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Report

Helicopter Safety Study 4

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Report

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ABSTRACT

The overall objective of the *Helicopter Safety Study 4* (HSS-4) is to contribute to improved safety in helicopter transport of personnel on the Norwegian Continental Shelf.

The report describes main developments in helicopter safety focusing on the period 2010–2020, but also looks ahead into the coming years. Relevant statistics on accidents/ incidents and transport activity are presented, and an analysis is made of recent accidents. The report looks somewhat in depth into selected topics like maintenance of helicopters, Crew Resource Management (CRM) and resilience in practice. A particular focus is put on investigating similarities and differences between helicopter operations in the British and Norwegian sectors.

The report concludes with a series of recommended measures to increase safety, as well as important prerequisites to maintain the current level of safety.

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Photo courtesy of Bristow Group.

Preface

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

The HSS-4 study is the fourth in a series of comprehensive studies of offshore helicopter safety and builds in particular on the previous HSS-3 study (2010) and the intermediate HSS-3b study (2017).

We thank all contributors for their openness and valuable input. We particularly acknowledge Ivonne Herrera and Irene Wærø for their contributions to the report.

The report is issued both in the Norwegian and English language.

Digital resources for the HSS reports can be found at: www.sintef.no/helikoptersikkerhet.

Trondheim, January 2023

Tony Kråkenes

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Executive Summary

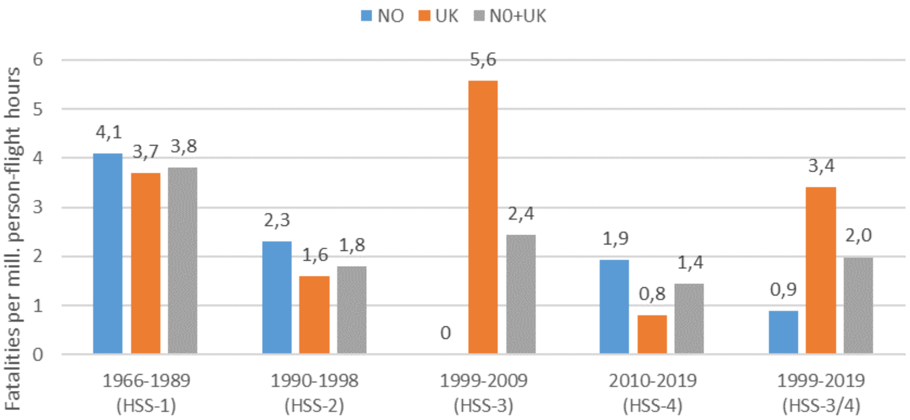
The safety standard of helicopter operations on the Norwegian Continental Shelf (NCS) is widely considered among the best in the world. Still, there is no guarantee against accidents and human loss, most recently demonstrated by the helicopter crash at Turøy in 2016 where 13 lives perished. Hence, safety work must never be relinquished. The overall objective of the Helicopter Safety Study 4 (HSS-4) is to contribute to improved safety in helicopter transport of personnel on the NCS.

The report describes main developments in helicopter safety focusing on the period 2010–2020, but also future development trends are included. Statistics on accidents/incidents and transport activity are presented, along with an analysis of recent accidents. The report looks in depth into selected topics like maintenance of helicopters, Crew Resource Management (CRM) and resilience in practice. Furthermore, important differences between helicopter operations in the British and Norwegian sectors are discussed.

Most importantly, the report presents and discusses a set of concrete *safety measures* for helicopter operations on the NCS. Recommended safety measures are highlighted, as well as particular focus areas and areas for future work within the study mandate.

The main study conclusions and recommended safety measures are summarized below.

1. <u>Accident statistics</u>
    - For the period 2010–2019 there have been two helicopter accidents on the NCS of which one was fatal with 13 fatalities (Turøy 2016). This gives a rate of **1,9** fatalities per million-person flight hours.
    - For the extended period 1999–2019 there have been three accidents (one fatal, 13 fatalities). This gives a rate of **0,9** fatalities per million-person flight hours.
    - The fatality rate on the NCS over the last decade (2010–2019) is higher than the UKCS. However, over the last *two* decades (1999–2019) the NCS fatality rate is far lower that of the UK.
    - For the British sector in the period 1999–2019 there have been 15 accidents of which 4 were fatal with a total of 38 fatalities. This gives a rate of **3,4** fatalities per million-person flight hours.
    - The British sector has seen a remarkable decrease in the number of accidents and fatalities over the last decade (2010–2019) compared to the previous decade (1999–2009).
    - Offshore helicopter traffic numbers on the NCS peaked in 2014 and then dropped significantly in the years after. From 2017, traffic volume is slowly increasing again.



Fatality rates for the Norwegian and British sectors and combined.

2. Main development trends
   - Diminishing petroleum resources and a strengthened focus on green energies make the future of the traditional petroleum industry uncertain. A downturn in the business may result in increased pressure on safety through downsizing and an overly strong focus on economy, both within the oil companies and the helicopter operators. Even though there is not a one-to-one relation between economics and the level of safety, the fear is that safety margins may erode over time due to decreased redundancy, loss of competence, longer maintenance intervals, etc.
   - Along with the expected decline in petroleum production, offshore wind is growing in volume. This may give rise to new helicopter activity, but also introduce potential new threats to flight safety. In the longer term, the decommissioning of offshore installations may also become a driver for activity.
   - The Turøy accident in 2016 created a new situation where a large part of the operating fleet (H225) was no longer available for passenger transport or SAR. The NCS today relies almost exclusively on the S-92A, which has a solid operational history, but the technology is ageing. Newer and smaller helicopter types seem to be slowly introduced, which will contribute to the robustness of the transport solution on the NCS.
   - Increased petroleum activity in the Barents Sea is introducing new and potentially bigger challenges for offshore transport by helicopter due to long flying distances and a harsh environment.

3. Potential threats to helicopter safety

The most important potential threats to helicopter safety in the coming years are to a large extent the same as those identified in the HSS-3 (and HSS-3b) study:

- Lack of the possibility to maintain established Norwegian additional requirements for offshore flights, or that it will not be possible to introduce new requirements adapted to the conditions on the NCS.
- Exemption from offshore special requirements and deviation from recommended guidelines.
- Lack of competence and resources regarding offshore helicopters in the Civil Aviation Authority – Norway (CAA-N).
- An overly strong focus on economy by the different actors on the NCS.

4. Maintenance of helicopters

The study activity on maintenance of helicopters highlighted the following important focus areas:

- Facilitate and ensure a **just culture approach** rooted throughout the entire maintenance organization. Experiences from fixed-wing have shown that this can be challenging due to liberalization and increased market competition.
- The importance of **clear responsibility and reporting routines** within maintenance organizations and helicopter companies should not be underestimated. New ways of organizing, e.g. subcontracting and organizational fragmentation renders this particularly relevant.
- **Adequate access to resources**, operational as well as managerial, including technical expertise and competence. Changed (and increasingly tougher) competitive conditions and requirements for efficiency per se in the industry mean that local technical competence should not be underestimated. In this context, independent inspections are also relevant to discuss.
- **Tripartite cooperation** is an important contributor to safety through safeguarding dialogue and exchange of opinions, as well as facilitating trust among the various industry stakeholders.

5. Crew Resource Management

The study activity on Crew Resource Management (CRM) highlighted the following important focus areas:

- **Communicative practices:** Even more focus on how CRM through training of communicative practices facilitates the handling of complex situations, particularly where checklists/SOPs are inadequate.

- **Handling incapacitation:** Specific focus on developing CRM training methods and tools to further ensure that pilots develop strategies to recognize situations involving own as well as each other's varying degrees of incapacitation.
- **Train critical task trajectories:** Train explicitly on the task trajectory and coordination involved when executing critical flight tasks during time-critical events.
- **Sufficiency of current CRM regulations:** Assess whether the current CRM regulations are sufficient to meet the need for flexible and thorough CRM training, as well as the need to ensure baseline CRM skills and identification of standard best practices.

6. Comparing helicopter operations in the British and Norwegian sectors

The study activity comparing helicopter operations in the UK and NO sector highlighted the following:

- On a macroscopic level, four "cultural themes" have been identified as fundamentally different between the sectors: a) government involvement; b) market; c) legislation; d) "greening". These themes represent lasting structures that are difficult to change.
- The cultural themes set the basis for understanding specific differences between the two sectors. A range of such differences have been identified and discussed in the report.
- Some persistent hearsays and claims about differences in cockpit behavior have been scrutinized and found groundless. Pilots in both sectors today largely share the same experiences and attitudes.
- It is recommended to establish new meeting arenas for helicopter safety personnel in the NO and UK, with the purpose of information exchange, mutual understanding and relation building.
- The report presents a range of lower-level recommendations for improving safety in helicopter operations, mainly focused on the UK sector.

7. Recommended safety measures

The HSS-4 study confirms that many of the recommendations from HSS-3/3b are still relevant today. This shows that effort and focus over time is needed to be able to implement improvements.

Several of the recommendations in the HSS-4 study builds on important prerequisites about the continuation of the current regime and practice. For instance, it is presumed that implemented and planned measures from HSS-3/3b (and earlier) are not halted or reversed. Some of the HSS-3/3b recommendations have been implemented in the ON-066 guideline, but full implementation will need to take some time. As such, the most important **prerequisites** are identified to be:

a) Continue compliance with ON-066 as a recognized norm
b) Maintain exemptions from the EU standardized regulation, e.g. ensure requirement for Norwegian AOC with all its elements intact
c) Maintain existing competence on offshore operations within the air traffic service
d) Develop an infrastructure for air traffic service and emergency response in the Barents Sea
e) Revitalize The Committee for Helicopter Safety on the NCS to become more than a forum for information exchange

A total of 39 *suggested* safety measures are described in this report. The shorter list of 18 *recommended* safety measures below is based on a combination of a) potential risk reduction; b) relatively low cost; c) short implementation time; d) an identified need in the industry. The list is not in prioritised order.

T1: Update passenger transport helicopters to new models
T2: Upgrade the older SAR- and shuttle helicopters
T3: Ensure availability of information in the electronic flight bag (EFB)
T4: Ensure continuous and updated information en route
T7: Ensure the infrastructure of a navigation system redundant to GPS

T9: Ensure maintenance and modifications are performed under Norwegian regulatory oversight
T10: Improve availability of spare parts
T11: Standardise requirements for "independent inspection"
T13: Improved training for technical personnel
T15: Maintain the pilots' basic competence
T16: Adjust content of simulator training
T20: Introduce requirement for communication for pilots on helidecks
T22: Implement completely ON-066
T23: Align on turnaround time and penalties
T27: Strengthen the capacity and required competencies in the CAA-N
T33: Develop relevant indicators and analyses for offshore helicopter transport
T35: Improve reporting system for feedback from pilots to helideck/heliport
T39: Mapping of perceived risk

The recommended safety measures should be addressed in a structured way by the relevant stakeholders in the industry. The follow-up of measures should be documented and coordinated by e.g. the Committee for Helicopter Safety on the NCS. Each measure should have an assigned responsible for its implementation; this could be an organisation, a task group or an individual. It is particularly important that the measures are *completely* implemented before being "closed". This means that specific closing criteria must be defined for each measure.

8. Recommendations for continued work

The study has identified the following main areas for further work:

- The current practice of conducting regular safety studies of the helicopter activity on the NCS should be maintained. Such safety studies have proven to be effective means to establish a common understanding and cooperation on the implementation of safety measures.
- A review should be conducted of safety recommendations made in previous safety studies (HSS and UK), as well as accident investigation reports. The review should give the status of implementation, assessment of continued relevance, and investigation into the mechanisms that stops or slows down the implementation.
- Helicopter safety in the far north has not received much attention and should be studied especially. Increasing petroleum activities in the Barents Sea represents new challenges related to helicopter transport under other conditions than further south on the NCS.
- It should be examined to what extent recent accidents and incidents – especially the Turøy accident – affect the perception of risk in helicopter transport. The RNNP project features a simple indicator on perceived helicopter risk that is updated biannually, but this is not sufficient. HSS-3 discussed perceived risk in depth as per 2010 but having an updated picture of the situation today would be valuable.
- The possible consequences of subcontracting CAMO to a third party (outside the AOC) should be investigated in a separate study.

As part of the study, a memo has been produced (appendix E) suggesting a specification for a web solution for following up the status of safety measures. This solution will be for everybody but should be administered by the CAA-N or the Committee for Helicopter Safety on the NCS. In addition to tracking the measures, it will be possible to also include indicators and status for other safety work (cf. measure T33). The aggregated status of implementation may in itself also constitute an indicator.

– PART I –

1 Introduction

1.1 Background

Offshore Norge (ON) has tasked SINTEF to carry out Helicopter Safety Study 4 (HSS-4). SINTEF has previously carried out four comprehensive studies on the safety of helicopter transport on the Norwegian Continental Shelf (NCS):

- The Helicopter Safety Study (**HSS-1**) for the period 1966–1990 was released in 1990. A/S Norske Shell and Statoil took the initiative and commissioned the study. One of the main conclusions was that the biggest potential for improvement of safety in the next 10–15 years, was of a technical nature, for example through implementation of the technical surveillance system HUMS (Health and Usage Monitoring System).
- The Helicopter Safety Study 2 (**HSS-2**) for the period 1990–1998 was released in 1999. Shell and Statoil were still initiators, but this time BP Amoco, Elf Petroleum Norge AS, Norsk Hydro ASA, Phillips Petroleum Company Norway, Saga Petroleum ASA, and the Civil Aviation Administration also contributed to finance the study. The study concluded, among other things, that despite a considerable risk reduction measured in the number of fatalities, there was still much room for improvement.
- The Helicopter Safety Study 3 (**HSS-3**) for the period 1999–2009 was released in 2010. Nine oil companies and the CAA-N had the financial backing. A main issue in HSS-3 was to verify whether the calculated risk reduction made in HSS-2 had been achieved, and in addition to estimate the risk for the coming ten-year period (2010–2019). Further, HSS-3 should map trends and give recommendations to improve or sustain the safety of helicopter operations on the NCS.
- The Helicopter Safety Study 3b (**HSS-3b**) was a limited update of HSS-3 focusing on the period 2010–2016. The study was released in February/May 2017 (Norwegian/English version). The study was funded by 16 oil companies, as well as Industri Energi (trade union) and the CAA-N. The study discussed possible consequences of recent UK accidents and the CAP 1145 safety report, as well as new EASA regulations on offshore helicopter operations. Like HSS-3, HSS-3b also mapped trends and gave recommendations to improve helicopter safety.

The HSS-3 and HSS-3b reports are available in both the English and Norwegian language.

