaires

Objective

The objective of the questionnaire survey was to identify and evaluate risk factors as experienced by the pilots in their daily work situation.

The rationale behind this approach was a belief that this experience and pilots opinions would be important sources of data for identifying and evaluating the risk factors.

Results and conclusions

The factor that on the average caused pilots most worry was the prospect of surviving an emergency landing on sea. The main reason behind this worry was that systems to stabilize the aircraft on the sea surface and keep it afloat are not designed to withstand the prevailing sea state in the North Sea most of the year.

The second most important factor was the fear of long term effects of vibration and noise inside the helicopter on pilots' health. Primarily, this item point to an important work environment question. However, the implications for safety are evident as something to worry about in daily work and as a potential factor for deterioration of health over time.

Third in importance was pilots' concern over civil aviation authorities supervision, where more strict regulations and practices are wanted. However, the data revealed distinct differences between companies in response to this question, and differences in attitudes to specific requirements vs. functional requirements.

A large part of the North Sea helicopter traffic takes place in uncontrolled air space. The worries regarding this situation expressed by pilots in the interviews were confirmed in the questionnaire by this factor being the forth in importance.

Failure in gearbox oil system was rated fifth. Such an event is a serious hazard which could require immediate landing. Pilots commented that they did not constantly think that a gear-box failure would occur, but if it occurred they would naturally be very worried.

The five next items with regard to pilots worries were, in order of importance:

- Management lack of receptiveness to safety problems the pilot felt was important and would like to see improved.
- Reduced safety standards or practices in the company due to economic constraints.
- Failure in the tail rotor.
- Seasonal variation in demand for transport, which may lead to long hours and feeling of over-exertion and fatigue in high demand time periods.

The following improvements were given highest priority, in order of importance:

- Aircraft technical reliability
- Cockpit comfort
- Survival systems for sea landings
- Air traffic regulation in the North Sea area.

3.9 Technical reports

Objective

The objective of the survey of technical reports was to identify the most failure-prone components of the rotorcraft, and if possible, to identify the most probable failure causes and/or failure mechanisms.

Results and conclusions

The majority of the technical reports involve the rotor and rotor drives.

The S61 and the Super Puma 332 have approximately the same number of technical reports. These two aircraft types amount to 78% of the total number of reports. (Be aware that there are different numbers of helicopters).

The most frequently observed failure causes/mechanisms are manufacturer (i.e. inadequate design and material selection) (26 reports, 19%), human error in maintenance (16 reports, 12%), quality of spare parts (13 reports, 10%), corrosion (12 reports, 9%) and wear (10 reports, 7%).

Additional comments to causes/generic factors:

- Corrosion and human error are the most frequent failure causes in the rotor system.
- For rotor drives, the most observed deviations can be traced to the manufacturer and leakage.
- For the rotors flight control, about 55% of the deviations can be traced back to the manufacturer. This especially concerns the Super Puma 332.
- For the Super Puma 332, failures can be traced back to: loosening (e.g. bolts), spare parts problems and manufacturer.

A total of 121 technical deviations may be traced back to maintenance (i.e. faulty manufacture, improper maintenance procedures, supervision, inspections schedules, tools & equipment, and human errors in maintenance). Approximately 80% of these deviations can be attributed to procedures (44 reports, 36%), QA/QC (22 reports, 18%), inspection schedules (14 reports, 12%) and human error (12 reports, 10%).

A special problem observed is lack of or insufficient maintenance procedures. This may result in faulty maintenance and extended maintenance time. However, no serious failures were traced back to procedures.

None of the technical reports in the period has been given highest priority by the helicopter operator.

Most of the technical deviations were observed during preventive maintenance by maintenance personnel or during flight by pilots. Very few deviations were observed while the helicopter was on the helideck. Very few new deviations were observed during execution of corrective maintenance.

3.10 Management survey

Objective

The objective of the management study was to identify organizational and managerial factors that contribute significantly to helicopter transportation risk.

Approach

The approach which was taken follows the conception of organizational pathogens (Reason et al, 1988; Reason, 1988). This approach focuses on general conditions and states in the organization which may underlie a range of specific safety problems. This is particularly valuable if the mechanism of influence is not explicit or is difficult to demonstrate.

Both general management factors and activities specific to managing safety are relevant in this connection. The quality of management in general will influence the accepted risk level of an undertaking with implicit hazards. It will, in many instances, be difficult to distinguish between the two. Factors of general interest that are important in helicopter operations have been included. However, it must be emphasised that general factors involved in the smooth and efficient running of any business enterprise company were not the main focus of the study.

To evaluate activities of direct relevance to safety the MORT concept was applied. In addition environmental constraints, to which offshore helicopter companies must adapt, were included.

The data source for management factors were interviews with representatives from four helicopter companies in three countries. An interview guide with 60 questions covering six topic areas was utilized. The topics were:

- Environmental adaptation
- Company policy goals and standards
- Information systems
- Hazard analysis process
- Safety programs and activities
- Personnel management

Altogether 24 employees were interviewed, covering Managing Directors, Operations Managers, Technical Managers (i.e. engineering staff), Flight Safety Officers and Chief Pilots.

The results showed that the customers, the oil companies, and the national aviation authorities exert considerable influence on the way these companies are run. Therefore, interviews with representatives from these organizations would have been desirable, but were not undertaken due to constraints of time and costs.

Results and Conclusions

General factors

Competent managers and well organized, conscientious day-to-day management of work was perceived to be very important, especially to employee morale, and to engender loyalty to the various company requirements. One recurring comment made by several, especially middle and lower managers, was the importance of managers' knowledge about aviation as a business activity; as important is their commitment (devotion) to the business of aviation. Instances were mentioned of turmoil and confusion amongst staff following changes in top management direction.

Examples included:

- Proclaimed reorganization in the company and fear of dismissal;
- Perceived unwillingness of the top levels of management to undertake long term investment in the company;
- Onerous contracts combined with over preparedness to please the customer; thus imposing considerable strain on staff.

Market and economy

Commercial terms determine the level of activity with regard to safety relevant activities and investments by the company. Initially requirements set by CAA, customers, and internal company standards must be met. Subsequently, although equally important, revenue permits investment in new and better equipment, and training, and assists the retention of expert technical staff.

Most of those interviewed perceived the economic situation as acceptable. However, it was remarked that although demand for helicopter companies' services may be satisfactory at present, and this permits the companies to continue trading, financial return on capital is too low to be healthy in the long run. Following from this was the assertion that the helicopter companies do not seem able to take advantage of the current situation, which they see as a sellers' market.

Regarding future commercial prospects, two conditions are seen to be of special importance. Firstly, potential changes in the level of activity of offshore oil prospecting and production in general. Secondly, the introduction of new technology and in particular developments in the automated control of offshore production installations. Both factors may alter (most likely reduce) the need for offshore helicopter transport.

In addition, North Sea helicopter operators expect that a new situation will prevail with in 1992, following EEC agreement about an open market. The position of Norway in this market is not clear at present, but in any case greater competition within the EEC is anticipated. Concern was expressed about the effects of fierce competition in what would become a buyers' market. Concern was expressed over possible implications for safety. The importance of oil companies and regulatory authorities acting to prevent any negative developments was emphasized. The lessons to be learnt from the current situation in the USA, following deregulation of commercial aviation, were mentioned.

Oil companies

The principal obligation of a helicopter company is to provide transport as required in a contract with an oil company. A frequently mentioned problem was the complexity of some contracts placed by oil companies. These might put the operator in a difficult position if the full implications of a contract had not been properly appreciated. Commercial pressure will be considerable, to provide contracted transport, on time, even in unforeseen and disadvantageous circumstances. Implications for safety include (but are not limited to) the strain which results from excessive utilization of staff, both air crew and maintenance and aircraft.

Similar problems may occur when the helicopter company is too eager to please the customer in supplying ad hoc charter.

Another problem mentioned was that contract negotiators from some oil companies, in particular negotiators with a background in accountancy and with merely a superficial knowledge of aviation, have a habit to base their criteria for an acceptable contract solely on the basis of the lowest possible price. They fail to appreciate that there are additional safety costs. To make their economic situation clear to their customers, some respondents advocated that the helicopter companies should operate an «open books» policy. This would entail providing the oil companies with financial information showing distribution of revenue: it would be possible to demonstrate that «safety» revenue was being expended on safety functions and not being taken as profit.

Contract arrangements regarding Company specific role equipment, and sole use clauses, make operations less efficient. In addition, variations between oil companies' requirements in the conduct and documentation of flight operations causes confusion and may thereby hazard safety. Several interviewees pointed out that standardized, commonly agreed, and civil aviation authority controlled, requirements similar to those in fixed-wing aviation, should be developed for offshore transportation.

Civil aviation authorities

There does not appear to be a well defined and co-operative relationship between the operators and the regulatory authorities. Helicopter operations are thought, by respondents, to be seen by governments as both part of the oil business, and at the same time as an aeronautical activity. There is uncertainty and ambiguity. North Sea helicopter transportation does not appear to be treated in the same way as are civil airlines; instead operations seem comparable to general aviation or charter activities. This perception by the authorities may explain some of the current difficulties.

There is general agreement among helicopter operators in all three countries that their regulatory authorities have insufficient resources to do their job properly. As a consequence authorization to operate is, to a large extent, based on each company's internal standards.

The problem seems relatively insignificant on the technical side, where manufacturers' specifications combined with well defined technical expositions provide the basis for establishing standards and work requirements.

In contrast, concerning operations, much is left to the discretion of (and negotiations between) helicopter operators and oil companies. Concerns have been raised that weak authorities, in a strongly competitive market, may allow the operation of helicopter companies with lower, and therefore less costly or more competitive, standards. Respondents want their authorities to play a more active role in regulating the industry. At the same time, they want common and consistent standards to be applied across all operators.

Of necessity, authorities need more resources to perform their supervisory and controlling function satisfactorily.

Several of the interviewees mentioned authorities' role in the regulation of offshore air traffic as especially important. The present situation was not seen to be satisfactory.

Company policy, goals and standards

The helicopter companies vary in the degree of formality of structure and activity of their management. All companies are in the process of adopting quality assurance systems, but only one company seemed to have completed the process and had a complete QA system properly in place and in operation for some time. The experience of using the QA approach is generally very positive in this company.

The absence of definitive (i.e. superior) policy document, required of an integrated QA system, in most companies, meant that safety goals were not stated or quantified. Verbally, all managers stated that safety was given the highest priority. At the same time, their conduct and responsibilities vis a vis safety were expressed in other documents, e.g. job descriptions.

The ethos for emphasizing safety, and for the regulation of activities through standardization, is pronounced in the aviation industry. At lower management levels, activities are well regulated via operations manuals and technical expositions. In addition, the majority of activities relevant to safety are undertaken by professionals whose competence is examined through official certification (i.e. pilots and aircraft engineers).

However, situations occur when the application of regulations may be in conflict with considerations such as convenience or cost. None of the companies systematically appraise their operations to detect and correct such situations. Lower levels of management, and pilots, recalled instances when higher management was perceived to speak hypocritically about situations where safety was to be sacrificed to commercial exigency, primarily due to the absence of effective or applicable regulations.

The promulgation of the overall safety policy, and more precise definitions of priorities between safety and other goals in QA systems, provides a basis for alleviating some of the conflicting messages received at lower levels within the companies.

Several respondents expressed skepticism about the desirability of a high degree of formal specification of job responsibilities, as may be found in a rigid QA system. Rigid specifications and assignment of responsibility was perceived as suppressing personal initiative. In addition, such specification calls into question individuals' professional judgment.

Information systems

Systematic reporting of deviating events in flight, and in maintenance, is part of aviation culture. Such systems exist in all the companies taking part in the study. However, the reporting formats and degree of systematic analysis and follow up varies between companies. Only one company has completely specified system for definition, analysis and follow up of reported events in flight if they are defined as significant. Systematic analysis of all flight reports and non normal events reported during maintenance is also undertaken by at least one company.

Some operations managers commented that the flight reporting system, although important, was of limited value when obtaining information at an early stage of a developing risk problem. It was maintained that taking part in the operation as a line pilot provided the operations manager with useful supplementary information, and served to alert him at start of problems.

Despite certain individuals' views, the exchange of information between helicopter companies operating in the North Sea is virtually non existent. One opinion, expressed by many, was that much benefit would follow from the sharing of information in company internal systems. A condition for such pooling of experience would be anonymous reporting.

Some companies practice full disclosure, to oil companies, of the data in their reporting system. However it was maintained that this situation would change rapidly if the oil companies started to apply information about reported events to their commercial evaluation of the operators.

Hazard analysis process

All companies have definitions of significant events which trigger specific hazard analysis and remedial action. As described above the degree of formal specification of the process varies between companies. There is a risk that absence of formal procedures may result in a detected hazard being disregarded, although such a situation was not possible to document in the present survey.

There is also reason to suspect that the lack of systematic procedures for analyzing data other than significant events makes the companies less aware of gradual changes in risk level. Only one of the companies has established and documented a systematic approach to the analysis of less significant events in flights and maintenance to detect possible underlying negative trends.

An example of a situation where systematic hazard analysis is lacking, concerns flight to new destinations. Representatives from one company expressed concern that such operations are undertaken on a basis of trial and error.

Formal hazard analysis, initiated on the basis of new external information, e.g. from manufacturers, very seldom takes place. A frequent comment was that communication with manufactures leaves much to be desired.

Safety programs and activities

All companies want safety issues to be an integrated part of their daily activities. However special initiatives to analyze or improve safety on a

long term basis through «action programs» are virtually non-existent. One company has reported that it has a cockpit environment improvement program underlay. Experience suggests that such work receives low priority by the technical department and takes a long time to implement.

A particular problem that engages pilots is their work environment. Much uncertainty has been expressed with regard to the long term health effects of cockpit noise and vibration.

Most managers state that resources for improving safety are adequate, but it may be justified to question if such answers are not the result of claims being tuned to what is perceived to be a realistic expectation. Ambitious improvement programs are virtually non-existent.

Personnel management

If the present level of helicopter activity persists, qualified personnel may become very scarce. The present stable work force is ageing, and companies experience difficulty in retaining younger staff who prefer working for fixed wing carriers: for greater pay, more stable conditions, and in more desirable locations. Alternatively they may be tempted by other operators' «poaching».

There is a particular shortage of avionics engineers (although this is an industry wide problem). Aircrew are particularly tempted to leave for the airlines. There are problems in recruiting aircrew with foreign licenses, and in qualifying co-pilots for command.

Simulator training is much valued by operators as a means of preparing pilots for the exigencies of North Sea operations. The cost of simulator acquisition presents exceptional problems. Although respondents from all companies declared that they provided training for the aircrew beyond that required by legislation, this does not appear to be the case. Type conversion, base, line, and instrument checks are the minimum required by the regulatory authorities, and these test of competency simultaneously serve as periods of instruction and practice.

Although respondents from all companies declared they were examining the possibility of training their own technical personnel, only one company, at the time of compiling this report, had instituted a program to train aircraft engineers.

Certain respondents commented that although there were duty limitations for aircrew, there were no restrictions on the hours, and shifts, that engineers worked. They commented that fatigue, and unsocial working hours, could adversely affect workmanship.

Most respondents emphasized the importance of good personnel management factors in their companies. Such management inculcates a safety culture and reinforces engineers' and pilots' safe work practices. There was a diversity of ways in which senior management believed they monitored their work-force, although these methods, as described, seemed fairly ad hoc. In one company in particular, pride in the company was seen, by senior management, as being of particular importance; and a variety of means were employed to develop and maintain this self-esteem.

3.11 Compilation of information from data sources

A rough overview of importance of risk factors according to each data source is given in the matrix below (table 3.2). The estimates are based on the detailed results from each data source. A high rating for «Technical reliability» in «Flight reports» reflects that this is a dominant risk factor in this data source. It is important to note that varying results between data sources may be attributed to varying accuracy and nature of reporting. It would e.g. not be expected that «Technical reports» would provide information regarding pilot errors. Codes used in the table are:

- High: ***
- Medium: **
- Low: *
- No information available: -

Note especially that «No information available» may indicate that:

- The risk factor is *not important* according to the information source, or
- The risk factor may be important, but is *not reflected* in the indicated information source.

An example of the latter is noise and vibrations, as reflected in flight reports. The table indicates that the risk factor «Ergonomic design & pilot working environment» is assigned «No information available» according to flight reports. This does not mean that noise and vibrations are unimportant, but rather that it can not be expected that pilots report this a deviation in flight reports. Other sources, such as pilot questionnaires, address this problem. This emphasizes the importance of using different types data sources.

Codes used in the table are:

- ICAO accident reports: AR
- Incident reports: IR
- Flight reports: FR
- AIB reports: AIB
- Maintenance questionnaires: MQ
- Pilot interviews: PI
- Pilot questionnaires: PQ
- Technical reports: TR
- Management survey: MAN

Table 3.2 Importance of risk factors based on data sources

	AR	IR	FR	AIB	MQ	PI	PQ	TR
OPERATIONAL FUNCTIONS								
Operating conditions	**	**	*	**	-	**	**	-
Heliports & helidecks	**	**	**	-	-	**	**	-
Pilot performance	**	***	*	***	-	**	**	-
Operating procedures	-	*	*	*	-	*	-	-
Pilot working conditions	*	-	-	-	-	**	**	-
Emergency preparedness	-	*	-	*	-	-	-	-
TECHNICAL FUNCTIONS								
Technical reliability	***	***	***	***	***	***	**	***
Inadequate design	-	***	**	***	**	-	-	-
Maintenance planning & tools	-	***	**	**	***	-	-	***
Human performance in maintenance	-	**	**	-	**	*	**	***
Spare parts	-	-	-	*	**	-	-	**
Equipment & provisions	-	-	-	**	-	*	-	-
Crashworthiness & design for emergencies	**	-	-	**	-	***	***	-
Ergonomic design & pilot working environment	-	-	-	-	-	**	***	-
GENERAL MANAGEMENT								
Policy	-	*	-	-	*	**	**	-
Organization & responsibility	-	-	-	-	-	-	-	-
Economy & budgets	-	-	-	-	-	*	**	-
Personnel management	-	-	-	-	*	**	**	-
QA & safety management	-	-	-	-	**	*	-	-
Communication & information flow	-	-	*	-	**	**	**	-
EXTERNAL FACTORS								
Oil companies	-	-	*	-	**	**	**	-
Aviation authorities	-	-	-	*	**	**	***	-
ATC, external navigation aids & services	-	*	**	-	-	***	***	-
Manufacturers	-	-	-	*	**	*	-	***

*** =High, ** =Medium, * =Low, - =No information available

A comprehensive discussion of risk factors is presented in section 6.

4. RISK SCENARIOS

4.1 Accident types

This section gives a summary of possible accident types related to offshore helicopter transportation in the North Sea area. The purpose of the summary is to:

- Give an overview over important accident types and possible causal relationships which may lead to fatalities in helicopter transportation.
- Provide a basis for the subsequent rating of risk factors.

Each accident type is described below and in figures 4.1-4.10. Risk factors related to these accident types are discussed in section 5.6.

Crash on take-off or landing on heliport

Fatal accident following crash initiated before critical decision point (take-off) or after critical decision point (landing) on heliport.

Crash following critical aircraft system failure during flight

Fatal accident following crash caused by critical system failure initiated after critical decision point (take-off) or before critical decision point (landing), e.g. in rotor, tail rotor, engine, etc. No possibilities of pilot intervention or no intervention attempted.

Sudden crash into terrain, obstructions or sea during flight

Fatal accident following crash into terrain, obstructions or sea initiated after critical decision point (take-off) or before critical decision point (landing), not caused by critical system failure, but because helicopter off course or out of control due to e.g. pilot disorientation, low visibility, faulty instruments, etc.

Mid-air collision with other aircraft

Collision with other helicopter, civil aircraft or military aircraft during flight. No failures in critical systems. Helicopter or other aircraft off course, low visibility, faulty instruments, etc.

Crash on take-off or landing on helideck

Fatal accident following crash into rig or sea initiated before critical decision point (take-off) or after critical decision point (landing) on helideck.

Unsuccessful emergency landing

Accident initiated by e.g. technical failure, disorientation, etc. after critical decision point, but with possibilities for pilot intervention through emergency procedures. Intervention by pilot attempted, but unsuccessful. Also includes fatal accident due to unsuccessful evacuation from helicopter following emergency landing on sea and capsizing.

Personnel accident outside aircraft

Fatality to personnel located outside aircraft, e.g. struck by tail rotor on helideck or heliport, personnel accident during hoisting operation.

Personnel accident inside aircraft

Fatality to personnel located inside aircraft, e.g. toxic gases caused by fire or cargo.