Following the HSS-2 study the oil companies and the authorities started a series of initiatives. The most significant contribution from the authorities was the completion of two Official Norwegian Reports (NOU) (in Norwegian; unofficial translation of titles):

- NOU 2001: 21: *Helicopter safety on the Norwegian Continental Shelf. Part 1: The structure and organization of the official public engagement*
- NOU 2002: 17: *Helicopter safety on the Norwegian Continental Shelf. Part 2: Developments, goals, risk influencing factors and prioritised recommendations*

The two NOU reports listed a series of recommendations. One of the main recommendations was to create a collaborative forum for helicopter safety, and The Committee for Helicopter Safety on the NCS was established in 2003. The committee was tasked to be a driving force towards the authorities and different stakeholders, in such a way that the given recommendations could be implemented. The committee has been an active player in the offshore helicopter community since its foundation.

1.2 The organization of the study

The petroleum industry through Offshore Norge has issued the task for the HSS-4 project. The financing of this project is a multi-client effort consisting of an owners' group (OG) of 13 oil companies, two trade unions, a service provider, two authority bodies and two helicopter operators. The study has been governed by a steering committee (SC) constituted by most members of the owner's group, as well as two additional trade unions. Table 1.1 presents the composition of the OG and the SC.

Table 1.1: Representatives in the Owners' Group (OG) and Steering Committee (SC) for HSS-4.

	Company / organization	**Representative**	**Comment**
Oil companies	Aker BP ASA	John Arild Gundersen	SC deputy chair
	ConocoPhillips Norway AS	Øystein Petterson	
	DNO ASA	Arild E. Lund	
	Equinor ASA	Øivind Solberg	SC chair
	Lundin Energy Norway AS	Bjørn Hoff	
	Neptune Energy Norge AS	Vibeke Mowatt	
	OKEA ASA	Arnt Olsen	
	OMV (Norge) AS	Svein Olav Drangeid	
	Repsol Norge AS	Øyvind Hebnes	
	A/S Norske Shell	Rolf Pedersen	
	Sval Energi AS	Arild Idsøe	
	Vår Energi AS	Norunn Strand	
	Wellesley Petroleum AS	Helge Hamre	
	Wintershall Dea Norge AS	Arne-Kjetil Nilsen	
Contract partner	Offshore Norge	Lars Petter Lundahl	Not in OG
Trade unions	Industri Energi	Henrik S. Fjeldsbø	
	Safe	Stig Rune Refvik	Not in OG
	Norsk Flygerforbund	Frode Moi	Not in OG
	Norsk Helikopteransattes Forbund	Tommy Olsen	
Helicopter operators	Bristow Norway AS	Heidi Wulff Heimark	Not in SC
	CHC Helikopter Service AS	Per Andre Rykhus	Not in SC
Service providers	Avinor ANS AS	Stein Løken Clason	
Authorities	Civil Aviation Authority – Norway	Ørnulf Lien	
	Petroleum Safety Authority	Sigurd R. Jacobsen	

Please note that there has been changes to some of the oil companies' names during the course of this project. Some of the companies' representatives have also changed during the course of the project. The table above depicts company names and names of representatives at the conclusion of the project. The following company changes have occurred since the initiation of the study:

- Faroe Petroleum has been acquired by DNO
- Capricorn Norge (Cairn Energy) has been acquired by Sval Energi
- Spirit Energy Norway has been acquired by Sval Energi
- Lundin Energy Norway has been acquired by Aker BP

The project group executing the study has comprised the following organizations:

- SINTEF (main contractor)
- Imperial College London (ICL)
- Norwegian University of Technology and Science (NTNU)
- Brim AS

In addition, a reference group consisting of helicopter experts and academics (both national and international), and other expert groups have participated with valuable input, expert judgements, discussions and quality assurance.

The project organization is shown in Figure 1.1.

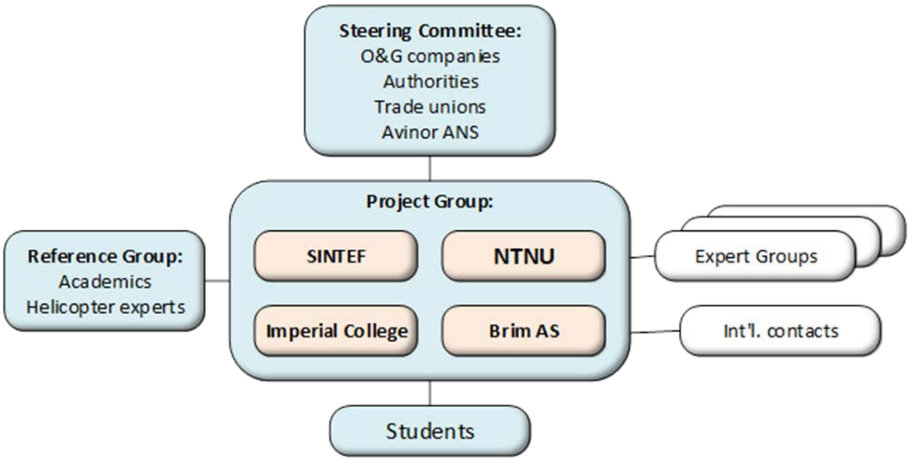


Figure 1.1: HSS-4 project organization.

1.3 Project scope

The HSS-4 study builds on the previous series of HSS studies, and focuses on the following areas:

- Important developments over the last 10 years
- Important developments for the coming 5–10 years
- Relevant statistics (accidents, incidents, activity)
- Review of recent accidents in the Norwegian and British sector
- Helicopter safety analysis model development
- Selected topics:
    - Maintenance of helicopters
    - Crew Resource Management
    - Comparing helicopter operations in the British and Norwegian sectors
    - Resilience in practice
- Recommendations for increased safety

Given the close relation between HSS-4 and the previous HSS studies, the reader will find many similarities in structure and content between the present report and previous HSS reports.

1.4 Main conditions and limitations

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

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

SINTEF does not consider as its duty to determine which respective agencies should be responsible for carrying out the presented recommendations. In general, this will often be evident given the nature and content of the recommendation.

Other more specific conditions and limitations are mentioned in the various chapters of the report.

1.5 Abbreviations

A	Accident category (A1–A8)
AAIB	Air Accidents Investigation Branch (UK)
AAIBE	Aircraft Accident Investigation Bureau Ethiopia
ABE	Norwegian reform on reducing bureaucracy and increasing efficiency
ACAS	Airborne Collision Avoidance System
ADS	Automatic Dependent Surveillance
ADS-B	ADS-Broadcast
AIC	Aeronautical Information Circular
AIP	Aeronautical Information Publication
AIS	Automatic Identification System
AltMoC	Alternative Means of Compliance
AMC	Acceptable Means of Compliance
ANS	Air Navigation Service
AOC	Air Operator's Certificate
ARA	Airborne Radar Approach
ATC	Air Traffic Control
ATM	Air Traffic Management
ATS	Air Traffic Service
BaSEC	Barents Sea Exploration Collaboration
BSL	Bestemmelser for sivil luftfart (Norwegian civil aviation regulations)
C	Consequence (contribution to risk)
CA	Canada
CAA	Civil Aviation Authority (UK)
CAA-N	Civil Aviation Authority of Norway
CAMO	Continuing Airworthiness Management Organization
CAP	Civil Aviation Publication
CFIT	Controlled Flight Into Terrain
CHS	Committee for Helicopter Safety on the NCS

COVID-19	Coronavirus disease 2019
CRM	Crew Resource Management (Cockpit Resource Management) (Company Resource Management)
CTA	Control Area
D	Dimension (of helicopter)
EASA	European Aviation Safety Agency
EBS	Emergency Breathing System
EBT	Evidence-Based Training
EEA	European Economic Area
EFB	Electronic Flight Bag
EMEA	Europe, the Middle East and Africa
EU	European Union
F/f	Frequency (contribution to risk)
FAA	Federal Aviation Administration (USA)
FAR	Federal Aviation Regulations
FDM	Flight Data Monitoring
FFS	Full Flight Simulator
FIR	Flight Information Region
FLIR	Forward-Looking Infrared
FMECA	Failure Modes, Effects and Criticality
FMS	Flight Management System
FRAM	Functional Resonance Analysis Method
FSTD	Flight Simulation Training Device
GM	Guidance material
GPS	Global Positioning System
GPWS	Ground Proximity Warning System
HCA	Helideck Certification Agency
HFIS	Helicopter Flight Information Service
HLO	Helicopter Landing Officer (on helideck)
HOFO	Helicopter Offshore Operations
HR	Human Resources
HRO	High Reliability Organisation
HSE	Health, Safety and Environment
HSS	Helicopter Safety Study
HTAWS	Helicopter Terrain Avoidance Warning System
HTI	Helicopter Triggered Lightning Index
HUET	Helicopter Underwater Escape Training
HUMS	Health and Usage Monitoring System
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ICT	Information and Communication Technology
IOGP	International Association of Oil & Gas Producers
JAR-OPS	Joint Aviation Requirements – Operations
JRCC	Joint Rescue Coordination Centre
LCD	Liquid Crystal Display
LDP	Landing Decision Point

MAC	Mid-Air Collision
MDA	Minimum Descent Altitude
MEL	Minimum Equipment List
MET	Meteorologisk institutt (Norwegian meteorological institute)
MoD	Ministry of Defence
MRM	Maintenance Resource Management
MSI	Motion Severity Index
NAA	National Aviation Authority
NCS	Norwegian Continental Shelf
NHF	Norsk Helikopteransattes Forbund (Norwegian Helicopter Employees' Association)
NO	Norway
NOU	Norges offentlige utredninger (Official Norwegian Reports)
NSIA	Norwegian Safety Investigation Authority
NTS	Non-Technical Skills
NTSC	National Transportation Safety Committee of Indonesia
NVIS	Night Vision Imaging System
NVG	Night Vision Goggles
OFIR	Oceanic Flight Information Region
O&G	Oil and Gas
OG	Owners' Group
OHRP	Offshore Helicopter Recommended Practices
ON	Offshore Norge
PBH	Pay by Hour / Power by Hour
PC	Personal Computer
PF	Pilot Flying
PM	Pilot Monitoring
PSA	Petroleum Safety Authority
QNH	Nautical Height
R	Risk
RAG	Resilience Analysis Grid
RIF	Risk Influencing Factor
RNNP	Risikonivå i norsk petroleumsvirksomhet (Trends in risk level in the petroleum activity)
RNP	Required Navigation Performance
RTC	Remote Tower Center
SAR	Search and Rescue
SC	Steering Committee
SIGWX	Significant Weather (chart)
SMS	Safety Management System
SOP	Standard Operating Procedures
SPA	Specific Approval
TCAS	Traffic-alert and Collision Avoidance System
TDP	Take-off decision point
TRM	Team Resource Management
TSB	Transportation Safety Board of Canada
UK	United Kingdom
UKOOA	United Kingdom Offshore Operators Association
UPRT	Upset Prevention and Recovery Training

1.6 Report structure

The report is organised into three main parts and appendices as follows:

PART I: Common HSS topics (ch. 1–7)

- The introduction is given in **chapter 1.**
- In **chapter 2** we describe the methodological approach.
- In **chapter 3** we describe the general development trends the last 10 years (2010–2019).
- In **chapter 4** we describe and discuss development trends forward towards 2030.
- In **chapter 5** we present statistics on accidents, incidents, and traffic volumes, and put these results in a longer time perspective.
- In **chapter 6** an analysis of helicopter accidents in the UK and NO sectors is performed.
- In **chapter 7** we describe the result of the updated quantification of the HSS model.

PART II: Specific HSS-4 topics (ch. 8–10)

- In **chapter 8** we document the results from the study on maintenance of helicopters.
- In **chapter 9** we document the results from the study on Crew Resource Management.
- In **chapter 10** we document the results from the comparison of helicopter operations in the UK and NO sectors.

PART III: Conclusions and recommendations (ch. 11–12)

- In **chapter 11** we discuss concrete measures identified in the study and perform cost-benefit analyses resulting in a recommended set of safety measures.
- In **chapter 12** we present the main conclusions and recommendations from the study, sorted by the different focus areas for this report.

APPENDICES

- **Appendix A** documents the results from the resilience in practice activity.
- **Appendix B** contains the HSS model description, including recent developments.
- **Appendix C** contains detailed descriptions of RIFs for *frequency*.
- **Appendix D** contains detailed descriptions of RIFs for *consequence*.
- **Appendix E** suggests a possible digital solution for the follow-up of safety measures

2 Method

The HSS studies are quite diverse in scope, and consequently a wide range of methods are applied in order to reach the project goals. HSS-4 draws heavily on both qualitative and quantitative approaches:

- Qualitative methods
    - Document studies
    - Interviews
    - Workshops / Focus groups
    - Resilience perspectives
    - Safety theory
- Quantitative methods:
    - Event data collection and analysis
    - Statistical methods
    - Risk Influence Diagrams (the "HSS model")
    - Cost-benefit analysis

The use of different methodological approaches is viewed as valuable as it allows for different perspectives and additional paths of insight into the study object at hand.

2.1 Sources and inputs

The input to the study may be categorized in four broad categories:

- Prior knowledge
- Interviews and workshops
- Written sources
- Helicopter event data

The SINTEF project group has a wide field of knowledge within the helicopter safety area, mainly acquired through the previous HSS studies. Still, the HSS-4 study – like all previous HSS studies – has depended heavily on active consultation with expertise in the offshore helicopter business today, i.e. helicopter operators, maintenance organizations, oil companies, authorities, service providers, etc. Many informants have shared their experience and knowledge in this regard. The information has been obtained through interviews, workshops, e-mail correspondence and telephone conversations.

Written sources include scientific studies and reviews, reports issued by various stakeholders, accident investigation reports, letters and statements concerning specific topics, meeting minutes, news reports and other information available on the Internet.

Event data for the period 2002–2020 have been provided by the CAA-N according to specified data fields of interest. The main purposes of the data have been to produce accident statistics and quantitatively populate the HSS model.

2.2 Methodological challenges

The informants are engaged in different parts of the helicopter business and thereby may hold different opinions and attitudes. Oil companies, helicopter operators, trade unions and authorities have different roles and agendas, which is reflected in *what* they are concerned with and *how* they communicate around various issues. A recurring contradiction is that between economy and security.

- The **oil companies** are buyers of helicopter services and are concerned with safe transport of their employees at a low price. General cost reduction programs in the companies come into play here.
- The **helicopter operators** shall deliver the safest possible service for customer's and own employees based on financial and other conditions. Focusing on costs is a natural part of the business.
- The **trade unions** for personnel at the sharp end, both within the oil companies and the helicopter operators, are primarily concerned with the safety of individuals, as well as job preservation. The cost aspect is thus subordinated.
- The **authorities** manage legislation and carry out supervision, and must strive for neutrality in all its work. Especially in recent years, questions about international vs. national regulations have been challenging.

Despite different points of view, there seems to be a common agreement in the industry on the main present and future challenges. The report reflects this shared reality in its descriptions of the status and challenges in the industry. In certain areas, however, there are clear differences of opinion among the informants. In these cases, SINTEF has sought further empirical confirmation through a) clarifying dialogue, b) third-party expertise or c) written sources. If the reality perception is still divided after this, an effort is made to provide a balanced presentation of the different views in the report, and to explain (theoretically) possible reasons why the differences exist.

Much of the material for the study has its origins in those parts of the industry that worry most about the state of affairs. Even though challenges may be exaggerated or biased – or disputed - it is important to recognize that all input represents real experiences, attitudes and concerns associated with helicopter activities.

A notable methodological challenge is the very limited amount of data or written sources available to support the large amount of information and claims presented to the study by the informants. Furthermore, SINTEF has limited possibility to double check and assess every piece of information, so we need to be selective and focus on those areas were we either *suspect* or *uncover* disagreement.

When it comes to the report's conclusions and recommendations, these are basically based on *all* parts of the report, i.e. the status description, the statistics/accident analysis, the model development and the various sub-studies. Specifically, the process for identifying and prioritizing measures is described in Section 2.4.

2.3 The HSS model

Central to the HSS studies is the *HSS model* which has been developed during the project series. The HSS model describes – both qualitatively and quantitatively – factors that influence the risk for both pilots and passengers within offshore helicopter personnel transport. The risk is viewed as a combination of the frequency and consequence of accidents and is measured by the number of fatalities per million-person flight hours.

The HSS model is an aid for structuring and quantifying a set of *risk influencing factors* (RIFs) in a way that facilitates:

- visual presentation of risk factors and their relations
- structured discussions in workshops
- thematical presentation of results
- quantification of risk

- contribution to risk from various accident categories and RIFs
- quantification of expected risk reducing effect of safety measures

The HSS model has been further refined in this study and the quantification of the model has been updated based on incident data from the period 2010–2019. See Appendix A for documentation of changes and quantifications. Main features of the model are also presented in the following.

2.3.1 Overall HSS model

The overall HSS risk model is presented in Figure 2.1. The model is based on:

- **Accidents** in offshore personnel transport with the potential of a fatal outcome.
- Separate influence diagrams for accident **frequency** and **consequence**, respectively. The **risk influencing factors (RIFs)** constituting the influence diagrams should be controlled to:
  - avoid accidents
  - reduce the consequences of accidents

A RIF is a group of similar conditions which influence the risk associated with offshore helicopter transport. The influence of a RIF on the development of a helicopter accident is expressed by the (quantitative) RIF contribution. The RIFs in the influence diagrams (both frequency and consequence RIFs) are organised into three levels:

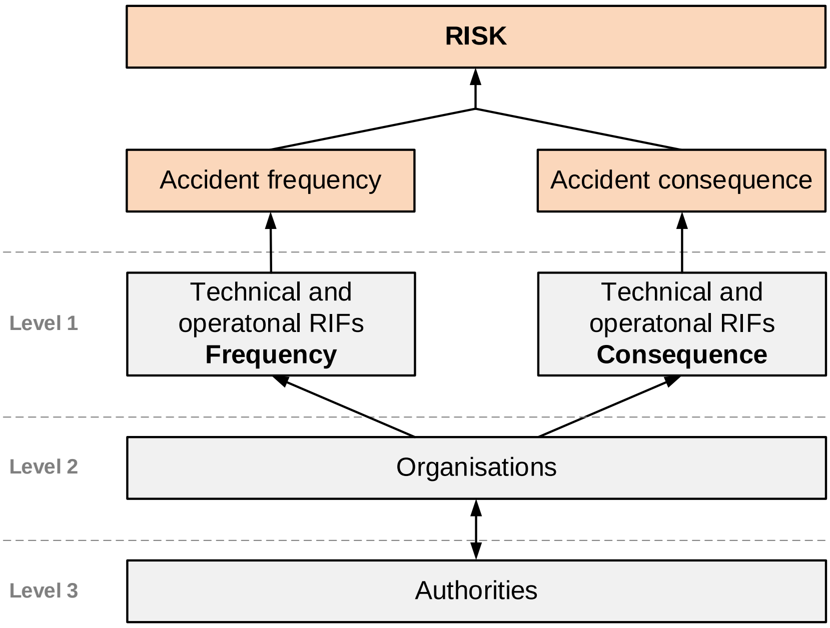


Figure 2.1: Overall HSS model.

Technical and operational RIFs (level 1)

Risk influencing factors/conditions related to the necessary daily activities to achieve safe and efficient offshore helicopter transport. The daily activities encompass aircraft technical dependability, aircraft operations dependability, necessary external support functions and some other external conditions.

Organizational RIFs (level 2)

Risk influencing factors/conditions related to organizations and their support and control of activities within helicopter transport. These factors are related to the helicopter manufactures and design organizations, helicopter operators and maintenance organizations, customers, heliport/helideck operators, air traffic service organizations, and search and rescue organizations. It should be noted that trade unions are implicitly represented through RIFs for helicopter operators, maintenance organizations and customers.

Authority RIFs (level 3)

Risk influencing factors/conditions related to requirements from authorities (national and international), as well as the quality of their activities.

2.3.2 Accident categories

In the HSS model, eight different accident categories are defined. Each accident category is associated with a frequency and a consequence, which will vary between the categories. The relative risk contribution (i.e. contribution to accident frequency and consequence) from each category is calculated individually based on accident/incident data. The consequences of accidents (i.e. expected number of fatalities) will vary significantly between the categories. For instance, a mid-air-collision (A4) is likely to kill most people on board, while for a ground collision (A8) the outcome will be far less serious. The eight accident categories are as follows:

- **A1: Accident during take-off or landing at helideck/heliport**
  Accident that occurs after passengers have boarded the helicopter and before TDP, or after LDP and before passengers have left the helicopter.

- **A2: Controlled emergency landing / Landing on uncleared helideck**
  Accident that occurs due to e.g. a technical failure or deviation from flight plan. The emergency landing can occur in sea, terrain or at uncleared landing sites (e.g. uncleared helideck).

- **A3: Uncontrolled landing or collision with terrain or sea due to loss of control**
  Accident that occurs due to e.g. technical failure in helicopter or pilot error.

- **A4: Mid-air collision with another aircraft (MAC)**
  Collision with another aircraft (fixed-wing, helicopter, UAV, etc.) during flight, without any prior technical failure.

- **A5: Controlled flight into terrain, sea or building (CFIT)**
  Accident caused by collision with terrain, sea, or building/structure after TDP and before LDP, without any prior technical failure.

- **A6: Fire, smoke, explosion or toxic gas**
  Accident caused by e.g. lightning strike, dangerous goods, or technical malfunction.

- **A7: Accident involving danger to persons located outside the helicopter**
  Accident involving danger to persons (pilot/passengers) located outside the helicopter caused by human errors (from pilot, passengers, and aerodrome personnel), for example the tail rotor striking a person, persons, a person is hit by baggage, or a person falls.
  (Note that danger to persons other than helicopter pilots and passengers, for example helideck personnel, is not included.)

- **A8: Ground collision (GCOL)**
  Collision on ground (heliport or helideck) with another aircraft, vehicle, or obstacle/structure.

Each accident category comprises one or more sub-categories reflecting *where* the accident takes place. See Appendix B for sub-categories and the accident categories' relation to ICAO event categories.

2.3.3 Influence diagrams

Influence diagrams are established to model accidents and to represent and visualise the importance of and corelations between the RIFs. Figure 2.2 and Figure 2.3 illustrate the influence diagrams for frequency and consequence, respectively. Each RIF is represented by a separate box in the diagram. The arrows between the RIFs illustrates the influence from one RIF to another. Most of the influences go from a lower to a higher level. However, this is not a requirement. The technical and operational RIFs on level 1 are grouped into *main groups* of RIFs, or "super RIFs" (illustrated by oval circles). These main groups are not dedicated RIFs and it should be noted that a technical and operational RIF *directly* influences the accident categories/frequency/consequence. The relevance or influence contribution from each RIF varies between the accident categories.

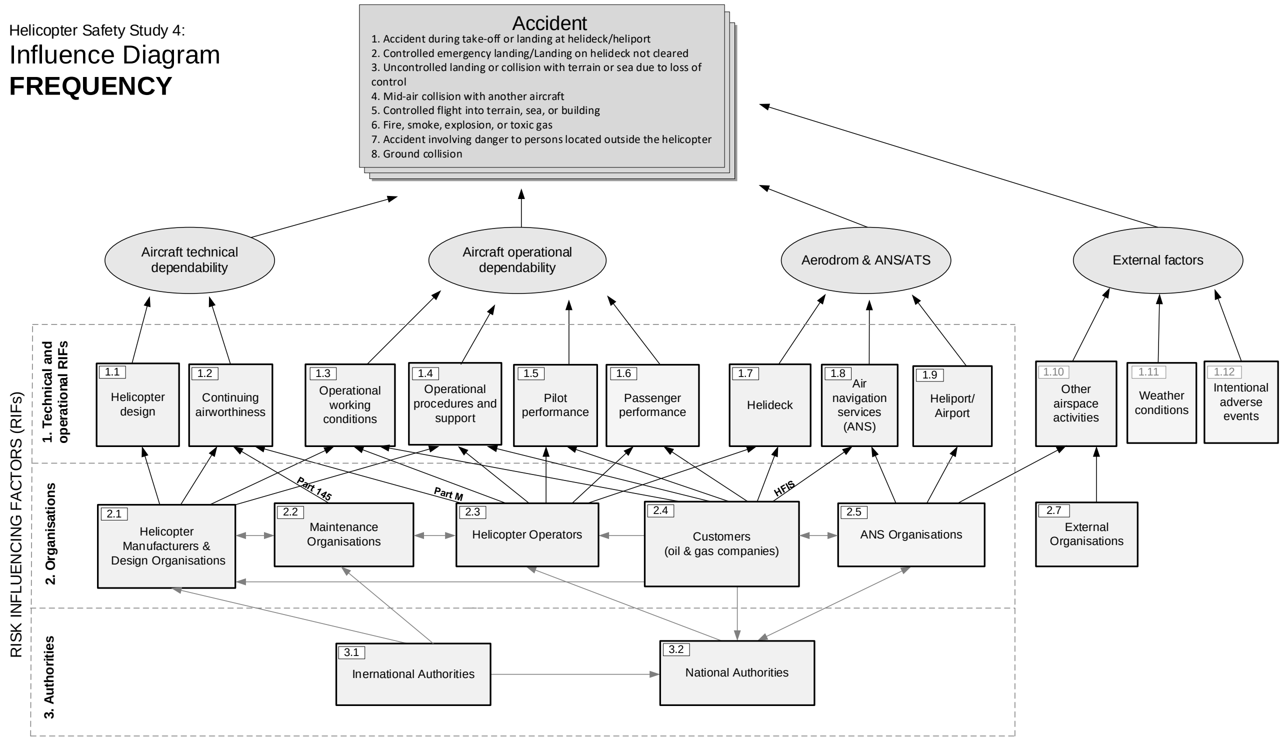


Figure 2.2: Influence diagram – Frequency (see appendix B for larger figure).

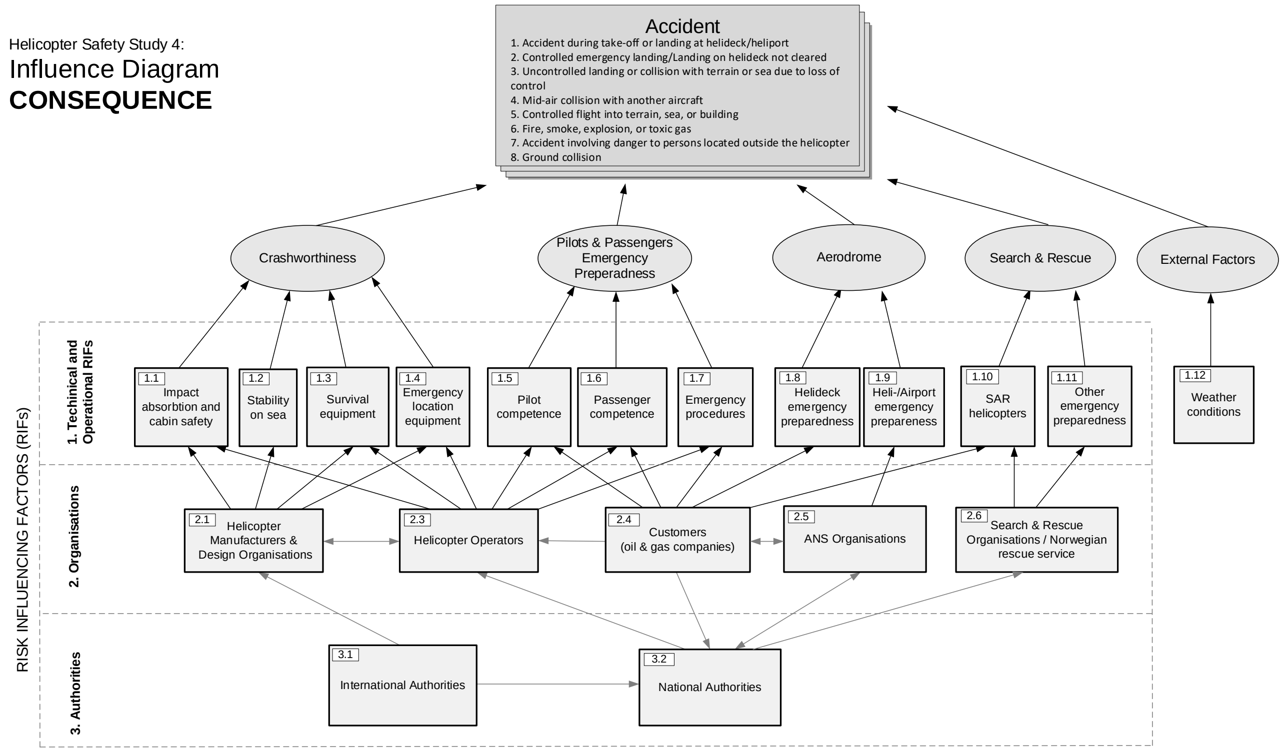


Figure 2.3: Influence diagram – Consequence (see appendix C for larger figure).

2.3.4 Risk

Total risk (R) is the product of the frequency (f) of accidents and the mean consequence (C) of accidents:

$$R = f \cdot C$$

Helicopter transport risk is measured by (expected) *number of fatalities per million-person flight hours.*

The frequency and consequence contribution from any accident category i (i = 1…8) are noted f_i and C_i, respectively. Hence, the risk associated with accident category i is:

$$R_i = f_i \cdot C_i$$

The total risk is then expressed by:

$$R = f_1 \cdot C_1 + f_2 \cdot C_2 + \cdots + f_8 \cdot C_8$$

The total accident frequency becomes:

$$f = f_1 + f_2 + \cdots + f_8$$

The mean accident consequence for an unspecified accident becomes:

$$C = (f_1 \cdot C_1 + f_2 \cdot C_2 + \cdots + f_8 \cdot C_8)/f$$

Hence, in order to quantify the risk, the frequency (number of accidents per million-person flight hours) and the consequence (expected number of fatalities per accident) must be quantified separately.