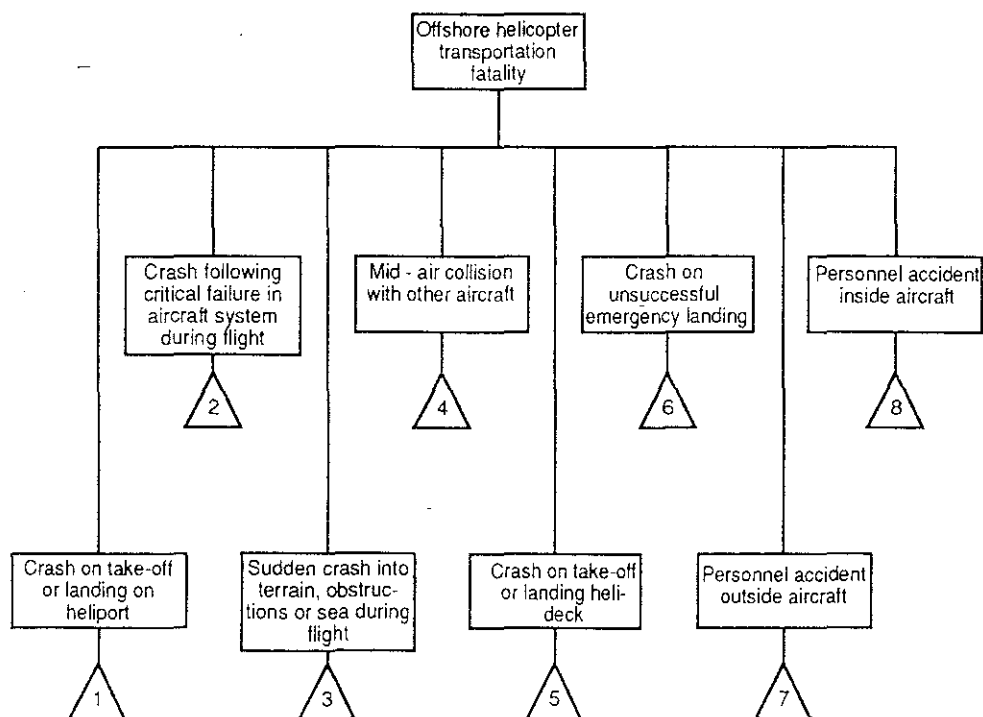


Figure 4.1 Accident types

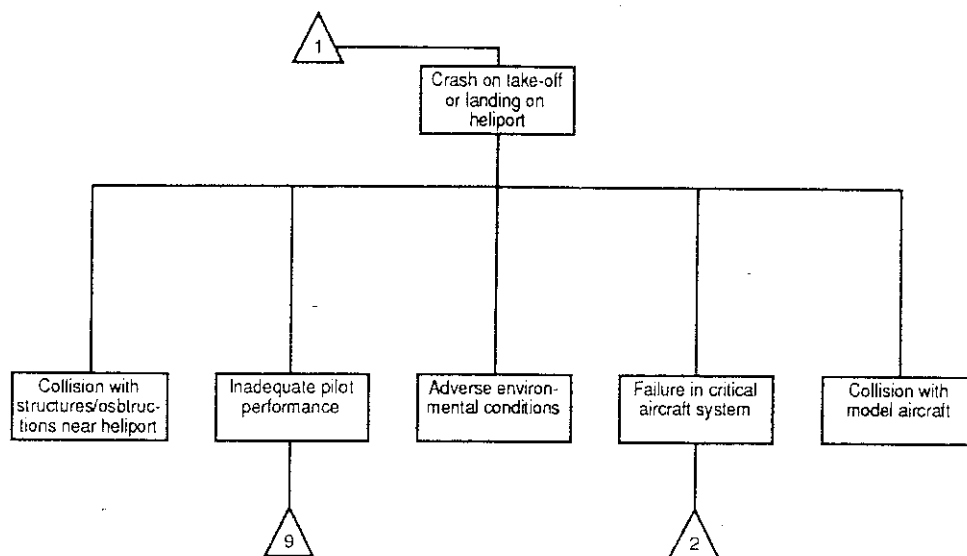


Figure 4.2 Crash on take-off or landing on heliport

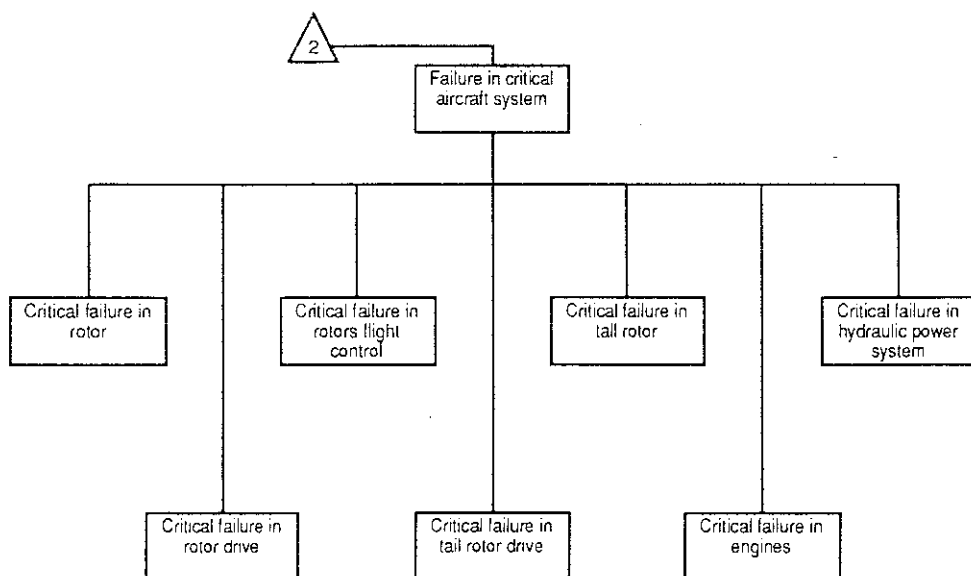


Figure 4.3 Crash following critical aircraft system failure during flight

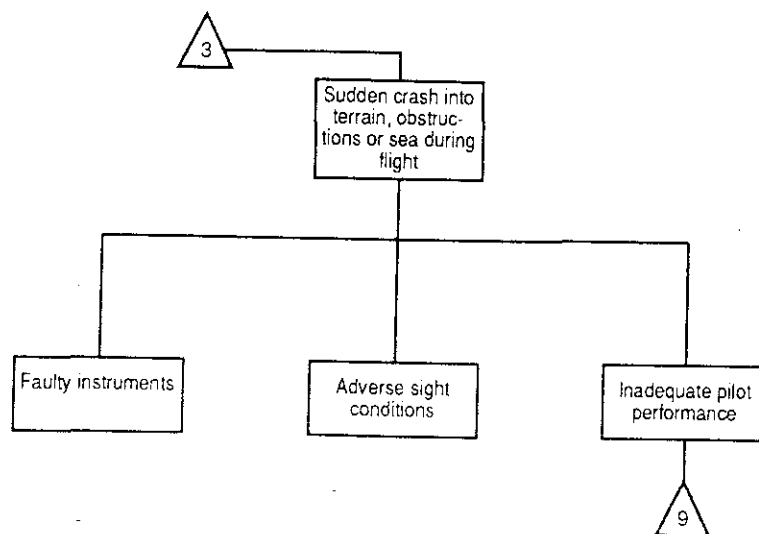


Figure 4.4 Sudden crash into terrain, obstructions or sea during flight

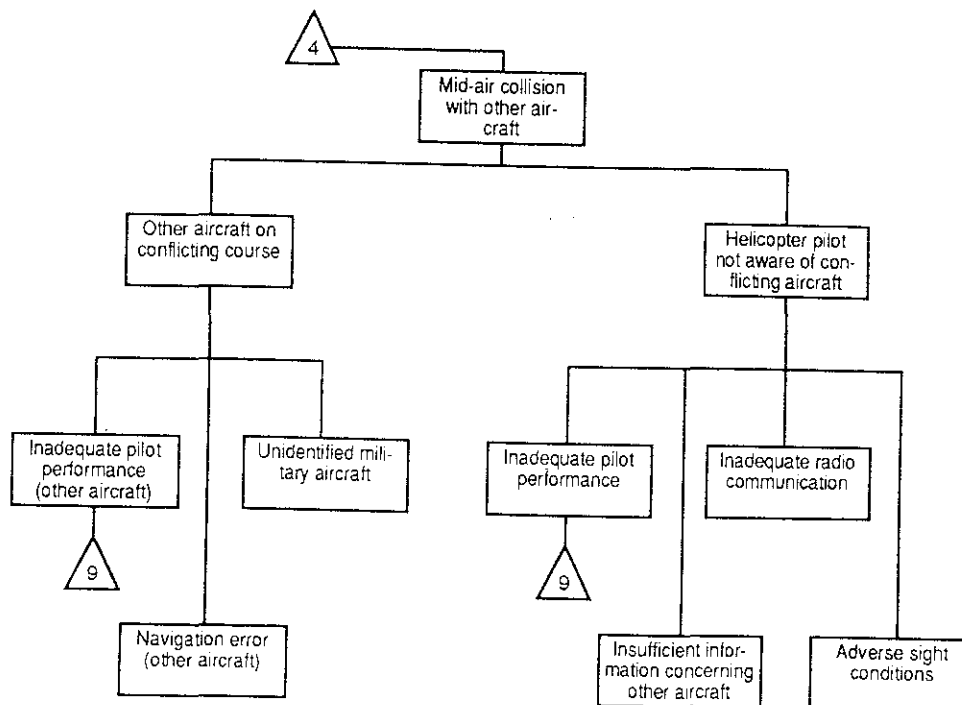


Figure 4.5 Mid-air collision with other aircraft

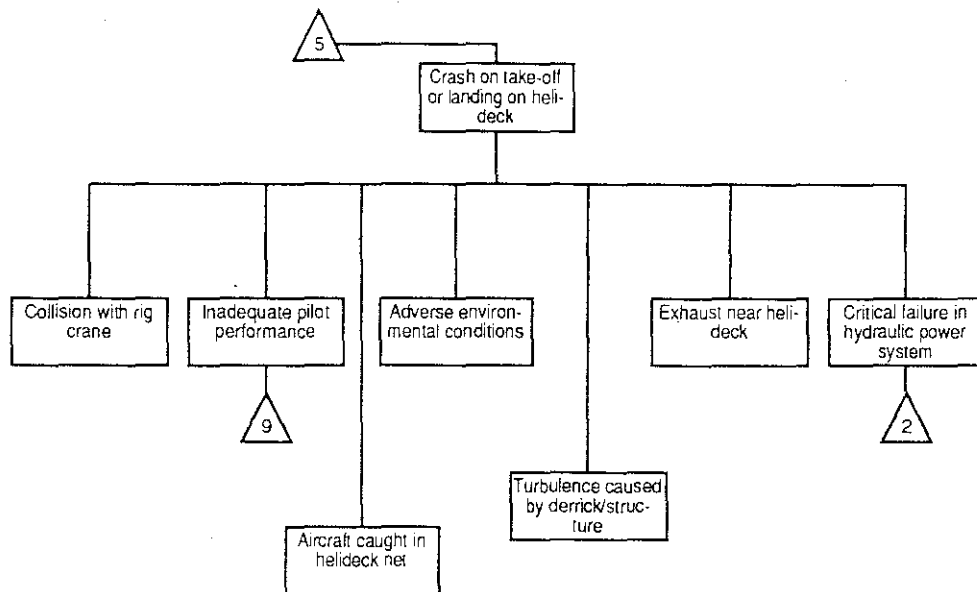


Figure 4.6 Crash on take-off or landing on helideck

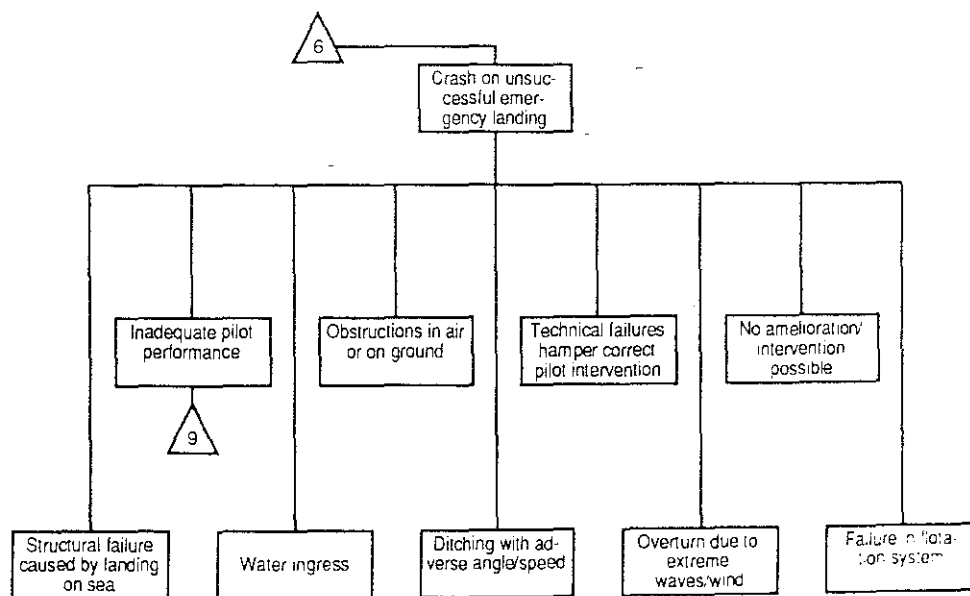


Figure 4.7 Unsuccessful emergency landing

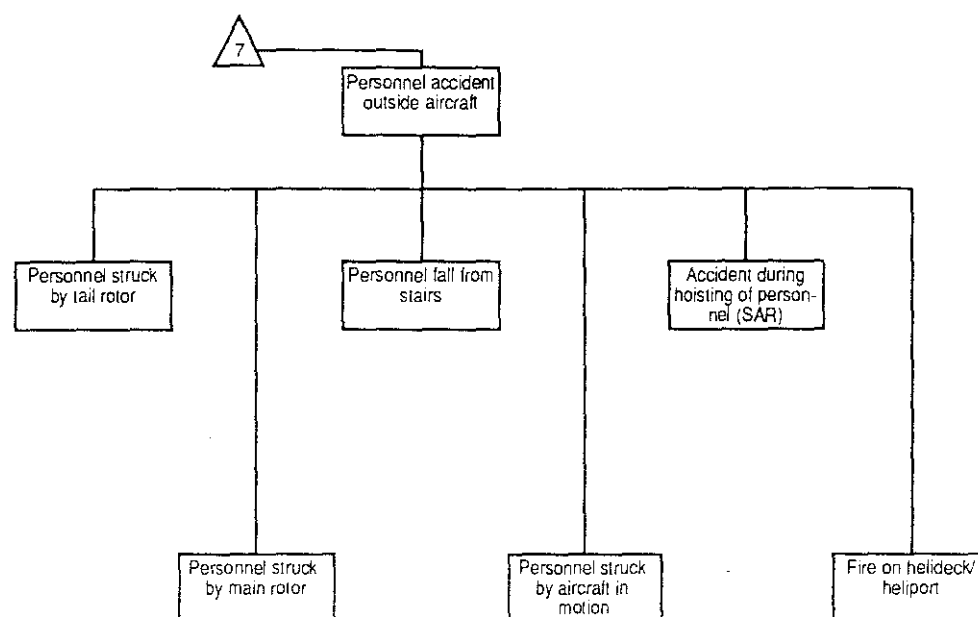


Figure 4.8 Personnel accident outside aircraft

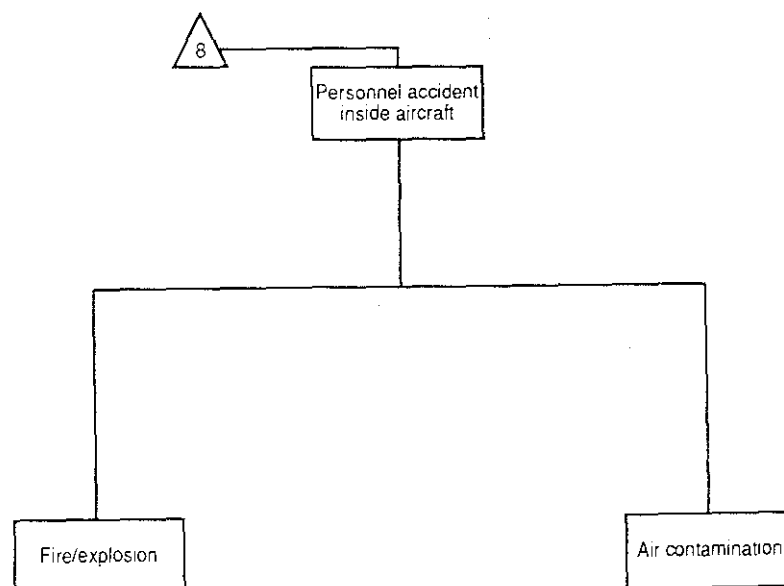


Figure 4.9 Personnel accident inside aircraft

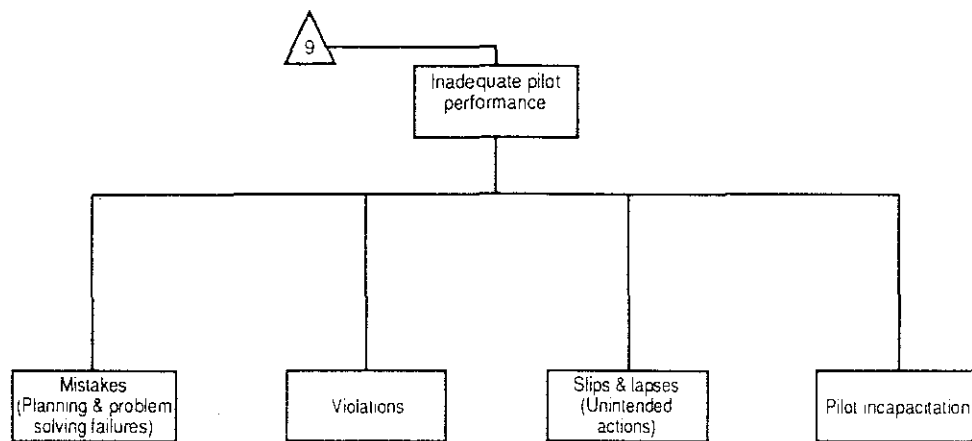


Figure 4.10 Inadequate pilot performance

4.2 Distribution of ICAO accidents

74 ICAO accidents in North Sea helicopter operations during the period 1968-88 were reviewed and placed in the different accident categories. The distribution is shown in table 4.1. (Source: «Personnel Offshore Transportation» and CAA SDAU Offshore Helicopter Operations Statistical Reports).

Table 4.1 Distribution of ICAO accidents

Accident type	Number of accidents	%
(Crash on) take-off or landing on heliport	9	12 %
(Crash following) critical aircraft system failure during flight	25	34 %
Sudden crash into terrain, obstructions or sea during flight	3	4 %
Mid-air collision with other aircraft	-	-
(Crash on) take-off or landing on helideck	20	27 %
(Crash on) unsuccessful emergency landing	12	16 %
Personnel accident outside aircraft	3	4 %
Personnel accident inside aircraft	1	1 %
Unknown	1	1 %
	74	99 %

4.3 Distribution of fatal accidents

Of the 74 ICAO accidents, the 12 fatal accidents have been extracted and placed in the different event categories. The distribution is shown in table 4.2. Two fatal accidents during training flights are not included. (Source: «Personnel Offshore Transportation» and CAA SDAU Offshore Helicopter Operations Statistical Reports).

Table 4.2 Distribution of fatal accidents

Accident type	Accidents		Fatalities	
	N	%	N	%
Crash on take-off or landing on heliport	-	-	-	-
Crash following critical aircraft system failure during flight	6	50 %	88	79 %
Sudden crash into terrain, obstructions or sea during flight	3*	25 %	19	17 %
Mid-air collision with other aircraft	-	-	-	-
Crash on take-off or landing on helideck	1	8 %	1	1 %
Unsuccessful emergency landing	1*	8 %	3	3 %
Personnel accident outside aircraft	1**	8 %	1	1 %
Personnel accident inside aircraft	-	-	-	-
	12	99 %	112	101 %

* Causes of these accidents listed as insufficient, but indications of sudden crash into sea and unsuccessful emergency landing respectively.

** Accident to person on ground, not included in FAR in table 1.1.

Tables 4.1 and 4.2 will, along with the accident types, be used in the further assessment of risk factors in section 5.

5. ANALYSIS AND RATING OF RISK FACTORS

5.1 Key terms

This section presents important terms used in the rating of risk factors. References to rows in tables 5.1 and 5.6 are presented in brackets [], and to sections in the text in parentheses ().

Accident types

The different categories of fatal accidents used for the purpose of the rating.

(4)

Example:

Crash on take-off or landing on heliport, Mid-air collision.

Fatal accident distribution (present)

The historical accident distribution shows the percentages of accidents which belong to each of the accident types.

For each accident type, the estimated accident distribution shows the likelihood that an accident of this type has occurred, given that a fatal accident has occurred.

The estimate for present fatal accident distribution is based on the historical data (1968-88), but may be different from the latter, because of improvement or worsening of operational and technical status.

(5.3)

Example:

If a fatal accident occurs, the likelihood that it is a «Crash on take-off or landing on heliport» is 0.09 (9%) (see row [7] in table 5.1).

Number of fatalities per accident (present)

The mean number of fatalities in a specified fatal accident type.

The estimate for present number of fatalities per accident is based on historical data (1968-88), but may be different from the latter, because of changes in operational characteristics.

(5.4)

Example:

If a fatal accident of type «Crash on take-off or landing on heliport» occurs, it is estimated that 2 persons are killed (see row [9] in table 5.1).

Risk contribution of an accident type

The percentage of helicopter fatalities caused by a specified accident type.

The estimate is based on the likelihood that a fatal accident is of a given type and the number of fatalities per accident.

(5.5)

Example:

It is estimated that 2% of helicopter fatalities will be caused by the accident type «Crash on take-off or landing on heliport» (see row [11] in table 5.1).

Causal or contributing factor

A risk factor is a causal or contributing factor with regard to a given fatal accident if and only if another state of that risk factor would have led to a lower number of fatalities. Note that more than one causal or contributing factor can be involved in an accident.

The probability that a risk factor is a causal or contributing factor in the accident types are estimated in the rating procedure.

(5.6)

Example:

The likelihood that the risk factor «Helidecks & heliports» is a causal or contributing factor in the accident type «Crash on take-off or landing on heliport» is 0.2 (see table 5.4).

Importance of a risk factor

A relative measure of the importance of a given risk factor as a causal or contributing factor in a specified accident type.

The importance estimate takes into account:

- The likelihood that the risk factor is a causal or contributing risk factor, given that the accident type in question has occurred,
and
- The risk contribution of that accident type.

The estimate is used to calculate the total importance of the risk factors relative to fatalities.

(5.7)

Example:

The importance score for the risk factor «Heliports & helidecks» in the accident type «Crash on take-off or landing on heliport» is 0.4 (see table 5.7).

Total importance of a risk factor

A relative measure of the importance of a given risk factor as a causal or contributing factor relative to fatalities.

The total importance of a risk factor is an estimate for the percentage of all fatalities which are caused by accidents in which the risk factor is a causal or contributing factor.

(5.7)

Example:

The total importance score for the risk factor «Heliports & helidecks» is 10.0, see table 5.7.

Potential for improvement of a risk factor

The estimated realistic improvement of a risk factor (in percent), over a specified period of time, given that other conditions are kept constant.

This improvement leads to a corresponding reduction in the risk factor's total importance relative to fatalities in offshore helicopter transportation.

(5.9)

Example:

The realistic improvement of the risk factor «Heliports & helidecks» over the next 10-15 years is estimated to 25% (see table 5.8). This leads to a $0.25 \times 10.0 = 2.5\%$ reduction in «Heliports & helideck's» contribution to fatalities in offshore helicopter transportation (see table 5.8).

5.2 Overview of rating of risk factors

The procedure for rating of risk factors consists of the steps below. References to rows in tables 5.1 and 5.6 are presented in brackets [], and to sections in the text in parentheses ().

- [1]-[5] The starting point of the rating is accident data from offshore helicopter operations during the period 1968-88. The accidents in the period are classified according to the accident types drawn up. (4.2)
- [6]-[7] The likelihood that a fatal accident is of a given type is estimated, assuming today's operational and technical standard. (5.3)
- [8]-[9] The number of fatalities per accident is estimated for each accident type. (5.4)
- [10]-[11] Each accident type's contribution to risk (i.e. «Likelihood» x «Consequence») is estimated, based on:
- The likelihood that a fatal accident is of a given type [7]
 - and
 - The estimated number of fatalities per accident [9].
- (5.5)
- [12]-[13] The likelihood that a risk factor is a causal or contributing factor in each accident type is estimated, based on information gathered through the study. (5.6)
- [14]-[15] The total importance of each risk factor, relative to fatalities, is estimated, based on:
- The contribution to risk of each accident type [11]
 - and
 - The likelihood that each risk factor is a causal or contributing factor in each accident type [12]-[13].
- (5.7)
- [16]-[17] The potential for future improvement of each risk factor is estimated, giving a reduction in fatalities achieved through the improvement. (5.9)

Note that the report does not include cost-effectiveness rating of improvements. This should, however, be carried out by experts later, based on the results generated by the procedure.

In the following, each step in the procedure is explained in detail. The following abbreviations are used to indicate accident types:

■ Crash on take-off or landing on heliport:	HP
■ Crash following critical aircraft system failure during flight:	CSF
■ Sudden crash into terrain, obstructions or sea during flight:	TOS
■ Mid-air collision with other aircraft:	MAC
■ Crash on take-off or landing on helideck:	HD
■ Crash on unsuccessful emergency landing:	UEL
■ Personnel accident outside aircraft:	PAO
■ Personnel accident inside aircraft:	PAI

Table 5.1 shows the figures used to calculate the risk contribution of accident types.

Table 5.1 Estimates in calculation of risk contribution of accident types
(Historical data in *italics*. Other figures are estimates for
present situation).

	Accident type:							
	HP	CSF	TOS	MACHD	UEL	PAO	PAI	
[1] No. of fatal accidents 1968-88:	-	6	3	-	1	1	1	0
[2] No. of all ICAO accidents 1968-88:	9	25	3	-	20	12	3	1
[3] Percentage of fatal accidents 1968-88:	-	50%	25%	-	8%	8%	8%	-
[4] Percentage of all ICAO accidents 1968-88:	12%	34%	4%	-	27%	16%	4%	1%
[5] Distribution of fatal accidents 1968-88 (average of percentage distributions of fatal and total accidents in [3] & [4]):	6%	42%	15%	-	18%	12%	6%	1%
[6] Present distribution of fatal accidents (arbitrary scale):	6	21	8	3	13	6	6	1
[7] Present distribution of fatal accidents (%):	9%	33%	13%	5%	20%	9%	9%	2%
[8] Avg. no. of fatalities per accident 1968-88:	-	15	6	-	1	3	1	-
[9] Avg. no. of fatalities per accident, present:	2	13	13	18	5	10	1	7
[10] Relative contribution to fatalities from each accident type ([7]x[9], arbitrary scale):	0.18	4.29	1.69	0.90	1.00	0.90	0.09	0.14
[11] Percent of fatalities caused by each accident type, i.e. risk contribution ([7]x[9], %):	2%	47%	18%	10%	11%	10%	1%	2%

5.3 Number of accidents per accident type

The likelihood that a fatal accident is of a given type is estimated, assuming today's operational and technical standard.

[1] Fatal accident distribution (1968-88)

The 12 fatal accidents occurring in offshore helicopter transportation during the period 1968-88 were identified in section 4, and classified according to the different accident categories. The number of fatal accidents within each category is presented in row [1] of table 5.1.

[2] All ICAO accidents (1968-88)

The total of 12 fatal accidents is a low number, and provides an inadequate estimate for the distribution of accidents. In order to obtain a better estimate, it was decided to utilize data on non-fatal ICAO accidents in the period as well, because:

- The number of non-fatal accidents is larger
and
- Although these accidents are not fatal, they have a large damage and fatal potential, and provide symptoms of typical problem areas.

The total number of accidents in the period (i.e. fatal and non-fatal) are presented in row [2] of table 5.1.

[3] Fatal accident distribution, % (1968-88)

The percentage values of the present fatal accident distribution 1968-88 are shown in row [3].

[4] All ICAO accidents, % (1968-88)

The percentage values of all historical ICAO accidents 1968-88 are shown in row [4].

[5] Estimated number of fatal accidents per accident type (1968-88)

An estimate for the number of fatal accidents per accident type in the period 1968-88 is obtained by combining data on fatal and non-fatal accidents. This estimate is obtained by using the average percentage value of fatal accidents (row [3]) and of all accidents that have occurred (row [4]).