2.4 Assessment of safety measures

Safety measures are actions and modifications that are neither implemented nor planned today, but which are realistic to implement during the next five to ten years and expected to have a lasting effect (many years). The process of assessing and recommending safety measures is done in three steps as illustrated in Figure 2.4.

First, a large set of *possible* safety measures were identified based on suggestions from the helicopter community, accident reports, event data and previous HSS reports – as well as from the various activities of the HSS-4 study. A total of **120 possible** safety measures were identified.

Second, a smaller set of *suggested* safety measures were identified based on screening of the possible measures. The screening was based on a coarse analysis of relevance and possible risk reduction, as well as some practical considerations. This prioritisation was done essentially by expert judgement. A total of **39 suggested** safety measures were identified.

Third, a final set of *recommended* safety measures were identified based on a cost-benefit analysis of the suggested measures. The analysis considered investment cost, running costs, expected risk reduction, industry needs and implementation time. This prioritisation was done using the quantified HSS model with input from expert judgement. A total of **18 recommended** safety measures were identified.

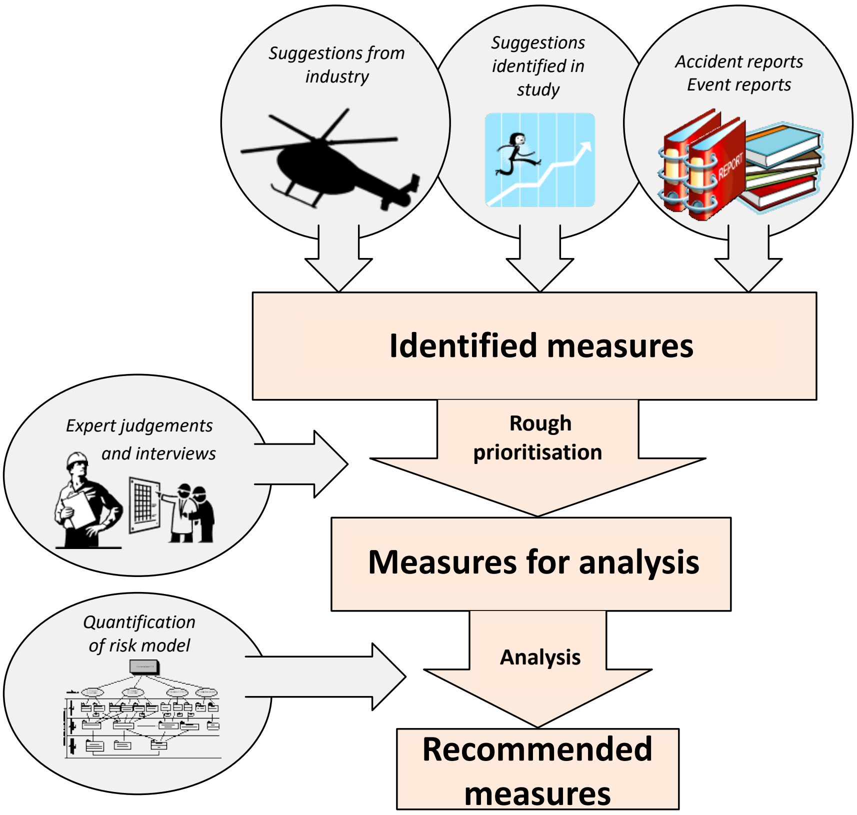


Figure 2.4: Assessment and recommendation of safety measures.

2.5 Framework conditions for safety

Over a ten-year period, changes will be seen in how the helicopter operations are conducted offshore. In the period 2010 to 2020, the industry has experienced development both in terms of operations, but also had to deal with regulatory processes from the authorities that have affected the framework conditions for the businesses, including implications for how safety has been assessed.

Even though helicopter accidents normally may be linked directly to either technical failure or human error, accidents investigations often illustrate that there can be several contributing causal factors to accidents. These factors can for example be time pressure, lack of competence, unfamiliarity with equipment, cultural differences, fragmentation of responsibility, etc. Such factors may be rooted on different organisational levels, such as industry, management and the planning level (Rosness et al., 2011; Starbuck & Farjoun, 2005; Vaughan, 1996). In order to manage and eventually improve safety, it is imperative to understand how such factors are being created and how they impact helicopter operations including decision making. These types of factors are labelled "framework conditions for safety" (Rosness et al., 2012). Hence, "framework conditions" refer to the conditions that influence the opportunities an organization, organizational unit, group, or individual has to control the risk of major accidents.

According to Rasmussen (1997), many societal levels are involved in creating these framework conditions - examples are politicians, regulatory bodies, business companies and organizations including both management and professional staff. It is important to note that safety professionals are not necessarily involved in creating framework conditions at the various stakeholder levels.

Offshore helicopter safety is a result of a multitude of decisions and actions – from the board of directors who decides on organizational restructuring, regulatory authorities doing audits or developing new legislation, technicians who perform daily helicopter maintenance, pilots who fly under varying weather conditions and air traffic controllers who handle the air traffic. These actors are *key stakeholders* when it comes to creating safety as a result of their varying work tasks and responsibilities. Rasmussen (1997) further argues the need to focus in particular on how these levels and key stakeholders interact in order to improve safety work. This chapter on developmental trends acknowledges this multi-level perspective as an analytical starting point.

It is important to note that an applied use of the concept of framework conditions means to understand both positive and negative outcomes of practice – to explore accidents as well as accident-free performance (Rosness, et al., 2013). Safety science has traditionally focused on the factors that make things go wrong, and to identify and arrange barriers to avoid similar accidents to happen again. Hollnagel (2014) argues that safety science should focus more on studying how things succed in an organization, which implies a focus on what people actually do at work - to understand the strategies and resources used when accomplishing work. This *work as done* or safety-II contrasts with looking into for example how to mitigate human failure through controlling its causes, i.e. *work as imagined* or the safety-I perspective (Hollnagel, 2014). Consequently, for framework conditions to be used in relation to development trends and safety, it is important to acknowledge that conditions impacting on helicopter safety need to be rooted in an analytical focus on empirical examples that illustrate effects regarding both successful operations as well as the opposite.

Furthermore, in order to understand offshore helicopter safety stakeholders' interactions, the analytical perspectives "senders" versus "receivers" (Rosness et al., 2012) will be used in this report. The idea behind these metaphors is that some actors (for example "senders") influence distinct framework conditions that other actors ("receivers") must relate to when handling various risks. It is important to view these influences as interdependent, meaning a non-linear and dynamic relationship among key actors in the risk management chain when adapting, producing and influencing the framework conditions for safety.

2.5.1 Globalization

Aviation including offshore helicopter operations is an international industry that is influenced by various global trends. The term "globalization" has various definitions (Le Coze, 2017), however for HSS-4 and development trends it is important to acknowledge that central aspects regarding globalization involve services, capital, trade, enterprises, information and ideas moving across borders. More specifically, this is about developments in ICT, including digitization, liberalization of financial flows and trade, as well as deregulation and privatization (Rosness et al., 2018). Similar to Rosness et al. (2018), but specifically angled towards offshore helicopter operations, this chapter assumes that globalization induces changes in framework conditions for safety. Rosness et al. (2018) highlights the following globalization aspects based on research on how key stakeholders within the four transport modes (sea, air, rail, road) are able to affect own framework conditions for safety, while also themselves being affected.

- **International regulation** – there is less room for national regulation, e.g. national special provisions.
- **Market liberalization** – the intention is increased competition.
- **Organizational changes** – e.g. that a business is outsourcing activities or that the authorities are splitting up a state monopoly to promote competition.
- **Technological changes** – innovation and new standards.

This understanding of globalization is shown in Figure 2.5 below. The point of the figure is to illustrate how "everything is affectable", which implies complex relationships. For that reason, it can sometimes be challenging to determine in which direction an influence is moving.

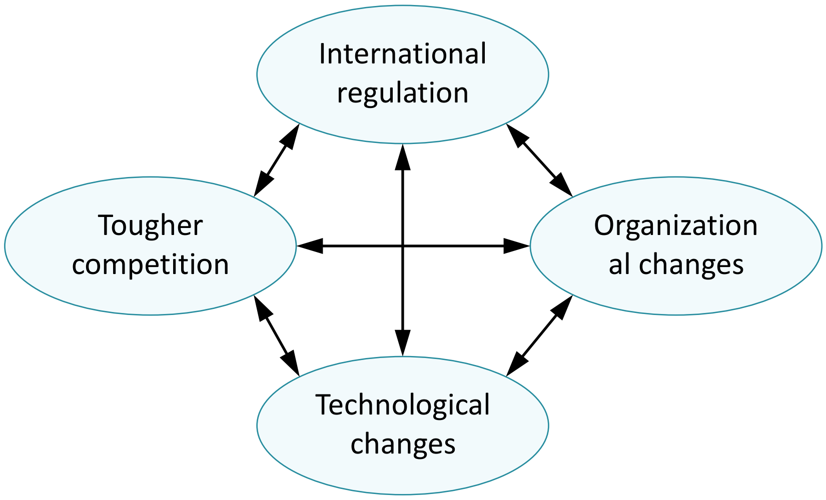


Figure 2.5: Globalization aspects that (dynamically) capture changing framework conditions for safety (Rosness et al., 2018).

In offshore helicopter operations, one can imagine organizational changes related to the restructuring and downsizing of administrative personnel in helicopter companies as a result of tougher competition. At the same time, outsourcing of maintenance at one helicopter operator may for example result in tougher competitive conditions for the competitor, which have not necessarily made similar changes.

2.5.2 Theoretical approaches

Table 2.1 shows theoretical perspectives that will be used to explore developmental trends and potential impact on safety within the offshore helicopter industry.

Table 2.1: Theoretical approaches for exploring framework conditions for safety (modified based on Rosness et al. (2012).

Approach	Relations between framework conditions and safety	Implications for safety work
Efficiency-Thoroughness Trade-Off Hollnagel (2004, 2009)	Individuals and groups produce variability as they try to balance efficiency and thoroughness requirements. Such variability becomes part of the framework conditions of other actors. Variability from different sources may "resonate" and trigger an accident.	Identify situations where actors have to make efficiency-thoroughness-trade-offs with an effect on safety, for example where variations in output may negatively affect the framework conditions of other actors.
Normalisation of deviance, or drift Vaughan (1996)	Adverse framework conditions can be conducive to processes where an organization gradually comes to accept serious anomalies as "normal".	Need to devise strategies that enable them to prioritise safety when they are faced with conflicting demands from their environment.

Normal Accidents theory, Perrow (1999)	System interactions are either linear or complex, or both – e.g. planned versus unfamiliar or unexpected sequences. Moreover, couplings are either tight or loose – e.g. two components directly coupled versus system components functioning independently of each other. A tightly coupled, complex system is at risk to experience a normal accident.	Need to ensure technical and organizational/system barriers – need organizational/system built in slack together with focus on system understanding through foremost linear (work) processes.
The High Reliability Organization (HRO) and organizational redundancy, Weick & Sutcliffe (2015), Reason (2001)	Organizations face unexpected events. In order to manage these, organizations must act mindfully through 5 principles coupled to anticipation and containment. The capability to act mindfully (and also to maintain redundancy) can be either strengthened or weakened through framework conditions.	Need to ensure that an organizations capability to act mindfully is supported – at the same time ensure organizational redundancy, e.g. defences in depth regarding safety critical tasks.

3 Development trends after 2010

This chapter describes and discusses some of the main development trends in various areas relevant for offshore helicopter transport.[1]

3.1 Technical developments

3.1.1 Airborne Collision Avoidance System (ACAS) II

The ACAS implementation TCAS II is an improved system that will replace TCAS I as a standalone solution. While ACAS I provides information on the altitude of nearby aircraft on intersecting courses, ACAS II communicates with both aircraft and instructs them to either climb or descend respectively. Requirements for ACAS II were implemented in connection with BSL D 2-3 and HOFO (July 2018). However, ACAS II is not implemented in all helicopters today. ACAS II also requires specific training, but simulators are not updated (apparently the instructor needs to call out e.g. "climb, climb" manually). This will be rectified. Today's training focuses on pilots being obliged to follow ACAS II messages without first informing ATC – which is done afterwards.

3.1.2 Navigation equipment

Avinor ANS wants to implement Required Navigation Performance (RNP) to avoid having to construct ground installations. However, because of potential jamming one must have some ground station redundancy to prevent loss of navigation capability if GPS signals are lost. For example, all pilots are checked out on RNP procedures. Avinor ANS has published several departure and approach procedures based on RNP, which the helicopter pilots consider a clear improvement. However, some procedures require two Flight Management System (FMS) computers in the helicopter, something Equinor has required / paid for in some machines. In addition, there are two S-92 machines (paid for by Equinor) with the possibility of RNP AR (the curved approach to avoid noise around Flesland). Sikorsky has not made this equipment part of the standard configuration since it requires replacement of LCD screens in the cockpit.

3.1.3 Helicopter types

After the Turøy accident in April 2016, the industry initially expressed concern about the lack of redundancy when no longer having two helicopter types in use. There are today no fully adequate alternatives to the S-92 after the H225 was taken out of service. The oil companies have accepted that there is only one helicopter type in operation, as the production risk is considered to be limited based on the strong operational record of the S-92. However, the technology is ageing and the production has ended, so it will at some point need to be replaced. In addition to the S-92 fleet, a few older Super Puma L/L1 are still in use for shuttling and SAR.

Following the Turøy accident, the helicopter types H225 and AS332L2 became subject of a national safety directive, which was eventually repealed by the Norwegian CAA-N (July 2017). This was coordinated with the UK CAA. This means that these helicopter types, from a regulatory perspective, again may be used on

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[1] Note that the previous HSS-3b report implies an already firm understanding of key trends in the industry, in particular discussions about the HOFO regulations and how Norway should relate to new operational requirements as a result of a possible HOFO implementation.

the NCS. There are no oil companies with immediate plans to use these helicopter types for personnel transport – there is also resistance associated with a future introduction of these helicopters from both the unions and the helicopter operators.

Bell 525, which is a new helicopter under development, is a medium-sized helicopter intended for use on the NCS, but the oil companies are somewhat reluctant to commit to this type until certification has been completed. In early 2020 however, Wintershall Dea and Bell signed a non-binding collaboration agreement where they will look into what's needed to get the Bell 525 ready for operations on the NCS. This work implies analyzing technical requirements as well as suitable operating models, and to work closely with helicopter operators, employee unions and other relevant stakeholders.

From a pilot perspective, the Bell 525 has smoother noise and vibration patterns compared to the S-92. The Bell 525 is perceived by some pilots to be "pilot friendly" by way of improved seating comfort, as well as being equipped with fly-by-wire as the first offshore helicopter. However, the Bell 525 will e.g. not be able to compete with the flexibility the S-92 offers in terms of range and capacity. Moreover, the Airbus H175 and Leonardo AW189 have not yet been introduced on the NCS although the AW189 is certified with anti-icing capability, while the H175 and the Bell 525 has this capability planned for 2024. The AW189 and H175 are in use by e.g. Equinor in other countries with largely positive experiences. In fact, a new helicopter operator intending to use the AW189 was on the verge of starting up in Norway, but the application was eventually withdrawn in 2018.

Sikorsky is also introducing new versions of the S-92, the S-92A+ and S-92B, where the former is an upgrade of the S-92A while the latter is a new machine with similar upgrades as the S-92A+. From a technical point of view, it is pointed out that the S-92 technology is proven in use, reliable and established on the NCS. For example, digitization of S-92 cockpit functions is a good example of how the introduction of new technology in an already proven and established helicopter concept can bring benefits through increased opportunity for troubleshooting inside the cockpit, which has become more integrated and is regarded as a clear improvement. However, there is also a distinct improvement potential regarding specific error codes and what should be done specifically as described in the S-92 maintenance manuals. According to helicopter technicians, the overall helicopter industry lags somewhat behind fixed-wing when it comes to technology innovation and utilization.

3.2 Operational developments

3.2.1 Health and Usage Monitoring System (HUMS)

HUMS is a system for monitoring the technical condition of the helicopters. HUMS records critical system and components' status based on various sensors in the helicopter in order to detect and thus handle defects as early as possible. Modern HUMS monitors significant moving parts, e.g. gearbox, fans, and rotor systems, and coupled to the operational context technicians can identify and analyze trends in order to proactively conduct performance-based maintenance.

HUMS is constantly developing, and downloading and analyzing HUMS data is performed by the helicopter operators after each flight, a requirement which was formalized via ON-066 in 2015. However, the helicopter operators practiced HUMS downloading long before 2015. The background for checking HUMS between each flight was specific events and accidents - previously the data was checked daily. In addition, independent inspection of HUMS data was introduced; this was influenced by the incident on the West Franklin platform where the crew lost control of the tail rotor. Independent inspection means that two helicopter technicians look at HUMS-data independently of each other - however helicopter operators can vary in how they practice this. The technicians' comment that checking between each flight is a safety gain, while the requirement for two technicians to look at HUMS data independently is felt somewhat unnecessary from a safety perspective.

Helicopter technicians point out that HUMS has become progressively better, more intuitive, and easier to understand. Right after landing, a technician transfers the HUMS flash memory device from the helicopter to a PC. The technician makes a quick assessment of the HUMS information, with the purpose of identifying any exceedances associated with various technical parameters. However, discovering trends needs more in-depth analyses. If deviations are identified from normally expected parameters, this is treated similarly to other deviations in the helicopter's systems. HUMS is now viewed in the same way as other vital systems in the helicopter, which according to the technicians is an improvement. Previously, HUMS was a system that was less integrated in the helicopter. See also section 4.4.3.

In HSS-3b, it was commented that live HUMS would be introduced in Bristow in 2017. However, this is still not implemented. In case of a potential live alert to the crew, the system must be reliable so that it does not result in unnecessary return flights, landings/ditchings and uncertainty due to spurious warnings etc. Helicopter technicians state that on an S-92 the system is much more stable than on a Super Puma regarding the occurrence of spurious warnings.

Sikorsky has been actively trying out HUMS to determine the service life of various components, but this has not yet been implemented in daily use. CHC has a HUMS center at Sola that handles data from all over the world, while Bristow downloads HUMS data locally and then sends it to the supplier for further analysis.

3.2.2 Flight Data Monitoring (FDM)

EASA OPS describes Flight Data Monitoring (FDM) as a proactive and non-punitive programme for gathering and analysing data recorded during routine flights to improve aviation safety. FDM is a statistics-based system that collects information related to how pilots fly, including the use of helicopter systems. The aim is to identify where practices differ from standard operating procedures (SOP). It is measured how the helicopter is flown in relation to set limit values (normal operations), which results in insight into which limit values are exceeded, as well as how and when this occurs. The starting point for the analysis of FDM data is three levels (L1, L2 and L3) that are predefined where level three (L3) is classified as a critical event, i.e. violation of one or more procedures.

For example, analysis of FDM data related to level one has identified trends during take-off where the helicopter's nose position is 20 degrees below the horizon, which is undesirable. Analysis of FDM data is about learning from previous events, so that one can proactively deal with unwanted situations that could be the result of a trend being allowed to continue or escalate. FDM is considered a very appropriate tool for stopping a negative trend early. However, grading events is challenging, especially in an international perspective where different cultures and perceptions of how FDM data should be used can vary. From a Norwegian perspective and in relation to Norwegian operations, it has been found that parameters have been set too narrow internationally, which results in unnecessary alerts.

Using Bristow as an example, raw FDM data are sent to an in-house FDM data centre located in the United States, and "cleaned" data are returned to the locally (e.g. Norway) designated FDM person. This person then follows-up on "exceedance events" categorized as L1, L2 or L3 depending on the severity. The procedure is to contact the crew for all L3 events to learn more about what happened. However, when it comes to reviewing FDM incidents, strict privacy guidelines are in place, as FDM data may neither be used for punishment nor distributed freely.

3.2.3 Recruitment, competence and training

As for recruitment, it is necessary to understand that the helicopter industry is experiencing cycles. When helicopter operators cut back on jobs, pilots and technicians disappear from the sector. With cycles, the younger employees are forced to leave the company while those with seniority continue - thus, there is a skewed demographic in the companies, which is challenging. The companies hire when demand arises, either because of increased volume or need to replace capacity when employees quit. Hiring of technical personnel including retired staff also occurs. According to the management of the helicopter operators, it is not the case that there are vacant positions that are not filled, but it takes longer to recruit today compared to previous years. Pilots and technicians are highly specialized occupational groups that cannot go straight from the street into the hangar and perform efficiently from day one. Hence, there is considerable training time and costs associated with new hires. For some categories of personnel, considerable previous experience is also required.

Apprenticeship programs exist on the maintenance side. CHC, for example, still has such a program, though not overly comprehensive - the point is to take good care of the apprentices already engaged, while at the same time seeing the number of apprentices in relation to company needs. When the helicopter operators recruit new pilots and technicians, they look for people that fit into the group and the established safety culture – people that are able to learn and fit in socially in addition to demonstrate the operational skills expected. The operators try to form a group of employees that thrives on each other. The focus of the operators flying offshore is that quality is most important - it is not necessarily only the number of flight hours that are decisive for recruitment. This means a focus on thorough selection processes of new pilots including the use of a psychologist and an assessment flight in the simulator.

Regarding pilot competency, there are similarities with today's fixed-wing labor market. i.e. pilots are available, but not always with the desired competence. If new hires are needed, the companies may be lucky to get pilots with a valid license, but the starting point is to provide a type rating after employment, something which also applies to helicopter technicians. Helicopter companies sometimes also bring back employees who have previously retired in order to ensure sufficient capacity and competence. There is normally an arrangement with a defined period where people that have been laid off, has a certain priority for reemployment.

Use of simulator
The amount of simulator training for *pilots* increased in 2010 to 16 hours a year from the previous 12 hours laid down in ON-066. At the same time, it was required that 8 hours be completed every six months. SAR pilots shall receive 2 hours extra training during the half year, i.e. a total of 4 hours extra per year. Moreover, acceptance is now given for dropping CRM courses every other year as CRM has now been systematically included in the simulator training, which has been received positively by pilots.

The CAA-N approves the use of simulators for training pilots. The regulations specify that a suitable Flight Simulation Training Device (FSTD) must be used (if available). The FSTD's performance must correspond to the helicopter's systems and performance as far as practically possible – any significant differences must be documented, and extra pilot training can be needed in this case.

However, ON-066 requires helicopter operators to use level D "full flight simulator" (FFS) if available. An FFS implies that the cockpit is moving and that all flight systems are identical to the (real) flying version. Moreover, it is also a customer requirement that the helicopter technicians perform simulator training on the helicopter systems. The following simulators located in Norway are currently available for the helicopter operators:

- FlightSafety S-92 Level D simulator at Sola airport, Stavanger
- CAE S-92 Level D simulator at Gardermoen airport, Oslo
- Thales H225 Level D simulator at Sola airport, Stavanger

For technicians, EASA requires continuation training and customer requirements in ON-066 specifies at least two hours yearly continuation training for B1 and B2 technicians with simulator or a suitable simulator system. Not all technicians experience this training as useful, as the training does not necessarily reflect daily issues. All technicians do not have system training by use of simulator as specified in ON-066. Also, it has been pointed out that ON-066 is not sufficiently clear regarding the training requirements, causing various training practices for technicians in different companies, as well as between Part-145 and in-house technicians.

Automation and evidence-based training (EBT)

Looking back a few years and comparing for example the AS332L2 with the H225, there are major differences in the levels of automation (including autopilots) of the helicopters. According to the helicopter operators, a large part of the training is done flying with the use of autopilot functions, because this can be intuitively different from flying the helicopter manually. Training is carried out, for example, on transitions from autopilot to manual flight, which is particularly important given the pilots' need for continuous situational awareness throughout the entire flight. The use of FDM-data in relation to training is also important – identified events or (unwanted) trends can be followed up in the simulator, for example to train particularly on departures to ensure correct flying according to procedure.

A new evidence-based training (EBT) framework for pilots is under development. Bristow has for example introduced the IASP (Initial Assessment Program). This is a program where everything that happens on a flight is rated, not only flying skills, but also communication, CRM, etc. The idea is to look at trends (collectively for all flights) in order to assess the adequacy of procedures. There is an indication that future EBT entails an initial individual training set that is evaluated, on which the rest of the training will be based – this gives a more individually tailored training. The regulations for EBT have been published in EASA OPS, but not yet the necessary associated AMC and GM for helicopters.

Electronic flight bag (EFB) and associated regulations have also recently been updated.

Also, there is more controlled airspace and new RNP procedures to deal with, which entails extra training due to regulatory requirements related to RNP check-out as part of new basic training for pilots.

When it comes to training for technicians, one day of technical training (flying) is required to better understand errors. Bristow has for example switched from in-house training to using Flight Safety due to an improved learning system. This is specific to Bristow and not a statutory requirement. This type of training may vary between operators, which can be seen in connection with different interpretations of ON-066.

3.3 Maintenance developments

3.3.1 Reporting culture

Industry KPIs used by Ptil in the RNNP report shows an increase in reporting of events from maintenance in general from the two helicopter operators in Norway. Interviews with helicopter technicians also indicate that there is an overall good reporting culture. Several challenges in reporting culture and possible improvement measures were presented by study informants. In particular, the unions express some concern about the overall reporting culture becoming less transparent because of maintenance personnel omitting to report undesirable conditions when it may result in sanctions for those involved. The regulations have been tightened in recent years in relation to what is mandatory to report – however, only one in six reports written by technical personnel are forwarded to the CAA-N according to the union representatives. When asked what is being reported, technicians will provide different answers – however, according to union representatives, technicians rarely report beyond reporting snag locally. Furthermore, there is little knowledge related to what the CAA-N does with received reports – and even less knowledge of what EASA is doing. It is claimed that both the Norwegian CAA and EASA have IT challenges related to compiling analyzes of various reports received.

The technical side considers internal reporting in Norway to be unproblematic in general. However, unions report that management in the helicopter companies, nationally as well as internationally, has taken a more active stance related to, for example, what to write and what not to write in technical reports. If one has been unlucky and damaged a helicopter, management may wish to respond to those involved. Such must be seen in the context of more active involvement, particularly from the helicopter companies' head offices abroad where technicians have experienced various types of pressure including reprimands. Consequently, it is felt that the term "just culture" does not necessarily always describe technicians' working conditions. As noted, there is less reporting to the CAA-N compared to previous years. The oil companies however receive all the reports they ask for, something which is contractual.

3.3.2 ICT systems

The helicopter companies have modernized various tools related to performing maintenance of helicopters. However, it may present challenges when introducing an ICT system in Norway that is basically designed and developed globally, often originating from fixed-wing. Electronic maintenance manuals have been introduced to replace paper-based versions, which helicopter technicians consider overall positive. Electronic manuals allow in principle, maintenance at any time to be performed according to the latest current version and available information. However, technicians find that the user interface is not always satisfactory and that it can sometimes be challenging to have a complete overview of the many procedures and to find specific information. Technical management systems used today allows customers to successfully manage maintenance, engineering, and logistics so that they comply with current aviation regulations. However, technicians argue that a system can be challenging to use because any given system is not necessarily designed based on the needs of all end users.

A few years back, maintenance organizations experienced a good deal of internal reporting related to a specific maintenance system, and the CAA-N became involved, including follow-up related to improvement measures. For example, technicians found that the serial number related to helicopter parts did not actually match the parts used on the helicopter. This can cause one to lose track of component life, and it is commented by one technician that there is not a complete trust in the system. However, this has improved over time. Arguably, the system in question does not handle the complexity of an organization, which could cause technicians to lose configuration control including inconsistent parts. This in turn puts more administrative work on technicians (e.g. registration of component replacements). There are also concerns about access control in the mentioned system, including that people outside a given company can enter and change components of a helicopter within, for example, the maintenance program. However, it is important to point out that this problem also existed before the introduction of the specific system described above.

Considering that the helicopters are certified by rigorous approval processes and maintained by an organization subject to strict approval regimes including approved aviation technicians - from a technical operational point of view, questions are asked as to why aviation IT systems are not approved in a similar manner.

3.3.3 Technical and planning competence

Employee unions point out that the industry's increasing focus on cost cuts has led to downsizing in helicopter companies. Economic pressure is thus seen in the context of cuts together with changes in how maintenance is performed. Technicians argue that they sometimes are being pushed to get the job done as quickly as possible and within distinct deadlines. When viewed in the context of, for example, daily inspections where technicians work alone on the helicopter, it can result in increased risk of ignoring defects or errors occurring, including insufficiently documenting what is done on the helicopter. Consequently, unions are worried regarding the overall quality of maintenance work both in the short and long term.

At the same time, there is also an increasing degree of contracting of technical personnel. When it comes to heavy maintenance, it was challenging to maintain sufficient expertise for a period after 2013. For example, it can sometimes be challenging for a C-certified technician to have an overview of available technical expertise at all times. Moreover, one of the helicopter operators experienced major capacity problems when moving base maintenance; many personnel quit, and initially there was insufficient expertise and resources at the new location. For a while there was a lot of temporary staffing among the technical personnel. This has improved in recent years; maintenance activities are completed when they need to, and the time needed inside the hangar is reduced. However, there are still some challenges associated with few personnel available. This entails substantial overtime as well as a need for hiring due to lack of capacity, for example sheet metal mechanics etc. At the same time, there are also some challenges associated with lack of type-related expertise, which means that some companies hire pensioners. The regulations state that 50 percent must be permanent employees - sometimes during weekends and evenings, operators are close to this limit according to unions.