Example:

Accident type HP (Crash on take-off or landing on heliport)

Percentage value for fatal accidents [3]: 0 %

Percentage value for all accidents [4]: 12 %

Estimated value for fatal accidents [5]: $(0 + 12)/2 = 6 \%$

[6] Present number of fatal accidents per accident type - estimated

The distribution of accidents in row [5] of table 5.1 presents an estimate for the distribution of fatal accidents based on historical data from the period 1968-88.

However, both technical and operational quality have changed during these 20 years. For the purpose of the rating, an estimate for the distribution of accidents *today* is required, not over the past 20 years. If the quality of operations has improved over the last 20 years up to today, the figures for the present distribution should be lower than the historical distribution in row [5].

Based on the above, the project group's estimates for the present distribution of accident is presented in row [6] of table 5.1. The estimates are adjusted values of the historical figures in [5]. The background for the figures is presented in table 5.2. These estimated values (row [6]) show the relationship between the accident types represent on an arbitrary scale, and the %-notation is therefore not included.

Example:

Accident type «Critical system failure» (CSF)

Average distribution for 1968-88 [5]: 42 (arbitrary scale)

Average distribution today [6]: 21 (arbitrary scale), i.e.
50% improvement

The historical fatal accident distribution (row [5]) adds up to 100, i.e. 100%. The corresponding sum of estimates for the present fatal accident distribution (row [6]) is 64, i.e. 64%. This means that the project group estimates that the present fatal accident distribution would have been approximately $100 - 64 = 36\%$ lower than in the period 1968-88.

Table 5.2 Background for present distribution of accidents (row [6])

Accident type	Fatal accident distribution
Crash on take-off or landing on heliport (HP)	No changes. Assume 6%.
Crash following critical aircraft system failure during flight (CSF)	Today's technology/level of experience is higher, e.g.: - Improved rotor design, materials, control methods. - Improved systems for maintenance, detection of deviations and utilization of operational data. Assume 50% improvement.
Sudden crash into terrain, obstructions or sea during flight (TOS)	Improved equipment (e.g. radio altimeter), training/procedures (rig approach), crew concept. Assume 50% improvement.
Mid-air collision with other aircraft (MAC)	Relatively high number of near misses reported. Increasing number of destinations. Presence of military aircraft that do not adhere to requirements with regard to identification. High density of aircraft in vicinity of rigs in combination with lack of formal control system (AFIS vs. ATC). To a certain degree inaccurate and unreliable navigation aids. Increase from 0 to 3%.
Crash on take-off or landing on helideck (HD)	Improved location of helidecks, but still many difficult helidecks with regard to wind conditions and turbulence. Better awareness of problems with regard to location of cranes, turbine exhaust outlets, etc. More awareness concerning need for coordination between helideck/platform activities and helicopter traffic. Assume 30% improvement.
Unsuccessful emergency landing (UEL)	Improved simulator training, emergency exits, survival suits, SAR services. Assume 50% improvement.
Personnel acc. outside aircr. (PAO)	No changes. Assume 6%.
Personnel acc. inside aircr. (PAI)	No changes. Assume 1%.

[7] Present number of fatal accidents per accident type, % - estimated

In row [7] of table 5.1, the present accident distribution in row [6] has been translated to a percentage distribution.

The figures in row [7] can be interpreted as follows: If a fatal helicopter accident occurs, the likelihood that it is of a specified accident type is given in row [7].

Example:

If a fatal accident occurs, the likelihood that it is a «Crash on take-off or landing on heliport» is 0.09 (9%).

5.4 Number of fatalities per accident type

The number of fatalities in each accident type is estimated.

[8] Number of fatalities per accident type (1968-88)

The average number of *fatalities per accident type based on historical data* is presented in row [8] of table 5.1.

[9] Present number of fatalities per accident type - estimated

Row [9] of table 5.1 presents the project group's *estimates for fatalities* per accident type with the present helicopter operation in the North Sea. This estimate is necessary because of the low number of fatal accidents in the historical data material (12 fatal accidents). The estimates are adjusted values of the historical figure in [8].

The number of fatalities in row [9] is based on an *average of 13 persons* in the helicopter.

The background for the figures in row [9] is presented in table 5.3.

Example:

If a fatal accident of type «Crash on take-off or landing on heliport» occurs, it is estimated that 2 persons are killed.

Table 5.3 Background for present number of fatalities per accident (row [9]).

Accident type	Number of fatalities per accident
Crash on take-off or landing on heliport (HP)	Low potential energy because helicopter near ground. Large number of incidents on heliport, but few fatal accidents. High level of emergency preparedness. Assume 2 fatalities.
Crash following critical aircraft system failure during flight (CSF)	No possibilities for reduction of consequences. High altitude and speed. Assume no survivors, i.e. 13 fatalities.
Sudden crash into terrain, obstructions or sea during flight (TOS)	No possibilities for reduction of consequences. High speed. Assume no survivors, i.e. 13 fatalities.
Mid-air collision with other aircraft (MAC)	No possibilities for reduction of consequences. High altitude and speed. Assume no survivors. Two aircraft involved (helicopter and another helicopter or e.g. military aircraft. Average number of persons in the «other» aircraft estimated to 5, i.e. a total average of 18 fatalities
Crash on take-off or landing on helideck (HD)	Low potential energy because helicopter near helideck. Large number of incidents on helideck, but few fatal accidents. Accident potential larger than heliport accident because of possibility of crash into sea. Assume 5 fatalities.
Unsuccessful emergency landing (UEL)	Limited possibilities for amelioration. High probability of capsizing on sea in rough weather. Assume 10 fatalities.
Personnel accident outside aircraft (PAO)	Rotor/tail rotor accident. Assume 1 fatality.
Personnel accident inside aircraft (PAI)	Fire in aircraft. Assume fatalities to half of the personnel, i.e. 7 fatalities.

5.5 Risk contribution of the various accident types

Each accident type's contribution to risk (i.e. «Likelihood» x «Consequence») is estimated, based on:

- *The likelihood that a fatal accident is of a given type, and*
 - *The estimated number of fatalities per accident.*
-

[10] Risk contribution of each accident type

We now have estimates for likelihood and consequence of the various accident types. Based on these estimates, we may derive an estimate for the *contribution to risk* by each accident type. This is obtained through the product of:

- The likelihood that a fatal accident is of a given type («Likelihood», row [7]), and
- The estimated number of fatalities per accident type («Consequence», row [9]).

The product derived (row [10]) is a expression of the relative contribution to helicopter fatalities caused by a specified accident type.

[11] Risk contribution of each accident type - percent

The risk contribution for each accident type is translated to a percentage distribution in row [11] of table 5.1, i.e. percentage of helicopter fatalities caused by a specified accident type.

Example:

It is estimated that 2% of helicopter fatalities will be caused by the accident type «Crash on take-off or landing on heliport».

5.6 Likelihood that a risk factor is a causal or contributing factor in the accident types

The likelihood that a risk factor is a causal or contributing factor in each accident type is estimated, based on information gathered through the study.

[12]-[13] Likelihood that a risk factor is a causal or contributing factor in the accident types

The *estimated likelihoods* that the various risk factors (section 1.6) are *causal or contributing factors* in the accident types are presented in table 5.4.

A risk factor is a causal or contributing factor with regard to a given fatal accident if and only if another state of that risk factor would have led to a lower number of fatalities. Note that more than one causal or contributing factor can be involved in an accident.

The likelihood estimates are given as:

	Likelihood:	Code:
High:	0.8	+++
Medium:	0.4	++ -
Low:	0.2	+

The «+»es are used to visualize the likelihoods in the table.

The likelihood estimates are based on a combined evaluation of the various data sources in sections 3.1 - 3.11 and represent the project group's best guesses. The likelihood is a weight of how much we believe that a risk factor influences the *frequency* and *outcome* of an accident.

Note that the sum of likelihoods for risk factors in one column may exceed 1.0. This is further discussed in section 5.8.

The background for the estimates in table 5.4 are presented in table 5.5.

Table 5.4 Likelihood that a risk factor is a causal or contributing factor in accident types
(High: 0.8, +++, Medium: 0.4, ++, Low: 0.2, +).

Accident type:								
	HP	CSF	TOS	MACHD	UEL	PAO	PAI	
OPERATIONAL:								
Operating conditions	+	+	+++	+++	++	+++	++	
Heliports & helidecks	+				+++		+++	
Operating procedures			++	+				
Pilot working conditions	+		+	+	++			
Pilot performance	+		++	++	++	++	+	
Emergency preparedness	++				++	++		++
TECHNICAL:								
Technical reliability	++	+++	++	+	++	+++		+++
Equipment & provisions			+	+				
Crashworthiness & design for emergencies	++				+++	+++		++
Ergonomic design & physical work environment	+		+		+	+		
EXTERNAL:								
Oil companies					+	++	++	++
Aviation authorities			+	+	+			
ATC, external navigation aids & services	+		++	+++	+			
Manufacturers		+						

Note: Background for this table is given in table 5.5.

Table 5.5 Background for likelihood that a risk factor is a causal or contributing factor in accident types (table 5.4).

Crash on take-off or landing on heliport (HP)

Operating conditions (+):	Wind, visibility.
Heliports & helidecks (+):	Design, location. Equipment including emergency facilities. Runway slippery.
Pilot working conditions (+):	Fatigue, causing human error or hampering emergency intervention.
Pilot performance (+):	Pilots skills, incapacitation.
Emergency preparedness (++):	Pilot skills on emergency landing.
Technical reliability (++):	Rotor failure, engine failure.
Crashworthiness (++):	Crash from low height.
Ergonomic design (+):	Poor ergonomics, e.g. position of engine controls.
ATC & services (+):	Wrong information from heliport services.

Crash following critical aircraft system failure during flight (CSF)

Operation conditions (+):	Harsh conditions triggering technical failure.
Technical reliability (+++):	Failure in critical systems causing loss of control.
Manufacturers (+):	Insufficient component/system testing in relevant conditions, lacking feedback or information from manufacturer.

Sudden crash into terrain, obstructions or sea during flight (TOS)

Operating conditions (+++):	More likely in poor visibility conditions.
Operating procedures (++):	Poor crew concept, situation not detected by copilot. Hazardous approach procedures.
Pilot working conditions (+):	Fatigue causing navigation error or inattention.
Pilot performance (++):	Navigation error. Inattention. Disorientation, vertigo.
Technical reliability (++):	Undetected failure in navigation aids.
Equipment & provisions (+):	Inaccurate navigation aids, weather radar.
Ergonomic design (+):	Noise and vibration inducing fatigue and inattention.
Aviation authorities (+):	Accepting hazardous operating procedures.
ATC & services (++):	Failure/inaccuracy in approach navigation aids. Wrong information e.g. from approach radar.

Table 5.5 Background for likelihood that a risk factor is a causal or contributing factor in accident types (table 5.4), cont.

Mid-air collision with other aircraft (MAC)

Operating conditions (+++):	More likely in poor visibility conditions. Icing causing change in altitude.
Operating procedures (+):	Offshore, procedures regarding the air traffic situation leaves much to the pilot in command.
Pilot working conditions (+):	Long hours may induce risk taking («get-home-itis»).
Pilot performance (++):	Offshore, all evaluations and decisions regarding the air traffic left to the pilot in command.
Technical reliability (+):	Failure in navigation aids causing deviation from planned course.
Equipment & provisions (+):	Inaccurate navigation aids.
Aviation authorities (+):	Regulations, requirements and surveillance.
ATC & services (+++):	Main cause-lack of airspace control.

Crash on take-off or landing on helideck (HD)

Operating conditions (++):	Wind intensity, direction.
Heliports & helidecks (+++):	Location and design of helideck. Helideck equipment. Coordination with platform activities.
Pilot working conditions(++):	Fatigue inducing human error.
Pilot performance (++):	Pilot skills. Incapacitation.
Emergency preparedness (++):	Pilot skills on emergency landing.
Technical reliability (++):	Rotor failure, engine failure.
Crashworthiness (+++):	Crash from low height.
Ergonomic design (+):	Window arrangement in some aircraft.
Oil companies (+):	Interaction with helicopter operators regarding helideck requirements.
Aviation authorities (+):	Requirements and surveillance.
ATC & services (+):	Coordination with platform HFIS personnel.

Unsuccessful emergency landing (UEL)

Operating conditions (+++):	Outcome at sea depending on sea state.
Pilot performance (++):	Airmanship, especially fuel management. Pilot skills, especially decisions.
Emergency preparedness (++):	Pilot skills, emergency landing. Passenger evacuation training.
Technical reliability (+++):	Rotor failure, engine failure.
Crashworthiness (+++):	Aircraft stability on sea. Frame and seat design (hard landings).
Ergonomic design (+):	Design and location of emergency equipment.
Oil companies (++):	Passenger evacuation training. SAR facilities.

Table 5.5 Background for likelihood that a risk factor is a causal or contributing factor in accident types (table 5.4), cont.

Personnel accident outside aircraft (PAO)

Operating conditions (++):	Wind conditions influencing aircraft position on helideck. Hoisting in adverse conditions (SAR).
Heliports & helidecks (+++):	Passenger and personnel control.
Pilot performance (+):	Pilot attentiveness, especially on start-up.
Oil companies (++):	Embarking procedures. Passenger instruction.

Personnel accident inside aircraft (PAI)

Emergency preparedness (++):	Crew and passenger evacuation.
Technical reliability (+++):	Most likely caused by fire, explosion.
Crashworthiness (++):	Possibilities for escape, emergency exits.
Oil companies (++):	SAR facilities.

5.7 Importance of risk factors

The importance of each risk factor, relative to fatalities, is estimated, based on:

- *The contribution to risk of each accident type, and*
 - *The likelihood that a risk factor is a causal or contributing factor in each accident type.*
-

[14] Importance of risk factors

The importance of the various risk factors in the accident types can now be assessed by combining the following estimates:

- The risk contribution of each accident type (table 5.1, row [11])
- The likelihood that each risk factor is a causal or contributing factor in the accident types (table 5.4)

Each row in table 5.4 (likelihood of being a causal/contributing risk factor) is multiplied by the corresponding risk contribution figure in row [11] in table 5.1.

An example for the risk factor «Heliports & helidecks» is given in table 5.6. Corresponding calculations have been carried out for all risk factors (i.e. each line), and results are given in table 5.7.

Through this procedure, we obtain a relative measure of the importance of a given risk factor as a causal or contributing factor in the accident types (row [14]). These estimates are used in section 5.8 to calculate the total importance of the risk factors relative to fatalities.

Example:

The importance score for the risk factor «Heliports & helidecks» in the accident type «Crash on take-off or landing on heliport» is $[11] \times [13] = 0.2 \times 2 = 0.4$.

Table 5.6 Importance of risk factors (Example shown for «Heliports & helidecks»)

Accident type:								
	HP	CSF	TOS	MACHD	UEL	PAO	PAI	
[11] Percent of fatalities caused by each accident type, i.e. risk contribution ([7]x[9]):	2%	47%	18%	10%	11%	10%	1%	2%
[12] Likelihood that «Heliports & helidecks» is a causal/contr. factor in accident (from table 5.4)	+	-	-	-	+++	-	+++	-
[13] Likelihood that «Heliports & helidecks» is a causal/contr. factor in accident (from table 5.4)	0.2	-	-	-	0.8	-	0.8	-
[14] Importance score of risk factor «Heliports & helidecks» in each accident type ([11]x[13])	0.4	-	-	-	8.8	-	0.8	-
[15] Total importance of risk factor «Heliports & helidecks» (sum row [14])								10.0
[16] Potential for improvement of risk factor «Heliports & helidecks»								25%
[17] Reduction in fatalities due to improvement of risk factor «Heliports & helidecks» ([15]x[16])								2.5%

[15] Total importance of risk factors

The total importance of each risk factor with respect to fatalities in offshore helicopter transportation is obtained by adding the importance scores for the risk factor, i.e. the sum of row [14] for risk factor «Helidecks & heliports», row [15].

Example:

The total importance score of the risk factor «Heliports & helidecks» is $0.4 + 8.8 + 0.8 = 10.0$.

Table 5.7 Importance scores for risk factors.