Lack of spare parts is sometimes a challenge for the helicopter operators. From a technical operational point of view, long-term maintenance planning in general is challenging. This involves lack of planning expertise; there are many new personnel at the expense of experience. Previously, the planners were technicians – today, less experienced workers who do not have the same necessary technical understanding are used. A good planner needs to have the *big picture*, i.e. ordering the right equipment and the right parts at the right time. For example, one must always be proactive when it comes to monitoring the running time of different components. However, it is important to point out that lack of planning is not always the cause of missing parts – this can also result from lack of support from the supplier. At the same time, good planning depends on individuals. Here, according to one of the unions, a quality system should be put in place to ensure this.

Heavy maintenance is also performed abroad, for example in the UK and Poland. Technicians look at outsourcing of maintenance with some concern, as they foresee a reduction in national competence and capability as a result of lower activity, as well as challenges related to future recruitment. In particular, the unions are concerned that the pressure the industry is experiencing today will result in the pride and enthusiasm that has traditionally characterized the engineering profession, to gradually disappear.

Manufacturers like for example Sikorsky focus nowadays on achieving more *efficient* maintenance. This entails for example to fly longer between each time maintenance is required, or to extend service life of the helicopter based on analyses of actual sensor data, etc.

3.4 Developments in air navigation services

3.4.1 Automatic Dependent Surveillance – Broadcast (ADS-B) and controlled airspace

The ADS-B project was launched in 2010 as a result of Avinor ANS having to cancel radar on Ekofisk for contractual reasons. The project started to investigate the possibility of using ADS-B, which was a completely new system and was not previously used for Air Traffic Control in Controlled Airspace. The implementation of ADS-B posed a considerable number of technical challenges, particularly related to offshore installation and stability of power supply, and certification of helicopters.

EASA/EUROCONTROL's future requirements for ADS-B in controlled airspace were adapted and designed for the airliner industry but are relevant also for heavier helicopters due to the weight of more than 5,7 tons including required duplication of systems on board. This posed some challenges related to the general weight limitations of helicopters. The issue was finally resolved, and the helicopter installations were certified.

The object of the ADS-B project was to establish controlled airspace between Sola and the Ekofisk area. Eventually, an overview of the cost picture was obtained, which also included the establishment of Balder CTA while maintaining Ekofisk CTA as the main target. Requirements by CAA-N to install ADS-B transponders in helicopters operating on the NCS were introduced in 2013 and applies to offshore helicopter operations in controlled airspace all the way up to Heidrun. This is experienced by pilots as a good safety development. ADS-B is now required by EASA airspace rules for most aircraft including these helicopters, which all now have ADS-B transponders installed.

After the Turøy accident, some older Super Puma machines were re-introduced to substitute H225 and Super Puma L2 helicopters. For a period of time, aircraft were granted exemption from the requirement to install ADS-B, but as of October 2019 all aircraft has ADS-B installed. Avinor ANS points out that there is a higher risk associated with a helicopter without surveillance service.

Today's ADS-B system runs as an isolated ATS-system but is integrated into the same surveillance picture in Avinor ANS's surveillance system NATCON. Avinor ANS experiences ADS-B as a reliable system for surveillance of traffic - it also provides good coverage almost all the way down to the helidecks. In the event of a malfunction of ADS-B, other surveillance sources (radar and WAM) automatically take over as much as possible. In the ADS-B system all sensors have overlapping coverage, so another sensor takes over if one falls out. The ADS-B sensors are in addition in use for Wide Area Multi-lateration (WAM), which is another way to give both ADS-B and non-ADS-B equipped aircraft surveillance by triangulation of transponder SSR-signals.

Table 3.1: ADS-B implementation and controlled airspace.

Control area	ADS-B status
Ekofisk CTA (2013)	ADS-B installation completed in Ekofisk ADS area 2011. A two-year trial period with Flight Information Service (FIS) only. Eventually established controlled airspace and Air Traffic Control in 2013. First controlled airspace with use of ADS-B.
Balder CTA (2015)	Installed with the Ekofisk ADS-B project in 2014. A one-year trial with FIS only. Established as Balder CTA in 2015.
Statfjord CTA (1995/2016)	Established in 1995 based on use of Gullfaks radar and land-based radars. ADS-B installed in 2016 to improve surveillance stability and coverage.
Heidrun CTA (2011/2018)	Established in 2011 based on use of Heidrun radar. Gyro-stabilized radar since the platform moves in figure-eight. In 2018, ADS-B was installed on several locations to cover blind spots – required back-up coverage.

Norne CTA (2022?)	Norne ADS area, including Aasta Hansteen, was initially part of the Heidrun project. Avinor ANS started the Norne ADS-B project to establish ADS-B based Norne CTA. Installation work on Norne and Aasta Hansteen is delayed due to lack of priority of access to the installations.

According to Avinor ANS, the traffic to Aasta Hansteen is currently the single most safety critical helicopter operation on the NCS due to lack of surveillance and missing VHF coverage. The process of establishing these capabilities has been significantly delayed.

When Norne CTA is established, a robust Air Traffic Service (ATS) system will cover the NCS where there is regular helicopter traffic from Ekofisk south in the North Sea to Aasta Hansteen north in the Norwegian Sea. Compared to the service provided to domestic commercial air traffic, the ATS offshore is at a similar level, albeit with some more vulnerable equipment offshore. Avinor ANS has entered into agreements with oil operators that Avinor ANS owns all radio- and navigation equipment, ADS-B- and radar sensors used for ATS provided by Avinor ANS. Avinor ANS is responsible for the general maintenance program, while first line technical support agreements are established with platform owners..

A major challenge in establishing Controlled Airspace was the interface between the Norwegian and British sectors that did not conform to airspace boundaries (for example, a part of Balder CTA is in British airspace, so that the service provided on the NCS enters British airspace). Norway and the UK have an agreement to provide Air Traffic Services in respective areas, ATS Delegated Airspace, up to 8,500 feet. However, establishing Controlled Airspace on the British side was politically challenging. The British Armed Forces sets the premises for Controlled Airspace in the UK, but when Norway establishes this instead, British military aircraft must take this into account, which may impose restrictions on UK military operations. According to Avinor ANS, many meetings and negotiations were held in which the CAA's Department of Airspace Policy and the Ministry of Defense (MoD) participated together with NATS and UK ANS (corresponds to Avinor ANS in Norway).

As a result, an agreement was established regulating UK military operations in Norwegian Controlled Airspace, where the British could operate without being controlled by Avinor ANS. Prerequisites for the agreement were good coordination between the parties, the establishment of Helicopter Traffic Zones (HTZ) for civil offshore helicopters, and the UK military traffic to avoid the HTZs. With this agreement the British MoD and CAA finally accepted a Control Area (CTA) to be established at Ekofisk and Balder.

3.4.2 Tampen HFIS

A Helicopter Flight Information Service (HFIS) is an offshore-based center whose main purpose is to provide Air Traffic Service (ATS) to local traffic in those cases where there is potential for airspace conflicts between helicopters in regular traffic. A HFIS covers several installations in the same area and was until recently (September 2022) a regulatory requirement (BSL G 2-1). HFIS units were first established in the 1980-ies at the field centres of Ekofisk, Oseberg and Tampen. In those days there was limited radio or radar coverage from land, and the HFIS units filled the information void for helicopters approaching their offshore destinations. Since then, technical resources for mainland-based ATS have drastically improved and coverage is no longer an issue today. Oseberg HFIS was shut down in 2009, while Ekofisk HFIS and Tampen HFIS are still operational.

The continued existence of Tampen HFIS has been discussed for many years. In 2005, in connection with the merger between Saga Petroleum and Hydro (and eventually Hydro and Statoil), Saga wanted Avinor ANS to take over the ATS at Tampen, thereby shutting down the HFIS. DNV conducted a study in which they investigated safety critical interfaces and recommended that one local HFIS should be responsible for all traffic at Tampen in the short term, while Avinor ANS should take over in the medium term. At the time, Avinor ANS were not organised to support a split in the offshore sector in two areas, which would be a necessary consequence of extending the responsibility.

In 2016, Equinor wanted to shut down HFIS Tampen as part of the internal efficiency process in the company, and (implicitly) transfer the ATS responsibility to Avinor ANS. Traffic at Tampen was also reduced in this period, while Avinor ANS had better access to technical and operational resources to separate three sectors (i.e. Ekofisk, Balder and the rest). However, the Turøy accident put the takeover process on hold. The project was then resumed in 2018, and DNV was engaged to make a new assessment of the safety implications of such an acquisition. This report showed that an immediate transfer of services to Avinor ANS would increase the overall risk, but concluded that the safety level could be maintained on the condition that a set of safety measures were implemented.

Avinor ANS has conducted an internal analysis identifying several safety gains related to a possible takeover, notably regarding the coordination of arrivals and departures in the area. There is relatively much traffic going through Tampen, and there is also a need for good coordination with the neighboring British installations. Avinor ANS further established a project together with Equinor where the most relevant recommendations in the DNV report were considered. The objective was mainly to safeguard local knowledge including weather restrictions, obstacles, approach directions, etc., and train the ATC personnel accordingly. In the start-up phase, a sectoral split was planned in order to ease the transition.

The question of transferring ATS responsibility at Tampen from Equinor to Avinor has been – and still is – quite controversial. Very different views exist on how such a transfer will impact safety in the area, and there have been lengthy discussions between Equinor, Avinor ANS, CAA-N and the unions. As for the DNV study, some criticism has been raised from both camps. On the one hand, workers and pilot unions believe that the study is biased towards HFIS removal, that the proposed compensating safety measures seem difficult to fully implement, and that there are issues related to independence in the reporting process. On the other hand, Avinor ANS argues that there is an unfortunate and misleading confounding of "pure" air traffic services and the other services that the HFIS unit performs today (such as SAR, maritime surveillance, weather observation and logistics).

The main argument against transferring responsibility to Avinor ANS – as voiced primarily by the unions – is that safety will be impaired if the local, hands-on competence represented by the HFIS is removed. Furthermore, this will be a violation of the principle that any changes made on the NCS should improve – or at least maintain – the current safety level. This claim is conditionally supported by the DNV study. The local competence is related to the traffic situation, maritime activity, weather conditions (visibility, wind), emergency preparedness, and any other information obtainable from the use of low-altitude radar or eyeball vision. This allows for detailed and updated local information during the approach and landing phase. An air traffic service based on the mainland will obviously not be able to cover these aspects equally well.

The Tampen area has a busy and rather complex traffic picture today, with dedicated traffic to and from the installations, internal shuttling and through-traffic. There is also a need for coordination with the adjacent UK sector. In addition, there is also substantial maritime traffic, either serving the installations or passing through the area. Another element in the mix is the Hywind Tampen project, with 11 tall wind turbines being installed in 2022/2023, and possibly more in the future. We are likely to witness a significant wind power development on the NCS in the coming years, and notably the Trollvind wind farm on the Troll field in the Tampen neighborhood is on the drawing board. In addition to being air traffic obstacles, the turbines will also generate additional maritime traffic. Finally, drone flights transporting goods to and from the installations has recently started, and this activity is likely to increase significantly on the NCS in the coming years. Overall, in such an environment, it would be beneficial to have local surveillance and guidance all the way down to the helideck, especially in low-visibility conditions.

Avinor ANS, on the other hand, has ATS as its core competence and extensive experience in the domain, and foresees no particular problems with incorporating the Tampen area in the existing ATM structure. Oseberg HFIS was successfully closed down and transferred to Avinor ANS in the past. Although Tampen is a more busy and complex area compared to Oseberg, Avinor ANS sees no *principal* difference between Oseberg and Tampen – a claim that is also supported by the DNV study. Although some challenges may be expected in the transition phase (as pointed to in the DNV study), the position of Avinor ANS is that the future service will have the right quality.

January 2020 was originally set as the target date for the acquisition, but the application for transfer of responsibility was not accepted by the CAA. This means that ATS at Tampen is currently still Equinor's responsibility.

3.4.3 Meteorological service

Extending TAF (Terminal Aerodrome Forecast)
Some years ago, it was decided to go from issuing TAFs every three hours to every six hours. From the point of view of pilots, it is a negative thing that weather information is generally limited and not continuously available.

Triggered Lightning forecast system
The system includes a display as part of the weather service that shows when there is a danger of lightning. The system is run by MET and financed by the oil companies, and the helicopter companies have developed guidelines as to use the forecast for flight planning purposes. In the event of a lightning warning, there are two aspects that the helicopter companies must consider. First, helicopter operators will experience challenges in planning and conducting flights in some areas. Second, in the event of a suspected lightning strike / static discharge, inspections of the helicopter will be required, which can be costly and time-consuming.

Wave Warning forecast
EASA airworthiness requirements mandate wave height restrictions on offshore operations. To support the operators’ implementation, work was started in 2015, which resulted in an initial wave warning system being established in 2017. The system requires reliable and frequent forecast of significant wave heights for flight planning purposes. This was assumed best reported as maps. The maps are developed by MET and published every 6 hours. They display hourly significant wave height forecast for the next 18 hours for the entire NCS.

3.5 Organizational and market development

3.5.1 Helicopter operators

When it comes to the helicopter companies' organizations, there have been some major changes since HSS-3. In 2015, for example, there were 50 large helicopters on the NCS, while today there are 35. CHC was taken over by a private equity fund during the financial crisis in 2008 and was listed on the stock exchange in 2014 – however, this was not a success. CHC was sold in 2015 at a time when the oil market was challenging, and considerable overcapacity and volume globally as well as locally in Norway disappeared. The parent company of CHC entered bankruptcy protection ("Chapter 11") in May 2016. Internally in CHC, management perceived this as a sensible process - significant restructuring was carried out in the group, which for the Norwegian part of the company also resulted in halving the number of employees and the helicopter fleet. The new organization meant fewer regions in the group. Previously Norway was its own region but is now part of EMEA (operators in Europe, i.e. Norway, Ireland, UK, Netherlands and Kazakhstan). CHC operated leased helicopters that could be returned to leasing companies to get rid of "assets". After Chapter 11, CHC got new ownership at the group level.