	Accident type:								
	HP	CSF	TOS	MACHD	UEL	PAO	PAI	Total	
OPERATIONAL:									
Operating conditions	0.4	9.4	14.4	8.0	4.4	8.0	0.4	-	45.0
Heliports & helidecks	0.4	-	-	-	8.8	-	0.8	-	10.0
Pilot performance	0.4	-	7.2	4.0	4.4	4.0	0.2	-	20.2
Operating procedures	-	-	7.2	2.0	-	-	-	-	9.2
Pilot working conditions	0.4	-	3.6	2.0	4.4	-	-	-	10.4
Emergency preparedness	0.8	-	-	-	4.4	4.0	-	0.8	10.0
TECHNICAL:									
Technical reliability	0.8	37.6	7.2	2.0	4.4	8.0	-	1.6	61.6
Equipment & provisions	-	-	3.6	2.0	-	-	-	-	5.6
Crashworthiness & design for emergencies	0.8	-	-	-	8.8	8.0	-	0.8	18.4
Ergonomic design & physical work environment	0.4	-	3.6	-	2.2	2.0	-	-	8.2
EXTERNAL:									
Oil companies	-	-	-	-	2.2	4.0	0.4	0.8	7.4
Aviation authorities	-	-	3.6	2.0	2.2	-	-	-	7.8
ATC, external navigation aids & services	0.4	-	7.2	8.0	2.2	-	-	-	17.8
Manufacturers	-	9.4	-	-	-	-	-	-	9.4

5.8 A note on the interpretation of importance scores for risk factors

This section is intended to promote the understanding of table 5.7, and may be skipped by readers who are mainly interested in the end results.

In a certain sense, the entries in table 5.7 can be interpreted as percentages. The first entry in the first row (top left) can be interpreted as follows:

- *«It is estimated that 0.4% of all fatalities are caused by heliport accidents in which operating conditions are a causal or contributing factor.»*

In a similar manner, the last entry in the first (top right) row can be interpreted as follows:

- *«It is estimated that 45.0% of all fatalities are caused by accidents in which operating conditions are a causal or contributing factor.»*

The reader will note that the sum of all entries in the last (right) column exceeds 100. The reason for this is that more than one causal or contributing factor may be involved in many accidents. An accident could, e.g. involve a critical system failure (risk factor «Technical reliability») which is less than optimally handled by the pilot (risk factor «Pilot performance») due to fatigue induced by long working hours (risk factor «Pilot working conditions»).

A more formal explanation of why the entries in the last (right) column do not add to 100 can be given on the basis that the risk factors are not disjoint and independent.

As an example, pilot working conditions will strongly influence pilot performance, and operating conditions will in the same way influence technical reliability. In the latter case we will, however, expect a weaker dependency.

The error made by using the described procedure can be illustrated by looking at the probability of the union of two events A and B (see figure 5.1),

$$P(A \text{ or } B) = P(A) + P(B) - P(A \& B) \quad (1)$$

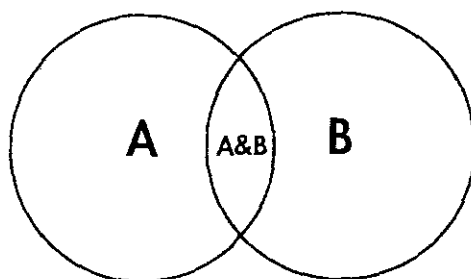


Figure 5.1 Venn diagram

When the two events are disjoint, then $P(A \& B) = 0$, and $P(A \text{ or } B) = P(A) + P(B)$, which is analogous to the procedure we have described above.

If event B implies event A with certainty, i.e. event B is included in event A, then $P(A \& B) = P(B)$, and thus $P(A \text{ or } B) = P(A)$.

When event B partly implies event A, we will get an intermediate result.

When we estimate the probability of the union of a high number of events, this probability may be far from the sum of the probabilities of the single events. The sum may be 2, 3 or more times as high. This is easily verified by looking at the Venn diagram.

Observe that when we want to assess the importance of a combination of two or more risk factors, we *cannot* take the sum of the importance values of the individual risk factors. This is because of the interdependency or overlapping between the risk factors. The combined importance of e.g. «Pilot performance» and «Pilot working conditions» will be very close to 20% (see total importance score for «Pilot performance», far right column in table 5.7), since «Pilot working condition»-problems almost solely are manifested through «Pilot performance»-problems.

5.9 Potential for improvement of risk factors

The potential for future improvement of each risk factor is estimated, giving a reduction in fatalities achieved through the improvement.

[16] Potential for improvement of risk factors

In this section, we will assess the *potential reduction* in the number of fatalities if a risk factor is improved.

The basis for this assessment is a time period in which we assume that 100 fatalities will occur if the current situation, and technical and operational quality is maintained throughout the whole period. The number 100 has been chosen to obtain percent values. More specifically, we are looking at a time period in which the technology will be relatively stable, approximately 10-15 years.

The realistic potentials for improvement have been estimated based on the project group's current knowledge, and are presented in table 5.8.

Example:

The realistic improvement of the risk factor «Heliports & helidecks» over a period of 10-15 years is estimated to 25%.

[17] Reduction in fatalities due to improvement

Table 5.8 presents the estimated *reduction in fatalities* in the time period when the risk factors are reduced according to the percentage values in [16]. The values in table 5.8 are calculated by multiplying the total importance scores (table 5.7) by the potential for improvement (table 5.8) (see also example in row [17] in table 5.6).

Example:

The realistic improvement of the risk factor «Heliports & helidecks» of 25% leads to a $0.25 \times 10.0 = 2.5\%$ reduction in «Heliports & helideck's» contribution to fatalities in offshore helicopter transportation.

5.10 Overview of risk influence rating

Risk factors, estimated potential for improvement and estimated reduction in fatalities are summarized in table 5.8. The risk factors are presented in order of estimated effect on fatalities.

Table 5.8 Summary of results from rating of risk factors

Risk factor	Potential for improvement	Reduction in fatalities
	[16]	[17]
1. Technical reliability	25 %	15.4 %
2. ATC, external navigation aids & services	50 %	8.9 %
3. Pilot performance	25 %	5.1 %
4. Crashworthiness & design for emergencies	25 %	4.6 %
5. Aviation authorities	50 %	3.9 %
6. Pilot working conditions	25 %	2.6 %
7. Heliports & helidecks	25 %	2.5 %
8. Manufacturers	25 %	2.4 %
9. Ergonomic design & pilot working environment	25 %	2.1 %
10. Oil companies	25 %	1.9 %
11. Equipment & provisions	25 %	1.4 %
12. Operating procedures	10 %	0.9 %
13. Emergency preparedness	5 %	0.5 %
14. Operating conditions	0	0

A realistic improvement of e.g. «Crashworthiness...» of 25% is thus estimated to reduce the number of fatalities by 4.6%. This reduction refers to an *isolated* improvement of this specific risk factor. Please remember the comments in section 5.8 about the overlapping of risk

factors. The reduction in the number of fatalities by improving two risk factors simultaneously will generally *not* be the sum of the single improvements.

Example:

«Pilot working conditions» is included in «Pilot performance». If the potential for improvement related to «Pilot working conditions» is fully realized, the remaining potential for reduction of fatalities related to «Pilot performance» is reduced (figures are taken from table 5.8):

<i>Risk factor:</i>	<i>Potential reduction in fatalities (table 5.8):</i>
---------------------	---

<i>Pilot working conditions</i>	2.6%
<i>Pilot performance</i>	5.1%

Remaining potential for improvement related to «Pilot performance» when improvement related to «Pilot working conditions» is fully realized:

5.1% - 2.6% = 2.5%

Another problem is related to the accident chain. It is obvious that the effect of an improvement of e.g. «Crashworthiness...» will be reduced if we at the same time also have an improvement of one or more of the risk factors influencing the probabilities of the accidents. A reduction in the number of technical failures will thus reduce the effect of improving crashworthiness and emergency preparedness.

Total reduction of risk

The above indicates a total reduction of risk per person flight hour of 30-40% within 10-15 years, compared to the present safety level.

5.11 Summary of assumptions and validity issues

The assumptions and validity issues relating to the preceding estimation of risk influence are summarized below.

- Implicit in the rating procedure is an assumption that risk can be viewed in terms of expected number of fatalities.
- The notion of risk influence as defined in this study, does not necessarily reflect the safety impact of negative changes in a risk factor, e.g. economic margins of helicopter operators getting tighter. This is the reason why consequences of change in a negative direction has been included in the discussion of some risk factors.
- The project group has based their evaluations on the widest possible range of data sources, to avoid too strong reliance on a single source.
- Basis for estimation of accident frequencies and fatalities are historical accident data which have been adjusted to take into account recent developments. The frequency estimate for «Mid-air collision with other aircraft» is particularly difficult, as collisions are very rare, but serious events. Errors in this estimate could influence the importance rating of «ATC, external navigation aids & services» substantially, while effects on other ratings would be insignificant.
- The number of persons per helicopter is assumed to be 13. Moderate errors in this assumption would, however, not have a significant influence on the importance ratings.
- Improvements are considered over a period of 10 - 15 years. The procedure assumes that the over-all operational pattern remains unchanged. A dramatic increase in e.g. the relative volume of shuttling could change the over-all picture.
- The rating is based on pooled data, and represents an over-all picture. This should be taken into account when specialized operations are considered. In e.g. shuttling, one might expect a higher importance of factors such as «Heliports & helidecks», «Pilot performance» and «Crashworthiness». In a similar manner, specific helicopter operators may deviate from the over-all picture in certain respects.

6. DISCUSSION

This section gives a detailed discussion of the most important risk factors identified through the study. Minor risk factors are discussed briefly.

6.1 Technical reliability

Technical reliability is defined as the ability of a component or technical system to fulfill an intended function under given environmental and operational conditions.

Technical reliability is the risk factor category with the highest risk influence rating. The conclusion that technical reliability is the major contributor to risk is supported by all relevant data sources. The pilots ranked aircraft technical reliability highest with regard to desired improvements.

The fact that technical reliability is the major risk factor in North Sea helicopter operations is not surprising, considering the basic concept of a helicopter with high vibration levels and non-redundant critical systems, and the hostile environment it operates in. However, it has been a common perception that human factors have played the major role in helicopter transportation risk.

Other underlying conditions that have a major impact on technical reliability are the operational patterns in the North Sea helicopter operations. These are factors related to flight frequencies, load patterns, distances etc., considered in relation to the characteristics of the aircraft. Operational patterns strongly influence the risk factors inadequate design and maintenance planning.

The original problem remains that the helicopter types used in the North Sea are not truly «offshore helicopters», but rather military aircraft adapted to this use. This means that the inherent assumptions with regard to:

- Utilization
- Payload
- Environmental loads and conditions

are to some degree inadequate. As an example, a commercial utilization of 1300 hours per year is not uncommon, compared to a normal military utilization of approximately 300 hrs per year. Furthermore, a large amount

of the North Sea helicopters fly most of the time with (or close to) maximum payload. Taking the hostile North Sea environment and the applied loads into consideration, this reflects the enormous challenge of reliability management in North Sea helicopter operations.

The study of ICAO-defined accidents, technical reports and flight reports indicates that the most critical failures occur in the main and tail rotors, main and tail rotor drives and rotors flight control. This is consistent with the response from the maintenance survey regarding most critical systems, with the addition of the hydraulic power system.

We have defined the following risk factors within the category technical reliability (see definitions in 1.6):

- Inadequate design
- Maintenance planning & tools
- Human performance in maintenance
- Spare parts

Importance of risk factors

The following weights of risk factors, given a critical technical failure, has been estimated based on flight reports, technical reports and incident reports:

■ Inadequate design:	45 %
■ Maintenance planning:	30 %
■ Human performance in maintenance:	15 %
■ Spare parts:	10 %

The above distribution is estimated from reported deviations/events of varying criticality, and is based on the assumption that the risk picture with regard to critical failures alone is similar.

It should also be noted that the figures are rough estimates based on different data sources reflecting varying data quality, levels of detail and different time periods, and on sound engineering judgments. The figures represent the best possible estimates based on the data available.

The distribution represents the historical contributions to risk and is not comparable to the risk influence as defined earlier in the report, as the potentials for improvement is not considered.

Each of the four risk factors is discussed in the following. It should be kept in mind that the amount of data is limited on this level of detail, and that the project team did not get access to all the data requested.

6.1.1 Inadequate design

Definition

The actual design of the aircraft (systems and structure) including design modifications and selection of materials. This class does not cover the ergonomic design or the physical work environment in the aircraft.

Influence

The most important factors within this class are:

- Defective detail design (not discovered during development testing)
- Faulty manufacture of components/systems (inadequate quality control, manufacturers)
- Inadequate accessibility/maintainability
- Material selection (corrosion, fatigue, wear)
- Modifications (changes of e.g. material quality, verification/implementation)

Data on detailed causes, e.g. whether failures are caused by faulty manufacture or defective detailed design, is frequently inadequate.

It is also difficult to distinguish between failures caused by defective design/faulty manufacture and general wear due to operating conditions.

About fifty percent of the respondents in the maintenance questionnaire survey disagreed that the systems they work with are easily accessible.

6.1.2 Maintenance planning

Definition

Conditions related to:

- Testing and inspection of the aircraft, identification of degradations e.g. through condition monitoring, failure diagnosis
- Maintenance planning
- Actual maintenance and tools and facilities used during maintenance

This class does not include supervision and human factors in maintenance.

Influence

The following factors are the most important, according to the data sources:

- Inadequate or lack of maintenance routines and procedures

The maintenance questionnaire survey showed a considerable degree of discontent with the maintenance routines and procedures. 35% disagreed that the procedures and job descriptions are easy to follow, and 46% agreed that maintenance plans often allow too little time to do the maintenance work properly.

- Preventive maintenance schedules

The questionnaire survey showed that 28% disagreed that the maintenance schedules in their company are revised regularly to take company internal experience into account. 52% agreed that the maintenance intervals are unnecessarily short in many cases.

A number of respondents stressed the general need for improved communication between the helicopter operating companies.

6.1.3 Human performance in maintenance

Definition

The degree to which the maintenance personnel can be depended on to carry out the required maintenance actions without errors, including supervision and quality control.

Influence

The most important factors are considered to be:

- Erroneous maintenance
- Supervision
- Quality control (job inspection)

About 30% of the respondents in the questionnaire survey agreed that they sometimes do a poor job due to time pressure.

About 75% of the respondents agreed that they would have done a better job if they received more feedback from their superiors.

The estimated importance of human performance in maintenance was 15%. This must be said to be relatively low compared to what is known from other types of maintenance. In general, the maintenance questionnaire survey gives the impression of highly competent personnel with a responsible attitude towards aircraft maintenance. Taking the importance of the maintenance task into consideration, any potential for deterioration is of more concern than the present state.

6.1.4 Spare parts

Definition

All conditions related to quality and availability of spare parts, including spare parts management, correctness of type, quality control, etc.

Influence

The most important factors are found to be :

- Inadequate spare parts quality
- Spare parts damaged/deteriorated in store
- Spare parts control
- Labelling of spare parts
- Lack of spare parts

About 35% of the respondents in the maintenance survey disagreed that all spares are authentic and reliable. A comment was made that spares are invariably authentic, but the reliability is often poor.

About 70% agreed that maintenance tasks are often delayed due to lack of spare parts. This may introduce time pressure when the job is to be done.

Spare parts problems is seen to be most relevant for the S61 in the near future.

6.1.5 Areas for improvements, Technical reliability

Possible improvements, based on the above discussions, are:

- Improved and more realistic fatigue test programmes.
- In-flight load measurement and recording as input to forecast lives of components and maintenance planning.
- Further development of Health and Usage Monitoring Systems.
- Examine possibilities for better utilization of company internal data. Review existing reliability management concepts, including systems for reporting and analysis of deviations.
- Improved exchange of reliability data between helicopter operating companies.
- Improved feedback from helicopter manufacturers to operating companies.
- Improved feedback from overhauling contractors to operating companies.
- Improved development testing and quality control, manufacturers.
- Improved reception control by the operating companies (including spare parts).
- Examine the possibilities for improving maintenance procedures and job descriptions (e.g. higher degree of standardization in procedure writing).
- The operating companies should specialize on fewer helicopter makes to obtain more effective maintenance, technical training and experience accumulation.
- Establish better routines for feedback within the maintenance organization and reduce time pressures.
- Improved spare parts management (logistics).

6.2 ATC, external navigation aids & services

Definition

Factors related to regulations, procedures, resources and practice of air traffic control (ATC), flight information service (FIS & HFIS), navigation aids (VOR, ILS, NDB, etc.), meteorological service, etc.

Regulation of air traffic

Regulation of all air traffic including helicopter flights is undertaken according to ICAO standard, which implies that the member states have sovereignty to draw up regulations within their own territorial border.

ICAO international regulations apply in international air space. It is important to note that ICAO regulations do not apply to military air traffic.

Most offshore installations are situated outside national territorial borders, which implies that national regulations cannot be established. Airways have been established to and from the offshore installations (HMR & HAR).