CHC has offshore operations from bases at Sola, Bergen, Kristiansund and Brønnøysund, as well as some short-term contracts in the Barents Sea. In addition, there is shuttle activity for AkerBP at Valhall (Super Puma). Furthermore, CHC has offshore SAR bases on Statfjord, Oseberg, Johan Sverdrup and Heidrun. CHC also operates three onshore SAR bases (for the Ministry of Justice) at Florø, Tromsø and Longyearbyen. CHC has a rather complex operating model, comprising regular transport, offshore shuttling, offshore SAR/medevac and onshore SAR, operating both S-92 and Super Puma L/L1. The CHC management points out that this places some extra demands on the organization from a flight safety perspective.

Organizationally, CHC has had gradual growth in capacity in terms of people from 2016 onwards, with an increase in the number of pilots and technicians, as well as some increase in support functions. But it is still the case that CHC's management expectations related to the NCS (regardless of location in the value chain) implies increased efficiency and lower rates. Ergo, one must still work with efficiency and optimization in all parts of the business, i.e. the helicopter operators need to find smarter ways to work.

Bristow Norway has offshore operations from bases at Sola, Bergen, Florø, and Hammerfest, in addition to SAR bases on Ekofisk and Hammerfest. Bristow owns and operates a fleet of about 25 S-92 helicopters.

Bristow as a group – like CHC a few years before – applied for bankruptcy protection in 2019, with subsequent restructuring of the company. Bristow Norway was previously a subdivision of Bristow UK, but the two countries are now on the same organizational level. It is perceived positively by the Bristow organization in Norway to not be a subdivision to the UK, as the path to the Bristow management in Houston seems shorter today. Moreover, the reasons for the challenging economic situation are valid also beyond the Norwegian part of the group, something which the helicopter operators argue illustrates how challenging it can be for them to achieve profitability in the industry in general.

Bristow merged with Era Helicopters in 2020 but continues under the Bristow name.

It has been pointed out by technicians that change of management in helicopter companies can affect how incident reports are handled internally; the current impression is that there is now a more active follow-up of incident reports compared to previous years.

3.5.2 Contractual and competitive conditions

In general, there has been little change in the content of contracts between helicopter operators and oil companies. However, pressure on prices increased after the downturn in 2015. This pressure persists, although the activity level has since increased. Shortly after the Turøy accident, the pressure eased, but nowadays the oil companies are running a line to reduce costs, streamline and digitize again. Focusing on the economy is of course vital for any company, but it is claimed by trade unions that procurement departments represented by economists have too much power regarding contract terms at the expense of e.g. safety professionals within the oil companies.

Contractual conditions

According to helicopter operators' management and employee organizations, the contract terms for the helicopter companies have deteriorated, especially after the latest oil crisis in 2015. It is claimed that the pressure on margins will make it difficult to operate a helicopter company in the long run if this development continues. However, the oil companies do not necessarily agree that conditions are worse and tend to question the lack of transparency in the cost structure of the helicopter companies.

The industry experienced a period of decline as a result of the fall in oil prices in 2015, and the helicopter activity was also much lower. However, after some time, one gradually started focusing on maintaining volume, profitability, and competitiveness when oil prices stabilized at a higher level than feared. Yet, predictability can be low due to short-term contracts (for drilling rig operators), some down to thirty days (new benchmark on how long it will take to drill a well). Some contracts are for ninety days, some for half a year, and in some cases one year. From a commercial and financial perspective, managing a helicopter company involves a high utilization rate on the asset side, as well as keeping helicopters and employees in production to secure revenue.

Short and long-term contracts contain the same requirements to helicopter operations, e.g. the same maintenance requirements and procedures. Today, there are fewer machines operating from the same number of bases as before, making it more challenging to achieve the economies of scale associated with having many machines at each base. However, the rates are somewhat better on short contracts, but this is necessary to compensate for the extra costs linked to the need for higher capacity and flexibility to handle such contracts. According to the helicopter companies, the unpredictability means that overall profitability over time is not higher. The helicopter companies tend to bid on "all" contracts while expecting (and almost hoping) not to win everything, as excessive market alterations would put a lot of pressure on the organisation. Contract periods are normally predictable, but simultaneous start-ups are often challenging. Moreover, there is often uncertainty whether the actual flight program matches the contract, something which is described as "reliable unreliability".

At the same time, one sees cooperation initiatives from some oil companies for better utilization of flights through the so-called ticketing system. The helicopter operators seek to be involved, but they are somewhat skeptical that more risk will then be transferred from the oil companies to the helicopter operators.

Although oil companies compensate helicopter operators for most expenses associated with new requirements, the helicopter operators point out that they too have made investments in technology development over the past decade, where they have mainly taken the risk themselves. The helicopter operators also experience an unbalanced commercial risk in the overall contract structures - the operators carry the risks related to the business cycle, including capital risk when capacity is to be increased (capital intensive industry). However, the helicopter operators point out that nobody commands them to submit bids - by bidding the operators accept the risk both financially and commercially. Helicopter operators point out that they have made a significant contribution to reducing the costs of the oil and gas industry. The consequence is that you fly very much with the resources you have, i.e. with very little backup capacity available. Thus, when a helicopter is not airworthy, there might not be a reserve, and the operators are uncertain whether this perception of reality exists throughout the industry. This is seen in the context of several new oil companies in the market who often lack the maturity and experience of the larger and established oil companies. Newer and smaller oil companies tend to be more inclined to view helicopter services like everything else they buy, and they do not necessarily have dedicated professionals within the company to always ask the proper flight safety questions.

Labour costs

The helicopter companies point out that the cost level associated with operational personnel is high in the industry. This is challenging but it is all about supply and demand according to the management. Wage conditions in the offshore helicopter segment are significantly better compared to e.g. onshore helicopter and some segments of fixed-wing. Working conditions have been relatively stable over the last decade, however, according to the helicopter operators, wages in general have increased despite the fact that turnover and profitability have declined.

The NCS has fewer helicopters operating today than ten years ago, which means that each individual helicopter spends more hours in the air than before. In this context, flexible labor is needed, i.e. that employees are willing to work extra on holidays as well as overtime after normal working hours. According to the helicopter companies, they take the risk associated with the unpredictability of the market. Short time horizons regarding contracts thus make it difficult to contract new personnel. There is no historical tradition in Norway for the contracting of aircraft operational and technical capacity. However, there are some contracted technical capacity for special projects, but mainly the companies use own employees. The unions argue however, that contracting of technical personnel increases also for ordinary production in the helicopter companies. It is not unusual that retired technical personnel are contracted back into service. For pilots, on the other hand, there is no opening for contracting given the current agreements with the unions.

Safety paradox

Despite tough market conditions, the helicopter companies believe that industry safety standards are still high. Furthermore, they focus on shielding operational personnel – technicians, pilots and other personnel that keep the helicopters in the air in accordance with airworthiness requirements – from the possible pressure arising from contractual obligations. If the airworthiness requirements cannot be kept, operations will stop, and management will have to deal with the consequences. Management understands that operational personnel are experiencing more hectic periods now compared to previous years. How this affects safety is a complex, empirical question. It is difficult to know how this for example affects individuals. However, the management points out that a flight can be delayed two hours, two days, or two months if that is what it takes for the helicopter to become airworthy. A concrete example of this is a helicopter operating today on the NCS that spent a whole year getting in airworthy condition – with the consequences that entailed.

According to the helicopter operators, having much to do in terms of planning and implementation does not affect how the flight operations are conducted. The argument is that audits show this – it is a comprehensive audit program internally, as well as good feedback from customer and authority audits. The helicopter companies feel that they maintain their own high-quality demands in addition to the demands of the outside world.

However, the CAA-N is concerned that today's economic pressure on helicopter operators is still noticeable. The concern is shared by pilots, technicians, and other operating personnel, who express fear that downsizing can result in too few technicians and pilots, which might pose challenges if and when extra resources are needed (support functions, supervisors, senior captains, etc.).

Penalty regime

Unions as well as helicopter operator management argue that framework conditions for helicopter operators are still a major consern and have not improved since the HSS-3b study. For example, the penalty regime has remained relatively unchanged in recent years. The starting point is a monetary penalty based on how much the helicopter is delayed, but the helicopter operators strongly believe that this should be organised differently. There are alternative models that do not have the one-sided relationship between a single flight and a possible penalty. An example is measuring availability over a full year, alternatively quarterly or at a frequency that avoids the one-to-one relationship between delay and penalty for a single trip. Some advocate that penalties could be linked to the failure to fulfill other organizational "responsibilities" like keeping a sufficient stock of spare parts or allocating necessary resources. The penalty scheme is not something that the management communicates to the employees, but management recognizes that personnel at the sharp end have this in mind in day-to-day operations. Some oil companies are said to be more active than others in using penalties, while others do not have penalty clauses at all.

3.5.3 New industry stakeholders

HeliOffshore

HeliOffshore was established in 2014 and has a total of over 120 member organizations worldwide. It is a global initiative that works to support the offshore helicopter industry. The organization is for a large part financed by oil companies in the IOGP Aviation Sub-Committee. HeliOffshore´s main objective is to promote safety through members' collaboration putting industry resources together, with a particular focus on providing a global, industry-wide safety program. According to HeliOffshore, progress in safety may be obtained via four workstreams focusing on:

- System reliability and resilience
- Operational effectiveness
- Safety intelligence and data
- Survivability

The organization's safety strategy promotes the importance of ensuring a collective view on action-taking, and the need to be aware of industry best practices and associated implementation tools. Furthermore, the strategy emphasizes measuring the impact of safety actions, as well as a culture that facilitates stakeholder collaboration through knowledge and resource sharing. HeliOffshore is actively working to make available safety-related information to the industry through various guidelines, such as a e.g. a HUMS best practice guide and guidelines for flight path management.[2] The latter provide guidance on how to fly an approach, i.e. the respective roles and tasks of the pilot who flies and the pilot who monitors. In this context, FDM data was analyzed based on six parameters that operators contributed.

LO Helicopter Committee

The LO Helicopter Committee was established in 2014 and consists of 10 member organisations, mainly trade unions. The committee has representation from pilots, technicians, rescuers, passengers, operations centre, HFIS, emergency preparedness, safety and training. The committee meets quite frequently and organizes an annual helicopter seminar for trade unions in the industry. The main focus is safety and emergency preparedness within the helicopter segment. Offshore is the largest segment, but the committee also follows up inland and military helicopters.

The LO Helicopter Committee has permanent representation in HeliOffshore, as the only employee group. The committee is in continuous dialogue with key stakeholders such as helicopter manufacturers, helicopter operators, leasing companies, CAA-N, EASA, relevant ministries and oil companies. The committee has also created a collaboration group for the North Sea basin and assisted the UK and the Netherlands in setting up similar national helicopter committees. The collaboration group represents a new and regular point of contact for the exchange of information and experiences, as well as actual cooperation to improve helicopter safety.

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[2] https://www.helioffshore.org/resources

3.6 Regulatory authority, legislation and guidelines

3.6.1 The Civil Aviation Authority in Norway (CAA-N)

The Civil Aviation Authority in Norway (CAA-N) follows a risk-based approach when auditing, and regulations allow to extend audit cycles, but since the offshore sector is considered a complex operation, inspections are nevertheless performed on an annual basis. An audit/inspection from the CAA-N involves the following areas: Technical (Part-M and 145), operational, HSE and finance, in addition to inspection and technical check of helicopters. Route inspections are sometimes performed, where an inspector participate during helicopter flights (on a jump seat). Furthermore, the secondary bases (Florø, Bergen, Hammerfest, etc.) are also inspected. The management of the helicopter companies experiences the CAA-N as active and cooperative in general – an questions are answered quickly. However, the helicopter companies sometimes experience that the CAA-N spends quite a long time on specific case processing.

The CAA-N and its resources

The CAA-N has limitations in budget and personnel and needs to prioritise the right use of its resources. It means that regulatory activities like oversight, approvals, competence and so on are prioritised first. Other activities like e.g. EASA rulemaking groups and international projects will have to be prioritised based on available resources. For example, the revision and subsequent publication of BSL D 5-1 in 2019 was several years delayed. Audit work is carried out as previously with approvals and inspections, etc. However, the auditing process and methods (checklists, ICT tools) have improved and is adapted to EASA regulation 965/2012. Discrepancies and findings are communicated in a brief report to the operators. The introduction of risk-based oversight does not yet appear to have changed the method and scope of oversight to any great extent.

The "ABE reform" on reducing bureaucracy and increasing efficiency, has been challenging also for the CAA-N but improvement in efficiency and digitalization has made it possible to fulfil the expectations in the reform. So far, the CAA-N has been able to replace inspectors when someone quits, and there have also been increases in the budget for building up the section for unmanned aviation (the "drone section"), for cyber security and for digitalization projects. For offshore helicopter safety, on the operational side there are two inspectors who mainly work with offshore and one who partly works with offshore, i.e. 2.5 positions (FTE) on the operational side.

It is argued from several sources that there is potential to strengthen the operational helicopter experience within the CAA-N, including offshore experience. Furthermore, it is claimed and that there is also potential for increased collaboration between the sections internally in the CAA-N – for example between different technical disciplines, where there has been more collaboration in the past.

Collaboration with EASA and the Department of Transport

The CAA-N experiences challenges in properly following up and keeping the overall status on all the EASA rulemaking processes. However, the CAA-N is trying to participate in relevant EASA activities. They are represented in technical bodies and standing committees (as observer). The CAA-N is most concerned with "Rule making tasks" where rules are being developed, and aspire to participate whenever rulemaking work is carried out (regulation groups, consultation rounds, etc.). However, this requires time and resources, and the prioritizing of such tasks depends on available resources. It is also challenging to keep track of when activities start up. In general, it is demanding when regulations are developed internationally where the priorities do not necessarily coincide with the Norwegian interests. In this context, the CAA-N consider it of great importance that Norwegian conditions are reflected in new regulations, and they are therefore active in the consultation process. The CAA-N comments on a tendency that newer regulations appear to be more influenced by the market, e.g. "performance-based" to give more flexibility. This also tends to increase the workload on authorities to define criteria for compliance.

Regarding the scheduled helicopter route between Bodø and Værøy, the CAA-N gave input to the Department of Transport that one should strive towards offshore requirements for the route (i.e. need for lifejackets, life-rafts etc.). The argument was that if there had been a boat at the Værøy location, the offshore requirements would have been the starting point. Even though it is less than ten minutes to the mainland, offshore requirements should still apply. The Ministry agreed with the CAA-N, thus several offshore requirements such as performance, training, equipment, etc. (based on SPA.HOFO and the national additional requirements to HOFO in BSL D 2-3) were included in the contract requirements. The CAA-N found it positive that there was political agreement on this recommendation.