The establishment of fully controlled airspace for the North Sea would have to be undertaken as a cooperation between countries situated around this area under the auspices of ICAO and imply considerable investments in equipment and personnel.

Present systems in the North Sea

In national territories, the operation takes place in controlled air space according to national regulations. National air information service is provided en route (FIS), and Helicopter Flight Information System is provided around installations with largest traffic (HFIS).

Enroute navigation is supported by OMEGA or DECCA navigation systems.

Air traffic zones are established around each installation (HTZ, in the Norwegian sector: 1.5 NM x 2000 ft). For larger fields with several installations, protection zones (HPZ) have been defined up to 2000ft, and control tower services are provided. The standard navigation aid on platforms is a non-directional beacon (NDB), and approaches are guided by the beacon and the on-board weather radar. The regulations and services vary somewhat between countries (UK - Viking Approach).

Safety problems

Traffic control and services may be involved as a contributory factor in the following accident types:

- Crash on take off or landing on heliport
- Sudden crash into terrain, obstructions or sea during flight
- Mid air collision with other aircraft
- Crash on take off and landing on helideck

No mid-air collisions have occurred up to the present date in the North Sea area. The relatively high weight attributed to this accident type (table 5.7) in spite of this fact has two reasons:

- The project group estimated that mid-air collisions could be expected to amount to 3 percent of all fatal accidents, if present status of air traffic regulation and services remained unchanged. This estimate was based on considerations regarding the expected activity in the future and available information from flight reports and other sources about incidents of inadequate separation.
- Mid-air collisions are the type of helicopter accident with largest expected consequence. The project group's estimate was 18 fatalities per accident on the average.

In the project data, the following safety problems have been noted:

Violation of airway regulations

Both flight reports and interviews have reported cases of inadequate separation of aircraft. Episodes involving military aircraft are most frequent. Military aircraft often come from own or other North Sea countries, but units from more distant countries are also reported.

In some cases, inadequate separation occurs in relation to other helicopters, especially the shuttle traffic around offshore installations. One case which was reported happened because of violation of airway regulations («short-cutting»).

Helicopters may be forced to leave assigned altitude due to icing conditions, and thus violate vertical separation regulations.

Inaccurate navigation

Present en-route navigation systems are inaccurate and sensitive to disturbances. In difficult weather conditions, course deviations may become considerable. Airways are planned to take inaccurate navigation into account, but inadequate separation still seems to be a possibility. In addition, inability to report exact position will reduce the efficiency of SAR operations in case of a ditching.

Pilots find lack of distance information on present platform navigation aids unsatisfactory.

Inadequate radio information

Heavy radio traffic may make it difficult to obtain radio contact with the offshore destination as planned. Several cases of this problem were reported.

Lack of competence in personnel providing offshore air information services may cause important messages not to reach pilots, or cause that wrong information is given (e.g. wind direction, wind speed or visibility). Several instances were reported in pilot interviews.

An information system for offshore helicopter operations instead of a control system like on airports implies that the responsibility for how air movement shall be undertaken, or the decision concerning when it is safe to take off, rests with the individual pilot in command. When the air traffic picture becomes complex with many airborne units moving simultaneously, it becomes more difficult to foresee future constellations, and the probability of running into «tight spots» increases. Commercial pressures might force some captains to take off into or fly through airspace which is too crowded for comfort or for safety. It is not known to what extent this is a safety problem today, but the conditions for such risks to occur are present in the existing system.

Inaccurate or wrong weather information

Weather forecasts in the North Sea area are not always reliable, partly due to the fact that conditions change rapidly. In addition, the system for updating of meteorological information may be lagging behind. Flight reports contain incidents of flights through not forecasted weather fronts causing damage to the aircraft.

Helicopter operations at airports

Where offshore helicopter transportation originates from ordinary airports, the helicopters use navigation means intended for fixed wing aircraft (VOR/DME, ILS, Radar). Problems mentioned in the project data were the slow speed of helicopters in relation to other traffic, and difficulties in flying standard approaches.

Future developments

Future developments in offshore activities will keep changing the picture described above. New areas of dense traffic may turn up, and operations may move to new, less known waters, e.g. the Barents Sea. Planning of air traffic control and services must take place ahead of the development, and not occur as a result of painful experience.

Improvements

The project group's estimate that a 50 percent improvement can be obtained in this factor rests on the assumptions that the full potential of new technology is taken into use to improve safety, that coordination with military traffic is made, and that the air traffic control in dense offshore areas is improved. Different areas of improvement are discussed in detail below.

New navigation systems

New, improved navigation systems are or will be available in the near future (LORAN-C, NAVSTAR/GPS, Microwave, Onboard: Integrated Flight Management Systems). Installation of these systems in the present fleet will increase navigation accuracy and reduce some of the risks described above. However, there is a danger that better navigation systems will lead to straighter and tighter airways with smaller safety margins, so that the potential benefits to safety of improved systems are cancelled by demands for increased efficiency.

New systems will contain possibilities for two-way transmission of position data, which opens up for more integrated, centralized overview of the traffic situation, and possibilities to monitor and control the air traffic. The potentials in new systems in this direction ought to be explored.

Coordination with military air traffic

Better coordination with military activity is possible and highly desirable. Military radar stations have better coverage over the North Sea basin which could be very useful if relayed to ATC and FIS services.

Improved offshore regulation

Improved offshore regulation is a matter of investments in more qualified personnel and better equipment. It is also a matter of regulations. The present state that leaves much to the individual pilot in command, is a potential risk in areas with dense helicopter traffic.

The possibilities of new technology should be used to set up a better air traffic control systems around offshore installations in the North Sea. Cooperation between countries concerned on common arrangements could make such solutions economically feasible.

6.3 Pilot performance

Definition

The degree to which the pilot(s) can be depended on to act in a manner required. This class also includes psychological factors such as attitudes.

Influence

When we discuss pilot performance as a «risk factor», we imply that pilots influence the over all risk level in two ways:

- (a) Positively, e.g. through proper handling of technical failures
- (b) Negatively, e.g. through incorrect decisions.

Examples of the positive impact of pilot performance are found in numerous occurrence reports where pilots detect conditions threatening safety and perform appropriate emergency actions, even in the absence of relevant or suitable procedures.

A sample of safety problems related to pilot performance are listed below:

- Non-compliance with procedures/rule-bending
- Inadequate check-out of aircraft
- Pilot incapacitation
- Disorientation under adverse operating conditions
- Inattention
- Reacting too swiftly (and incorrectly) to problems occurring during flight
- Incorrect timing of reaction
- Wrong diagnosis of technical problems
- Landing on wrong platform

Current accident and incident data indicate that the positive influence of pilot performance by far outweighs the negative influence. Only a minor part of all fatalities are caused by pilot error. Furthermore, the pilots play a crucial role in avoiding serious consequences through proper emergency action in the far greater number of non-fatal accidents and incidents. We realize, however, that the reporting of pilot errors in some sources (e.g. flight reports) may be limited by a self-protective bias, i.e. pilots may be reluctant to reveal their own mistakes.

It is important to view the crew concept as a whole when pilot performance is considered. Crew coordination is thus an important aspect of pilot performance, cf. the discussion of crew concept below.

Improvements

Efforts to enhance pilot performance should focus at the higher level risk factors which influence pilot performance:

Pilot working conditions

This is a significant risk factor in its own merit, see table 5.10. Particular attention should be paid to conditions leading to fatigue or stress. Present work schedules should be reviewed critically. It is important that the frequent high workloads associated with shuttling is given proper consideration. The project group considers this an area in which the *aviation authorities* should use their regulatory power. In addition, the oil companies should be observant of the possible effect on this factor from contract conditions, e.g. demanding transport on short notice or by causing seasonal variations in demand.

Ergonomic design and physical work environment

The current disparity between fixed wing and rotorcraft ergonomic standards should not be accepted. Results from the Pilot Questionnaire Survey in the present study indicate that vibration and noise is a major cause of worry among pilots. A comprehensive set of recommendations in this area can be found in a study performed by the *Helicopter Human Factors Working Group* (CAA Paper 87007).

Emergency preparedness

The highest current standards of pilot emergency training should be implemented in all companies. We see no adequate substitute for extensive and regular simulator training.

Personnel policy

Important aspects of this factor are selection, training, health monitoring, and general conditions (e.g. wages). We have found that the fatal accident rate (per hour) in North Sea helicopter transportation is about an order of magnitude greater than that of scheduled fixed wing services. The fact that critical technical failures occur more frequently in helicopter transportation leads us to the conclusion that the capabilities of North Sea helicopter pilots have a greater safety impact than that of most fixed wing pilots. The personnel policy in helicopter companies should be planned, implemented and evaluated with this consideration in mind. Selection, training and medical standards should be comparable with the best practices in fixed wing operations. Extensive transition of pilots to fixed wing aviation should be taken as a possible sign of shortcomings in this area. The long term health effects of low frequency vibration and noise should be given specific attention.

Procedures and regulations

Consistent implementation in all companies of a *crew concept* which maximizes the safety benefit from having two pilots may be the most important factor in this area. This is not only a question of defining a set of formal rules. An effective crew concept requires a high copilot qualification level, and may in some cases require profound changes in the attitudes and style of cooperation.

An important function of procedures is to give the pilots unambiguous criteria for all decisions which imply a trade-off between safety and economy. This aspect should be borne in mind when procedures are developed or reviewed.

Policy, economy and budget

These factors have an impact through management decisions regarding, e.g. personnel policy and working conditions. In addition, company policy

and management decisions may influence pilot attitudes and critical pilot decisions in informal ways. An acceptable safety level can only be achieved if the safety consciousness of pilots is maintained at a very high level.

It should be realized that the present safety level in North Sea helicopter transportation depends on a very high level of pilot performance. A lowering of standards in this area (e.g. reduction in the amount and frequency of simulator training) would not only lead to more frequent pilot errors, but would also reduce the capability of pilots to handle emergencies caused by technical problems and adverse operating conditions. The current turbulence in the helicopter transportation market brings about diverse challenges, such as shortage of qualified pilots, high work loads, transfer to fixed wing, and uncertainty about the future of pilots in their present companies.

6.4 Crashworthiness & design for emergencies

Definition

Design characteristics of the aircraft which directly influence the opportunities for emergency handling and the consequences of a crash or ditching. This also includes e.g. single engine performance.

Safety problems

The limited possibilities of surviving a ditching in the North Sea was the highest worry among pilots in one of the detailed studies in the project. This clearly points out the importance of the risk factor, and indicates that under unfavorable circumstances, the prospects of surviving a ditching may be slim. Many will maintain that the relatively small number of fatalities following ditchings up to now may to a large extent be attributed to luck, especially with regard to the weather conditions at the time of the incident.

Safety problems are particularly related to the aircrafts instability on sea, due to a high center of gravity and low center of bouyancy. The probability of capsizing increases with the onset of adverse weather conditions such as strong winds and heavy waves, which are commonplace in the North Sea.

Flotation systems are designed to increase the helicopters stability on sea. There have, however, been cases of ditchings where flotation systems have not functioned as intended.

«Second-impact» with the aircraft interior following hard landings causes injuries to passengers and crew. In addition, opportunities for escape from an overturned helicopter (e.g. emergency exits and seating arrangement) determine the personnel's possibilities for evacuation.

A particular problem related to the S61 is the possibility of failure in sponsons following a hard landing. This reduces the helicopter's stability, and increases the likelihood of overturning. In addition, the helicopter's low engine capacity may contribute to a difficult emergency handling of a single engine failure on take-off or landing on helideck.

In the HARP Report, prevention of post-crash fires is pointed out as another important aspect of helicopter crashworthiness.

Improvements

Important measures include improvements of aircraft stability on sea through e.g. reliable flotation systems and water pockets/scoops.

In addition, the aircraft's ability to absorb impact upon hard landings may be increased (and injuries consequently limited) by e.g. providing energy attenuating landing gear and fuselage.

Personnel evacuation possibilities should be considered by evaluating the number of emergency exits and seat arrangement around exits.

Measures concerning aircraft interior include improved seat belts, aircraft interior/cockpit and seat design and absorption properties.

The HARP Report also suggests crash-resistant fuel tanks through better protection and self-sealing provisions.

Note that measures aimed at increasing helicopter crashworthiness have significant negative effects in that they may increase aircraft weight and reduce aerodynamic properties.

Other measures related to crashworthiness include helmets, emergency equipment provisions, evacuation training of passengers and crew, and pros and cons of survival suits.

6.5 Other risk factors

Aviation authorities

The policy and practice of national and international regulating bodies. Problem areas include incomplete regulations for offshore helicopter transportation and inadequate control.

Pilot working conditions

Conditions related to the pilot's working situation, except helicopter ergonomic design and physical work environment, which may influence his performance. Examples are extraneous tasks (e.g. loading of cargo, paper-work), time pressures, long work hours and fatigue. See discussion in section 6.3.

Heliports & helidecks

Factors related to location, layout, equipment, heliport/helideck personnel etc. while the aircraft is on the heliport/helideck. Identified problem areas are:

- Cranes near helideck/runway
- Helideck/heliport crew errors
- Inadequate helideck/heliport housekeeping
- Turbulence caused by structures near helideck
- Exhaust near helideck, causing loss of lift
- Inadequate communication on rig, e.g. causing unexpected crane movements during landing/take-off.

Manufacturers

Conditions related to the activities of helicopter manufacturers, excluding those directly covered by the risk factors «Inadequate Design» and «Spare Parts». Inadequate overhaul procedures have been identified as a problem.

Ergonomic design & pilot working environment

Design aspects of the helicopter and its equipment which influence pilot performance. Problems identified are noise and vibrations, inadequate instrument design, poor temperature regulation and poor seats. See discussion in section 6.3.

Oil companies

Conditions related to the interaction of oil companies with the helicopter operators, excluding the provision of helicopter facilities and services. Examples of identified safety problems are varying oil company requirements, frequent last minute re-scheduling, and lacking information concerning cargo properties/weight.

Equipment & provisions

This risk factor refers to the availability and quality (performance) of equipment in the helicopter, e.g. navigation aids, autopilot. It does not cover the technical reliability of such equipment. One problem mentioned by pilots is the accuracy and reliability of present navigation systems.

Operating procedures

The helicopter operators' written procedures, standards, requirements, etc. regulating operating practice. Note that emergency procedures are considered under a separate heading («Emergency Preparedness»). Procedures are generally complete and well-founded, but certain procedures are incomplete or conflicting in certain situations. In addition, updating of procedures may be inadequate.

Emergency preparedness

Equipment and organizational preparations (e.g. training) directed at the handling of emergencies. The class does not include factors directly related to helicopter design, e.g. stability on sea. Emergency procedures are included in this class. See discussion in section 6.3.

Operating conditions

Operating conditions involved in offshore helicopter operations e.g. wind, rain, icing represent a significant contribution to risk. These conditions are however not possible to influence, and must therefore be addressed through other measures, e.g. minimum/maximum requirements and operating procedures.

6.6 Management risk factors

Policy

Most helicopter companies have a potential of improvement in establishing a definitive (i.e. superior) policy document, required of an integrated QA system, where safety goals are quantified and stated.

Although the ethos for emphasizing safety, and for the regulation of activities through standardization, is pronounced in the aviation industry, situations occur when the application of regulations may be in conflict with considerations such as convenience or cost. None of the companies systematically appraise their operations to detect and correct such situations.

Organization and responsibility

The quality of management in general will influence the accepted risk level of an undertaking with implicit hazards. General factors involved in the smooth and efficient running of any business enterprise company were not the main focus of the study.

Economy and budget

The demand for helicopter companies' services may be satisfactory at present, and this permits the companies to continue trading. However, the financial return on capital is perceived as too low to be healthy in the long run.

Onerous contracts combined with over preparedness to please the customer have been experienced to impose considerable strain on staff.

Personnel management

There is a particular shortage of avionics engineers. The present stable work force is ageing, and companies experience difficulty in retaining younger staff.

Although there were duty limitations for aircrew, no restrictions on the hours and shifts that engineers worked existed. They commented that fatigue and unsocial working hours could adversely affect workmanship.

QA and safety management

The helicopter companies vary in the degree of formality of structure and activity of their management. All companies are in the process of adopting quality assurance systems, but only one company seemed to have completed the process and had a complete QA system properly in place and in operation for some time.

Lower levels of management, and pilots, recalled instances when higher management was perceived to speak hypocritically about situations where safety was to be sacrificed to commercial exigency, primarily due to the absence of effective or applicable regulations.

Communication and information flow

Systematic reporting of deviating events in flight, and in maintenance, is part of aviation culture. Such systems exist in all the companies taking part in the study. However, the reporting formats and degree of systematic analysis and follow up varies between companies. Communication with manufactures leaves much to be desired.

6.7 Concluding remarks

HARP Report

The HARP report (1984) provides a review of existing requirements for public transport helicopters, including recommendations for improved safety standards.

The main recommendations in the HARP report point at developments in:

- Human error reduction
- Technical reliability, i.e. helicopter usage, maintenance planning and condition monitoring
- Crashworthiness, i.e. structures, seats, landing gear, fuel systems and stability.
- Activities of aviation authorities

The HARP report accepted earlier evidence indicating that human factors were the major concern in helicopter safety, whereas the present study points out technical reliability as most important. It should be noted that the HARP report concerned airworthiness, and human factors were therefore not included in the scope. The HARP report included all public transport helicopters in the UK, whereas this study includes only offshore operations in the UK, Norway and the Netherlands.

7. VERIFICATION OF RESULTS THROUGH REVIEW OF AIB AIRCRAFT ACCIDENT REPORTS

7.1 Introduction

Background

The project group reviewed 22 UK AIB (Accidents Investigation Branch) Aircraft Accident Reports in order to verify the risk picture identified earlier in section 5 of the report. Results are shown in section 7.2. The value of AIB reports as a data source lies in their consistent standard of investigation and reporting.

Validity of AIB reports

Note that the calculations involving the AIB reports were based on only 22 historical accidents. In addition, the criteria for in what cases an AIB report is prepared are not quite clear. Finally, the AIB reports included information from one country only.

All these factors limit the validity of the results and conclusions derived from the AIB reports. Discrepancies from the results in section 5, which are based on a number of different data sources, should therefore not be surprising.

7.2 Results

The results from the review of AIB reports are presented in tables 7.1-7.2. A discussion of the results is provided in section 7.3.

Table 7.1 Summary of AIB accident data, and comparison to relevant data in table 5.1.

	Accident type:							
	HP	CSF	TOS	MACHD	UEL	PAO	PAI	
Historical distribution of accidents (AIB)	9%	18%	18%	-	5%	46%	-	5%
Historical distribution of accidents (ICAO 1968-88), table 5.1 [4]:	12%	34%	4%	-	27%	16%	4%	1%
Avg. no. of fatalities per accident (AIB):	-	17	2	-	1	1	-	-
Avg. no. of fatalities per accident (ICAO accidents 1968-88), table 5.1 [8]:	-	15	6	-	1	3	1	-

Accident distribution

The differences between AIB and ICAO accident distributions may partly be explained by the differences and limitations in the data used, in particular the low number of accidents, see section 7.1.

Also, there is some uncertainty as to the classification of the «Unsuccessful emergency landing»-accidents. Many of these typically involved a technical failure, followed by a successful landing, evacuation and rescue. Only two of the 10 UEL-accidents in the AIB material were fatal. The accidents were, however, classified as UEL in order to allocate them to the most relevant accident category.

Average number of fatalities per accident

The figures obtained for the historical number of fatalities per fatal accident are very similar in ICAO accidents (table 5.1 [8]) and in the AIB reports.

The rationale for the estimated number of fatalities per accident type in future accidents, which include changes compared to the historical data, are given in table 5.3.

Reduction in fatalities following improvement of risk factors

The project group classified the causal and contributing factors in the 22 AIB reports according to the classification scheme in section 6. The likelihood that a risk factor was a causal or contributing factor in each accident type was calculated using the same calculation procedure as in

section 5. Based on this information, the potential reduction in fatalities following improvements of risk factors was calculated. Results are shown in table 7.2.

The risk contribution of each accident type obtained in table 5.1 [11] was used as basis for the calculations, since the data in the AIB reports was considered too limited.

Reduction in fatalities based on AIB reports was significantly lower for «ATC, external navigation aids & services», and significantly higher for aviation authorities. All other differences must be considered minor when the small number of AIB accidents is taken into account.

Table 7.2 Reduction in fatalities following improvement of risk factors

Risk factor	Potential for improvement	Reduction in fatalities:	
		SINTEF	AIB
Technical reliability	25%	15.4%	18.0%
ATC, external navigation aids & services	50%	8.9%	0
Pilot performance	25%	5.1%	6.2%
Crashworthiness & design for emergencies	25%	4.6%	1.3%
Aviation authorities	50%	3.9%	12.9%
Pilot working conditions	25%	2.6%	0.5%
Heliports & helidecks	25%	2.5%	0.1%
Manufacturers	25%	2.4%	4.1%
Ergonomic design & pilot working environment	25%	2.1%	0
Oil companies	25%	1.9%	0.8%
Equipment & provisions	25%	1.4%	3.2%
Operating procedures	10%	0.9%	0.7%
Emergency preparedness	5%	0.5%	0.4%
Operating conditions	0	0	0

7.3 Discussion

Technical reliability

Minor differences in reduction in fatalities following improvement of «Technical reliability» were obtained using the original data (15.4%) and the data from the AIB reports (18.0%). In addition, «Technical reliability» had the highest potential for improvement in both cases.

ATC, external navigation aids & services

A significant difference in the results regarding «ATC, ...» was found between section 5 and the AIB reports. In section 5, «ATC, ...» had the second highest reduction-effect on fatalities (8.9%). This risk factor did not occur in the AIB material, and no potential for improvement was therefore found.

The explanation for this is that «ATC, ...» is particularly important in the accident type «Mid-air collision». There were, however, no accidents or incidents of this type in the AIB data.

Pilot performance

The difference in potential reduction in fatalities following improvement of «Pilot performance» in section 5 (5.1%) and using the AIB data (6.2%) was found to be minimal. In both calculations, «Pilot performance» was ranked with the third highest potential for reducing fatalities.

In section 5.9, the effect of the risk factors «Pilot working conditions», «Ergonomic design», «Operating procedures» and «Emergency preparedness» on «Pilot performance» was explained. Only minor differences in potential reduction in fatalities were obtained for these risk factors, i.e. «Pilot working conditions» (2.6%-0.5%), «Ergonomic design» (2.1%-0%), «Operating procedures» (0.9%-0.7%) and «Emergency preparedness» (0.5%-0.4%).

Crashworthiness & design for emergencies

A lower potential reduction in fatalities for «Crashworthiness» was found in the AIB material, compared to section 5. This may be explained by the nature of the AIB reports, and the subsequent classification of accidents, especially the accident type «Unsuccessful emergency landing». UEL accidents in the AIB material typically involved technical problems leading to a successful emergency landing, evacuation and rescue of personnel.

Aviation authorities

The effect of improving the risk factor «Aviation authorities» showed a marked difference in section 5 and in the AIB data. The plausible explanation for this is that in the AIB data, the contribution of «Aviation authorities» was significant in several accidents of type «Critical system failure». This accident type has a high risk contribution (47%), and the calculated importance of this risk factor is subsequently large.

Manufacturers

Reference is made to the discussion of «Aviation authorities» above. A similar effect regarding the risk contribution of «Critical system failure»-accidents is found for «Manufacturers», accounting for a more important effect on fatality reduction in the AIB material (4.1%) compared to section 5 (2.4%). Note that «Manufacturers» also may reflect problems related to «Technical reliability».

7.4 Conclusion

The review of AIB reports suggested the same risk picture in North Sea helicopter operations as in section 5, i.e. a dominating effect of «Technical reliability».

Regarding the effect of improvements of risk factors, certain discrepancies were found, but these can be explained by limitations in the AIB material. The results confirmed that the uncertainty with regard to the risk factor «ATC, external navigation aids & services» is high, as the rating of this factor depends strongly on the frequency estimate for mid-air collisions.

Key figures in section 5 were not altered as a result of the review. The figures were, however, subject to an expert panel review, see section 8.

8. VERIFICATION OF RESULTS THROUGH EXPERT PANEL REVIEW

8.1 Introduction

Background

An expert panel review was carried out in order to verify and adjust key figures in section 5 of the report. In particular, a discussion of the following estimates was sought:

- Present distribution of fatal accidents ([7] table 5.1)
- Average number of fatalities per accident ([9] table 5.1)
- Likelihood that a risk factor is a causal or contributing factor in accident types (table 5.4)
- Potential for improvement of risk factors (table 5.8)

Based on these estimates, a new calculation of the effect of improvement of risk factors could be carried out for comparison purposes.

Procedure

The expert panel review was carried out with 8 persons currently involved in North Sea helicopter operations. All participants were familiar with the SINTEF study, and the estimates in the SINTEF study were available prior to and during the meeting.

The participants were asked to complete the questions for discussion prior to the meeting. However, only 3 persons provided complete answers in advance.

During the expert panel meeting, which lasted 1 day, the participants were divided into two groups. Four separate sessions covering the above topics were carried out, and estimates were obtained.

Section 8.2 presents averages of the estimates obtained by the two groups. References to estimates by SINTEF are provided throughout the chapter.

8.2 Results

This section presents the results from the expert panel review. Regarding the procedure for calculation, reference is made to section 5.

Table 8.1 Present distribution of fatal accidents (%)

	Accident type:							
	HP	CSF	TOS	MACHD	UEL	PAO	PAI	
Average, expert panel:	5%	39%	14%	4%	21%	12%	7%	1%
SINTEF estimates ([7] table 5.1):	9%	33%	13%	5%	20%	9%	9%	2%

Table 8.2 Average number of fatalities per accident

	Accident type:							
	HP	CSF	TOS	MACHD	UEL	PAO	PAI	
Average, expert panel:	2	13	13	18	6	8	1	3
SINTEF estimates ([9] table 5.1):	2	13	13	18	5	10	1	7

The results in table 8.1-8.2 indicate minor differences between the expert panel estimates and SINTEF's estimates used in the calculations.

Based on these results, an estimate for risk contribution of the accident types can be estimated in table 8.3 (see also section 5.5).

Table 8.3 Percent of fatalities caused by each accident type («risk contribution»)

	Accident type:							
	HP	CSF	TOS	MACHD	UEL	PAO	PAI	
Expert panel:	1%	51%	18%	7%	13%	10%	1%	0.3%
SINTEF estimates ([11] table 5.1):	2%	47%	18%	10%	11%	10%	1%	2%

Table 8.4 Likelihood that a risk factor is a causal or contributing factor in accident types

SINTEF estimates (S) and average of expert estimates (E) indicated.

High: 0.8 (+++), Medium: 0.4 (++), Low: 0.2 (+)

Accident type:								
	HP	CSF	TOS	MACHD	UEL	PAO	PAI	
Operating conditions	+	+	+++	+++	++	+++	++	(E)
	+	+	+++	+++	++	+++	++	(S)
Heliports & helidecks	+				+++	+	+++	(E*)
	+				+++		+++	(S)
Pilot performance	++		+++	++	++	++	+	(E)
	+		++	++	++	++	+	(S)
Operating procedures	+		++	++	+	+	++	(E)
			++	+				(S)
Pilot working conditions	+		+	+	+			(E)
	+		+	+	++			(S)
Emergency preparedness	++				++	++	++	(E)
	++				++	++	++	(S)
Technical reliability	++	+++	+		+	+++	++	(E)
	++	+++	++	+	++	+++	+++	(S)
Equipment & provisions			++	+			+	(E)
			+	+				(S)
Crashworthiness & design for emergencies	++				+++	+++	++	(E**)
	++				+++	+++	++	(S)

...continued on next page

*: Average of estimates for Heliports/Helidecks

** : Estimate available from one group only

Table 8.4 Likelihood that a risk factor is a causal or contributing factor in accident types, cont.

Accident type:							
	HP	CSF	TOS	MACHD	UEL	PAO	PAI
...continued from previous page							
Ergonomic design & physical work environment	+	+		+	+		(E)
	+	+		+	+		(S)
Oil companies				+	++	++	(E)
					+	++	(S)
Aviation authorities	+		+	++	++	+	(E)
			+	+	+		(S)
ATC, external navigation aids & services	+		+	+++	+		(E)
	+		++	+++	+		(S)
Manufacturers		+++					(E)
		+					(S)

¹ The likelihood estimates from the expert panel were in some cases provided in terms of decimal numbers. The average of the estimates (Avg.) were converted into high/medium/low/zero ratings according to the following rules:

0.56 < Avg. < 1.0: Likelihood = 0.8, High (+++)
 0.28 < Avg. < 0.56: Likelihood = 0.4, Medium (++)
 0.14 < Avg. < 0.28: Likelihood = 0.2, Low (+)
 Avg. < 0.14: Likelihood = 0

Table 8.5 Potential for improvement of risk factors

Risk factor	Average, expert panel	SINTEF estimates
		(table 5.8)
Operating conditions	0%	0%
Heliports & helidecks	25%*	25%
Pilot performance	20%	25%
Operating procedures	18%	10%
Pilot working conditions	10%**	25%
Emergency preparedness	10%	5%
Technical reliability	30%	25%
Equipment & provisions	38%	25%
Crashworthiness & design for emergencies	20%	25%
Ergonomic design & physical work environment	25%	25%
Oil companies	20%	25%
Aviation authorities	40%	50%
ATC, external navigation aids & services	38%	50%
Manufacturers	30%	25%

*: Average of estimates for Heliports/Helidecks

** : Estimate available from one group only

8.3 Reduction in fatalities

Table 8.6 Total influence score, reduction in fatalities following improvement and rank of risk factors

Risk factor	Total influence score:		Reduction in fatalities:		Risk factor rank:	
	Exp.	SINTEF	Exp.	SINTEF	Exp.	SINTEF
Operating conditions	44.0	45.0	0%	0%	14	14
Heliports & helidecks	13.4	10.0	3.4%	2.5%	7	7
Pilot performance	27.0	20.2	5.4%	5.1%	4	3
Operating procedures	15.2	9.2	2.7%	0.9%	9	12
Pilot working conditions	7.8	10.4	0.8%	2.6%	13	6
Emergency preparedness	9.6	10.0	1.0%	0.5%	12	13
Technical reliability	55.5	61.1	16.7%	15.4%	1	1
Equipment & provisions	8.7	5.6	3.3%	1.4%	8	11
Crashworthiness & design for emergencies	18.9	18.4	3.8%	4.6%	6	4
Ergonomic design & physical work environment	8.4	8.2	2.1%	2.1%	11	9
Oil companies	11.0	7.4	2.2%	1.9%	10	10
Aviation authorities	13.8	7.8	5.5%	3.9%	3	5
ATC, external navigation aids & services	12.0	17.8	4.6%	8.9%	5	2
Manufacturers	40.8	9.4	12.2%	2.4%	2	8

8.4 Conclusions

Figure 8.1 gives a graphic presentation of the estimated reduction in fatalities, illustrating the differences in estimates for the six main risk factors by the expert panel and by SINTEF.

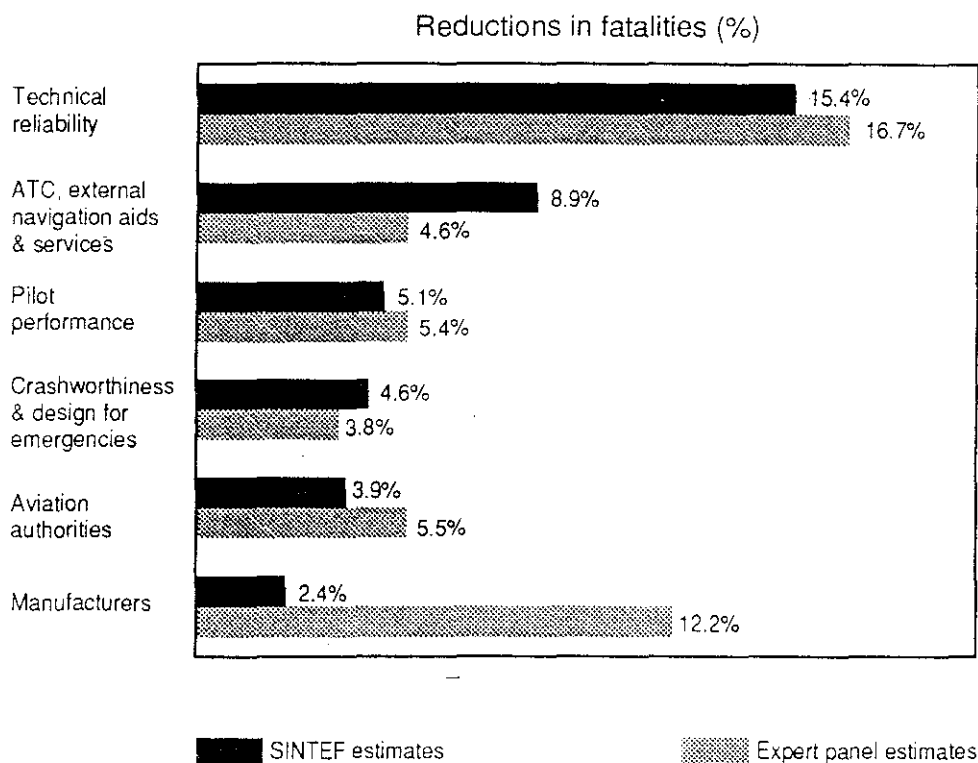


Figure 8.1 Reduction in fatalities due to realistic improvements of risk factors (SINTEF and expert panel estimates)

Correlation of rankings by SINTEF and experts

A calculation of the agreement between the rankings found by SINTEF and the expert group shows a correlation of $r = 0.72$ (Spearman rank correlation coefficient), which is a very high agreement.

Total reduction in fatalities

The expert panel estimated a higher total reduction of fatalities following improvements of risk factors (approximately 40% compared to 30-40%). This difference may to a large extent be attributed to the difference in estimates for the risk factor «Manufacturers», see below.

Technical reliability

The risk factor «Technical reliability» had a slightly higher estimate by the expert panel (16.7% compared to 15.5%).

The expert panel placed less emphasis on the importance of technical failures on take-off and landing offshore, and fires in the aircraft.

The expert panel gave «Technical reliability» a higher potential for improvement (30% compared to 25%).

In spite of this, the differences in estimates are regarded to be marginal.

In both cases, «Technical reliability» was the risk factor with the highest potential for improvement (1st).

ATC, external navigation aids & services

The risk factor «ATC, ...» had a lower estimate by the expert panel (4.6% compared to 8.9%).

The expert panel placed less emphasis on the effect of this risk factor in the accident type «Sudden crash into terrain, obstructions or sea during flight».

The expert panel gave «ATC, ...» a lower potential for improvement (38% compared to 50%).

«ATC, ...» was ranked 5th by the expert panel and 2nd by SINTEF.

Pilot performance

The differences in estimates for «Pilot performance» in the two cases were negligible, and both estimates equaled approximately 5%.

The expert panel placed more emphasis on the importance of problems such as navigation error, inattention, disorientation and vertigo, especially related to take-off and landing on heliports. Quality of, and adherence to procedures was mentioned as particularly important.

The expert panel gave «Pilot performance» a lower potential for improvement (20% compared to 25%).

«Pilot performance» was ranked 4th by the expert panel and 3rd by SINTEF.

Crashworthiness & design for emergencies

The differences in estimates for «Crashworthiness» in the two cases were minor (3.8% compared to 4.6%).

There were no differences in the emphasis on causal/contributing factors.

The expert panel gave «Crashworthiness» a lower potential for improvement (20% compared to 25%).

«Crashworthiness» was ranked 6th by the expert panel and 4th by SINTEF.

Aviation authorities

The risk factor «Aviation authorities» had a higher estimate by the expert panel (5.5% compared to 3.9%).

The expert panel placed more emphasis on aviation authorities' requirements and surveillance regarding helidecks and offshore traffic in general.

The expert panel gave «Aviation authorities» a lower potential for improvement (40% compared to 50%).

«Aviation authorities» was ranked 3rd by the expert panel and 5th by SINTEF.

Manufacturers

The risk factor «Manufacturers» had a higher estimate by the expert panel (12.2% compared to 2.4%).

The expert panel placed more emphasis on testing of components and systems under realistic conditions, certification and information/feedback from the manufacturer.

The expert panel gave «Manufacturers» a higher potential for improvement (30% compared to 25%).

«Manufacturers» was ranked 2nd by the expert panel and 8th by SINTEF.

Concluding remarks

The differences between SINTEF and the expert panel in estimates for distribution of accidents (table 8.1) and average number of accidents per accident type (table 8.2) have a minor effect on the end results.

The differences in the calculations are mainly attributed to varying estimates for:

- The likelihood that a risk factor is a causal or contributing risk factor in the accident types, and
- The potential for improvement of risk factors.

Although there occasionally are significant differences in the estimates, the most important risk factors and main conclusions are consistent. An exception from this is «Manufacturers», which was ranked much higher by the expert panel compared to SINTEF. However, this risk factor ultimately affects technical reliability, through testing of components and systems under relevant conditions, certification and information/feedback from the manufacturer. Because of this, the results from the expert panel suggest an even greater emphasis on technical factors compared to SINTEF's results.

The results of both estimates have been considered in the development of proposals for further research.

9. PROPOSALS FOR FURTHER RESEARCH & DEVELOPMENT

This section presents 11 research and development projects outlined by the project group, on the basis of the Helicopter Safety Study. The sequence of presentation indicates a rough prioritization of the proposals. The priorities will, however, depend on the relative weights assigned to such criteria as expected effect, cost-efficiency, feasibility, time to complete and implement the results, etc.

9.1 Effective use of operational experience for helicopters

Problem

The Helicopter Safety Study concluded that the most important risk factors are associated with technical failures and malfunctions. The study also revealed that failure events and failure indications are not reported and followed up in an optimal way. Today, failure symptoms are corrected as soon as possible, more or less with the same priority, without taking into account the criticality of the symptoms/events.

Proposal

The main objective of the study is to develop a decision tool for maintenance based on safety ranking and operating data, in order to predict safe and economic lifetimes, and trace any reliability patterns.

Justification

The decision tool will contribute to optimal safety, regularity and maintenance cost.

Implementation

Two aspects should be specifically focused upon:

- A method for criticality ranking of failure modes and failure symptoms.
- A method for data recording, analysis and presentation to identify trends and failure patterns, as a basis for maintenance decisions and eventually improved design requirements.

9.2 Guidelines and tools for safety management

Problem

The Helicopter Safety Study indicated that the overall approach to safety management is based on tradition, rather than a systematic approach. The benefit from implementation of safety programs, systematic use of risk analysis e.g. in connection with technical or operational changes, does not seem to be fully understood. Most of the operators are now in the process of incorporating safety management as a part of their quality assurance system.

Proposal

The objective of the study is to analyze and describe management functions critical to safety in offshore helicopter transportation, in order to provide guidelines and tools for safety management.

Justification

The results will provide means of more efficient and comprehensive safety management to the operators and oil companies.

Implementation

The study will provide:

- Helicopter companies and oil companies with guidelines to safety management, and
- Parameters, criteria and checklists for performing safety audits.

9.3 North Sea helicopter operator safety data exchange

Problem

The free passage of safety related information between helicopter operators and their personnel was identified as being highly desirable during the Helicopter Safety Study.

Proposal

An examination of existing channels of communication suggests they are not adequate for optimum safety data exchange. A computerized system for the purpose should be established (Safety Data Exchange).

Justification

There is a need for a safety database, which overcomes the disadvantages of existing systems.

An academic organization that meets the criteria of being commercially independent and having aeronautical and human factors expertise, should supervise and maintain the Safety Data Exchange database.

Implementation

Implementation would be achieved by using microcomputers and the operation of a «Bulletin Board System» (BBS). This is the computer equivalent of a notice-board, which can be written to, and read by, helicopter operators and their staff, using microcomputers and the public telephone system.

In addition, contributors would be encouraged to send reports by telephone, facsimile, and by post. Quarterly reviews and an annual report would be published. Contributors would be encouraged to conduct their own analyses on the information held on the database.

Control of access to the BBS, anonymity, administration and costs should be considered.

9.4 Factors influencing maintenance performance

Problem

The Helicopter Safety Study revealed that maintenance performance is an important contributing factor and may be affected by such factors as economic pressures and difficulties in recruiting qualified personnel.

Proposal

The objective of the study is to identify factors which have a major impact on maintenance performance, and suggest improvements.

Justification

A study in the area outlined would cover human performance and certain aspects of design and maintenance planning. It can thus be estimated that maintenance performance as delimited is a causal or contributing factor in approximately 25% of all critical technical failures, and approximately 15% of all fatalities in North Sea Helicopter transportation.

A possible spin-off from the study could be the transfer of successful practices to areas outside helicopter transportation.

Implementation

The following activities are proposed:

- A detailed survey of errors and critical incidents in helicopter maintenance, focussing on factors influencing performance.
- An analysis of the maintenance cycle
- A specific study of helicopter maintenance performed offshore
- A study of factors influencing recruitment of maintenance personnel

9.5 Long term health effects for offshore helicopter pilots

Problem

The specific working conditions of offshore helicopter flying can be assumed to have very specific health effects on the pilots. Although various health effects have been documented through existing research, there is lack of substantial evidence on whether some of these effects are temporary or more permanent.

Proposal

The objective of the study is to establish which are the long term negative health effects caused by the specific working conditions of offshore helicopter pilots and possible ways in which they can be prevented.

Justification

The Helicopter Safety Study concluded that the long term effects of noise and low frequency vibrations should be investigated. These effects have probably an impact both on the general health condition of the pilots and the pilot in-flight performance.

Implementation

The study should include:

- A literature survey of the various specific effects on work performance, permanent injuries, physiological processes, and comfort produced by noise and/or vibrations.
- A questionnaire survey among helicopter and fixed wing pilots regarding piloting history, medical history, etc.
- A complete medical examination of pilots (physiological and psychological tests).
- A survey of the incidence of and causes for early death and loss of license due to health reasons among pilots.

9.6 Safety management circles**Problem**

Many aspects of the safe operation of helicopters in the North Sea are dependent upon the correct procedures being implemented by the staff of the oil companies.

Proposal

The aim of the study (Safety Management Circles programme) is to increase the awareness of the individuals in their role in helicopter safety. The Safety Management Circles programme is a logical extension of the concept of Total Quality Management. The safety emphasis changes from one of being provided by the company, to one of collective responsibility. This approach to safety management will also have applications outside the area of helicopter transportation.

Justification

The programme will enhance the awareness of potential risks in relation to the helicopter operation and allow individuals to assume a more active role in safety management.

Implementation

Implementation will be through the analysis of the helicopter company and oil company infrastructures and mutual interface. Functionally related, safety-dependent components will be identified in which the feasibility of

the establishment of safety circles will be assessed. Emphasis is placed on encouraging self-implemented safety management procedures and encouraging the free exchange of safety information.

9.7 Recruiting and retention of maintenance engineers for North Sea helicopter operations

Problem

Operators of helicopters in the British sector of the North Sea are beginning to experience a chronic shortage of skilled helicopter engineers. They are also having difficulty in retaining this personnel.

Proposal

The research will identify factors associated with encouraging appropriate people to train as engineers and establish the significant reasons for skilled engineers leaving the helicopter operators employment.

Justification

The safe and efficient operation of helicopters in the North Sea is dependent upon the highest standards of engineering and maintenance.

Implementation

The research will be implemented using well established measures of job satisfaction amongst current employees. It will also survey the future career decisions of potential sources of aircraft engineers. This will include those already trained (e.g. from the traditional sources of recruitment) and those with the potential to be trained.

From these factors short term and longer term remedial actions will be suggested.

9.8 Problems and solutions associated with Air Traffic Control in the North Sea

Problem

Air Traffic Control (ATC) is one of the largest risk factors in helicopter transportation in the North Sea.

Proposal

Due to the international nature of air traffic, the feasibility of improving ATC should be considered in the vicinity of North Sea oil installations. In addition, en route navigation, surveillance and communication should be addressed.

Justification

Improving ATC will directly enhance the safety of helicopter operations and the pilots feeling of security en route and around offshore installations.

Implementation

A two level approach to the problem is suggested. Short term solutions should focus on potential training and procedural changes in the vicinity of installations. Emphasis should be on the minimum acquisition of new ATC equipment. Longer term improvements should examine projected new ATC surveillance, communication and navigation equipment, both on the ground and in the cockpit.

9.9 Design specification of a helicopter optimised for North Sea petroleum support operations

Problem

None of the aircraft operating in the North Sea have originally been designed for the task they perform. As a consequence, the reliability of these aircraft is not as high as it could be, due to high levels of maintenance required, poor design for maintenance and an inability to fly in the often hostile conditions in the North Sea. The diverse fleets operated by the helicopter companies also make great demands on spares holdings and type ratings, etc.

Proposal

Development of a design specification for a helicopter optimized for the North Sea oil industry will permit current fleet composition and contractor requirements to be evaluated.

Justification

Identification of specific shortcomings of each helicopter type will permit recommendations to be made for future aircraft procurement.

Implementation

Research into types of helicopters, operational employment and customer requirements would proceed a «conceptual» design study for an optimum vehicle. Current helicopter types would be compared with the conceptual design. The costs and benefits of upgrading and/or modifying current types would be derived.

9.10 The North Sea helicopter pilots cockpit environment

Problem

A helicopter cockpit is noisy, cramped and hot. Pilots complain about cockpit ergonomics, including layout, seating, stowage and environmental conditions. Implicit in the complaints is the suggestion that a poor cockpit environment leads to a deterioration in pilot performance, and hence reduced safety.

Proposal

There is a need to develop a «general cockpit model», i.e. a representation of factors affecting the pilot. The model would be a tool to assess and evaluate the pilot's working environment.

Justification

The model would be of value to helicopter designers and operators. It would allow regulatory authorities a means of assessing flight regimes under different conditions. It would allow helicopter customers (i.e. the oil companies) an additional criterion when auditing helicopter companies.

Implementation

Field data from helicopter pilots using questionnaires, rating performance, activity diaries, and observation should be collected.

In addition, methods for environmental data capture should be devised, based on a literature review of the effects of environmental variables. Representative cockpits should be simulated. Subjects representing pilots «flying» the simulation, should be study to determine possible performance decrement associated with carrying out flight-related tasks in typical and future cockpit environments. Conditions of increasing environmental stress should be covered.

9.11 The in-flight determination of pilot performance**Problem**

Pilot performance is expected to be a contributing or causal factor in approximately 20% of North Sea helicopter accidents (Helicopter Safety Study).

There are no warning devices which can provide a «caution» to the aircrew that they are not functioning properly.

Proposal

A multi-phase project should be initiated to develop a system to alert pilots that they are not functioning properly. It is envisaged that such a system would employ computer based «artificial intelligence» techniques to monitor aircraft system parameters.

Justification

There is, demonstrably, a need for such a «cautionary» system. It is to address this need that the research project is proposed. The ultimate goal of the project would be the development of an alerting system, analogous to the «health and usage» systems being developed to monitor aircraft system functioning.

Implementation

The initial stage of the project should review artificial intelligence techniques, pilot behaviour and modification, and helicopter performance monitoring systems.

The initial stage should identify the problems of developing and integrating the techniques in question, and recommend options concerning future research. Based on this, a detailed proposal to conduct additional stages could be made.

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JAR: Joint Airworthiness Requirements.

Acceptable Means of Compliance.

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ABBREVIATIONS

AIB	Accidents Investigation Branch
ATC	Air Traffic Control
BBS	Bulletin Board System
CAA	Civil Aviation Authority
DECCA	(Radio navigation system)
FAR	Fatal Accident Rate
FIS	Flight Information Service
HAR	Helicopter Alternate Routes
HARP	Helicopter Aiworthiness Review Panel
HFIS	Helicopter Flight Information Service
HMR	Helicopter Main Routes
HPZ	Helicopter Protection Zone
HTZ	Helicopter Traffic Zone
HUMS	Health and Usage Monitoring System
ICAO	International Civil Aviation Authority
ILS	Instrument Landing System
LORAN-C	Long Range Navigation - C (Radio navigation system)
MORT	Management Oversight and Risk Tree
NAVSTAR/GPS	(Sattelite navigation system)
NDB	Non-Directional Beacon
OMEGA	(Radio navigation system)
QA	Quality Assurance
QC	Quality Control
RCM	Reliability Centered Manitenance
S61	Sikrosky 61
SAR	Search and Rescue
SDAU	Safety and Data Analysis Unit (of the UK CAA)
VOR	Very High Frequency Omni Directional Range Radio Navigation System

Abbreviations of data sources

AR	Accident Reports
FR	Flight Reports
IR	Incident Reports
AIB	Accidents Investigation Branch (AIB) accident investigation reports
MQ	Maintenance Questionnaire
PI	Pilot Interviews
PQ	Pilot Questionnaire
TR	Technical Reports

Abbreviations of accident types

CSF	Crash following critical aircraft system failure during flight
HD	Crash on take-off or landing on helideck
HP	Crash on take-off or landing on heliport
MAC	Mid-air collision with other aircraft
PAI	Personnel accident inside aircraft
PAO	Personnel accident outside aircraft
TOS	Sudden crash into terrain, obstructions or sea during flight
UEL	Crash on unsuccessful emergency landing