A need to improve maintenance definitions

Technicians point out that it is sometimes challenging to know if the maintenance is to be defined as either base or line maintenance. This is particularly important because the responsibilities a technician has during line maintenance are different from base maintenance. According to NHF (Norwegian Helicopter Employees' Association) maintenance defined as line maintenance involves simpler tasks where the technician issuing CRS (B1/B2) has full and complete responsibility for the work performed. On the other hand, base maintenance involves using a different setup to verify the maintenance done. For base maintenance, support staff (B1/B2 technician) are used, who will verify that the work performed is correct in accordance with current standards, regulations, and documentation. Upon completion of base maintenance, CRS (Category C) is issued based on supporting documentation and verification of the prepared performance documentation. The argument is that the CAA-N is not sufficiently clear on what distinguishes base and line maintenance, which can cause undesired situations with insufficient administrative control.

CAA-N is perceived as less visible

Labour unions point out that from an operational point of view the CAA-N is perceived as less visible, including less stringent audits and fewer physical visits from the CAA-N. According to technicians, the "simple2 things are addressed during audits, such as tool control and date labelling, while aspects such as organizational management competence and planning are not emphasized accordingly. It is pointed out that if the CAA-N is to identify system failure, it is also necessary to follow procedures from start to finish. This means focusing on process and component review with an understanding based on concrete insight, which the technicians believe the CAA-N possessed to a greater extent in the past. However, according to the CAA-N, the number of audits during the last years have been stable, except for 2020 that saw a dip due to Covid-19.

It is further commented from unions that the CAA-N lacks practical experience from offshore helicopter operations. Given the complexity of e.g. maintenance of helicopters, it is challenging for the CAA-N to obtain sufficient overview today unless they have received specific information in advance. One union proposes two aspects that the CAA-N should focus on in the future:

- sufficient operational competence to be able to ask the right questions to the helicopter operators
- more process-based oversight, i.e. participate out in the field and follow and review procedures from start to finish

More relevant competence is called for when the CAA-N conducts audits. Moreover, one of the unions comment that specific information the CAA-N has received unofficially is not necessarily reviewed, on the grounds that this is the company's responsibility. According to the union, this can be challenging if the helicopter companies are not aware of their own role responsibilities related to safety. However, from the technical operational point of view, the local management of the helicopter companies is seen as open-minded, which means that the CAA-N's lack of proactivity does not necessarily have safety implications.

3.6.2 Legislation

General regulations 965/2012 with amending regulation 2016/1199
The EU regulation on HOFO was introduced in July 2018 as a national regulation (BSL D 1-1). As part of the national regulations, the requirement for a Norwegian AOC is included. Formalization between the EU and Norway has not yet been established, but Norway acts on the basis that HOFO applies to operations on the NCS as a national regulation, not as a European regulation.

HOFO AltMoC
If a different way of complying with certain Implementing Rules (IRs) e.g. in HOFO are seen as necessary, a mechanism in the regulation called Alternative Means of Compliance (AltMoC) may be used instead of the published Acceptable Means of Compliance" (AMC). Operators can design their own AltMoC that can be approved as a substitute for specifications in the regulations. AltMoCs must be approved by the CAA-N, and EASA is informed. This is not necessary for HOFO, though, as it is a national regulation. Two prominent examples of AltMoC on the NCS are:

- **EBS Cat A:** The current re-breather does not cover the main intention of the implementation AMC. An alternative approach is to still use the re-breather (EBS Cat B) for passengers (all pilots have EBS Cat A when flying.) The requirement states that all on board shall "carry and be instructed in the use of breathing systems". Training and Cat A vs. Cat B requirements are addressed, partly in the AltMoC and partly in BSL D 2-3. The CAA-N points out that operators cannot expect to avoid Cat A in the long term, and encourages adhering to the requirement as far as possible. This includes making necessary preparations, execute training, change suit design etc. According to the CAA-N, it is necessary to find technological solutions and training regimes that do not increase the total risk of using Cat A. A risk assessment was carried out by the consultant OTG a few years ago, which showed increased risk when training with Cat A. HSS-3b, on the other hand, concluded that the safety benefit was unclear and that CAT A should not be introduced. A task group led by Equinor has started work towards the implementation of Cat A, but the trade unions are highly critical of this process.
- **Shoulder width:** AltMoC addressing seat placement and marking of passengers. A work group has also been established to work on this.

Wave height restrictions
The national guidance on the interpretation of EASA airworthiness directives on wave height restrictions was introduced on December 2017 (AIC-N 24/19). It was evaluated in autumn 2018 with adjustment and re-evaluation in May 2019. The guidance allows operations in higher seas during daylight on certain conditions than what is allowed on the UK side, but total risk has been considered, while not disturbing the flights more than necessary. There are also other limitations (fog, lightning, etc.), and perceived risk can increase when flights are canceled / postponed more often due to weather conditions.

Offshore helicopter operations regulation (BSL D 2-3)
BSL D 2-3 entered into force in July 2018 and contains additional requirements for 965 / HOFO. The requirements are partly based on customer recommended guidelines (ON-066) and partly a widening of the scope of some HOFO requirements to include all HOFO operations/aircraft. BSL D 2-3 is a starting point where the intention is to expand gradually.

BSL D 2-3 also sets requirements for equipment including anti-icing, ACAS II, and terrain warning system.

Helideck regulation (BSL D 5-1)
The new BSL D 5-1 entered into force in July 2019 with expanded guidance and formalized so that there is no doubt that it applies to the helicopter operators. The regulation is a further harmonization with ICAO and

CAP 437 and without drastic changes, but is to a greater extent "performance-based". Flight to wind turbines is not included.

Reporting regulation (376/2014)
The reporting regulation entered into force in Norway in July 2016. Many of the requirements were already met because previous Norwegian rules were quite similar. However, some requirements are more demanding for the aviation community as well as for the aviation authority, and this is a common European experience. The helicopter companies are good at reporting, but it is difficult for the companies to carry out risk assessments and follow-up as required by the reporting regulation. The CAA-N has established procedures to ensure that all submitted event reports are read, de-identified, quality checked and entered into a database utilized by EASA and all EASA member states. If needed, the CAA-N will ask the companies for supplementary information. In the case that several companies submit a report on the same event (e.g. one report from the helicopter company involved and one event from the air traffic service), the information from the different reports are combined, resulting in one single event in the database. The original reports will still exist, however. All occurrences are distributed to the inspectors according to their area of responsibility. The inspector assesses whether follow up of any event is needed or not. In some cases, the inspector immediately initiates dialogue with the company or companies involved to ensure that safety is assured. In other, less urgent cases, the event will be addressed during oversight activities at a later stage.

Also, looking for trends or groups of occurrences is part of the oversight planning process – i.e. identifying companies or areas of greater concern, to focus oversight activities. Standard statistics have been available for many years, but use of business intelligence tools to allow for even more and easier access to customized statistics will enhance the CAA-N’s utility of occurrence data. Work on business intelligence has started and the CAA-N has also improved mechanisms to ensure even higher quality of occurrence data. Hence, more and improved analyses are expected, which in turn will improve the CAA-N’s ability to identify areas of greater concern.

Operators indicate that there is still little useful output from these systems made available for use.

3.6.3 ON-066

It is pointed out by one of the helicopter operators that the ON-066 recommended guidelines has come a long way in the last ten years. ON-066 represents a joint expectation of how the industry should behave. The helicopter operators argue that if something is particularly important and has a real impact on flight safety, it should be a regulatory requirement, which involves supervision by regulators rather than customer follow-up. The helicopter operators are nevertheless loyal to the ON-066 guidelines although questions are raised about the necessity of some requirements. The argument is that requirements should be more empirically and professionally justified. For example, there are no guidelines for how guidelines should be designed, and quality assured per se.

Recently, some parts of ON-066 have also become regulatory requirements, which is considered a positive development. The guideline is owned and governed by the oil companies, although there is some involvement from other stakeholders e.g. when revisions are made. Given the strong status of ON-066, the question has been raised whether future 066 work should be a tripartite effort, like many other safety initiatives in Norway. The Committee for helicopter safety on the NCS is a good example of this, bringing together stakeholders from helicopter operators, oil companies, authorities, service providers and employee unions.

3.6.4 BaSEC

The Barents Sea Exploration Collaboration (BaSEC) was established in April 2015 by Statoil, Eni Norge, Engie (GDF Suez), Lundin and OMV, and subsequently all operators on the NCS were invited to join the collaboration. The purpose of BaSEC is to enhance exploration operations in the Barents Sea through increased cooperation and common solutions. The fact that industry players has come together to discuss special offshore safety challenges for the operation in Barents Sea is viewed as exclusively positive.

BaSEC has published reports looking into special challenges with operating in an artic environment, including recommendations for emergency response. The safety-related findings and recommendations in the BaSEC reports should be considered as possible requirements for future activities in the Barents Sea.

3.7 Emergency preparedness developments

3.7.1 SAR bases

Table 3.2 gives an overview of the SAR bases established by the oil industry, as well as the SAR helicopters used both before the Turøy accident (2016) and today. For Hammerfest, which is the only land base, area preparedness is today reduced to 15/30 min. Better facilities are still needed, including a new hangar and crew accommodation.

Table 3.2: Overview of bases and operational SAR helicopters.

Base	Before Turøy	Today	Comment
Hammerfest	H225	S-92	On land
Heidrun	AS332L1	AS332L1	Offshore
Statfjord B (Tampen)	H225	S-92	Offshore
Oseberg	H225	AS332L	Offshore
Johan Sverdrup	H225	S-92	Offshore; moved from Sola in 2019
Ekofisk	H225 (x2)	S-92 (x2)	Offshore

3.7.2 SAR helicopters

The transition from H225 to S-92 is completed except for the Heidrun and Oseberg platforms where hangar limitations still require the use of older Super Pumas. The primary purpose of offshore-based SAR helicopters is to carry out rescue within the safety zone of an installation, while everywhere else it is the responsibility of the national rescue service. However, helicopters in the oil industry are sometimes used for missions outside the safety zone, such as e.g. the Viking Sky incident.[3] This may represent a challenge if an offshore incident/accident occurs at the same time near an offshore installation or vessel. Oppositely, the national rescue helicopter service may also assist in offshore situations if needed. The introduction of the new national rescue helicopters (AW101) has improved the capacity of the national rescue service to carry out missions.

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[3] See e.g. (in Norwegian): https://industrienergi.no/nyhet/evakueringen-av-viking-sky-viser-hvor-viktig-den-offshorebaserte-helikopterberedskapen-er-bade-for-oljeindustrien-og-samfunnet-forovrig/

4 Development trends ahead and framework conditions

4.1 Helicopter technical development

From the pilots' point of view, there is an overall desire to be connected to the Internet during flight. This is something that is also communicated to Sikorsky. The reason is that this provides more updated lightning warnings, weather information as well as information about the current rig, etc. Pilots also want to introduce "live HUMS" – which is used within fixed-wing today. If this is introduced in helicopters, there will be a discussion about how the information is used, including whether data is to be communicated to the pilots during the flight, which is something the pilots themselves want.

With fly-by-wire technology (such as in the Bell 525), some new safety barriers may be introduced. It can be envisaged that the helicopter itself takes over in dangerous situations, e.g. in the event of obstacles (although the Bell 525 does not have this ability). A system that helps pilots in difficult situations is positive. However, it is problematic from a pilot perspective if the pilot becomes a passenger, as the recent Boeing 737 Max accidents and the Air France 447 crash in the Atlantic Ocean have shown. Fly-by-wire demonstrates how the helicopter industry is decades behind fixed-wing technology in some areas.

The preparation of an improved offshore terrain warning system is now under way. The HTAWS (Helicopter Terrain Avoidance Warning Systems – a further development of the EGPWS) is a SPA.HOFO / BSL D 2-3 requirement, but an improvement with specific helicopter offshore modes has been introduced in the IOGP OHRP 690 requirements. Only AW189 and AW139 have developed this feature today, much due to incentives from the IOGP Aviation Sub-Committee. S-92 and H175 are also in the process of getting this system.

4.2 Helicopter operational development

4.2.1 Drones, jamming and cyber attacks

Drones are a hot topic the industry and are currently used for offshore inspection and transport of goods. From an operational point of view, it is hoped that the CAA-N will be at the forefront so that drone operations remain a limited challenge for helicopter safety. There will likely be regulations imposing stricter requirements for drones. People with malicious intentions could cause a lot of damage with drones, as demonstrated by numerous disrupting airport infringements (e.g. at Gatwick south of London) and more recently (Autumn 2022) drone observations in the vicinity of offshore installations on the NCS.

Recent and repeated incidents of GPS jamming have been an eye-opener, especially for Avinor ANS who wanted to shut down all radar ground stations as part of modernizing the infrastructure. However, ensuring a backup solution to GPS using more traditional navigational aids, would require maintaining ground-based installations and equipment. Furthermore, false GPS signals (spoofing) that affect approaches can be dangerous, as pilots can be tricked into thinking that the helicopter is at a different location.

Safety issues related to drones and jamming correspond to the problem where pilots are blinded/disturbed by laser light. Barriers are needed to control this, which the CAA-N believes should be possible. However, the challenge of drones and jamming (and laser) applies to all aviation and is nothing special to offshore helicopter operations. This is not a regulatory issue at the moment but has been addressed in the Committee for Helicopter Safety on the NCS. Helicopters should possibly copy traditional aviation and to a greater extent be self-reliant in terms of navigation, which means alternative methods such as inertial navigation.

It is also the case that the helicopter operators' systems can be hacked, which can lead to a stop in helicopter operations for a period of time – this will be challenging given the socially critical importance of offshore helicopter traffic. This vulnerability also applies to the helicopters themselves in the event of a future connection to the Internet during flight.

4.2.2 Helicopter operations in the Barents Sea

Neither the CAA-N nor Avinor ANS fully share the understanding some industry players have about the Barents Sea representing a major and significantly different challenge, and they believe existing regulations are generally adequate. Beyond distances, infrastructure and facilitation of activity (satellite-based ADS-B and simultaneous communication), there is actually little difference between the Barents and elsewhere on the NCS according to the CAA-N and Avinor ANS. However, the oil companies point out that changing weather and long distances to alternative airports are indeed challenging. For example, Johan Castberg and Wisting will have installations far from land with no surrounding infrastructure. Moreover, according to the CAA-N, to maintain safety, suitable instrument (IFR) approach and departure procedures must be addressed, including at necessary alternative IFR landing sites with hangar facilities. This is relatively easy to arrange if desired but will entail financial costs.

Regulating air traffic
Avinor ANS points out that air traffic is well regulated in the south of Norway, while in the north it is more randomly regulated. The Barents Sea has operated with lack of procedures and route limitations, but efforts are being made to make traffic in the Barents Sea more regulated. When starting an operation from Kirkenes to Gjøkåsen including a SAR helicopter in Vardø, Avinor ANS investigated what was needed to secure such an operation. Avinor ANS defined a route via points into both Russian and ICAO airspace. A letter was sent to Russia to establish a point on the border and over the rig to exchange information, and the Russian reply was that this was okay as long as Avinor ANS took care of practicalities. Flying the route (first winter route) provided a lot of experience related to winter challenges.

Infrastructure development
Avinor ANS argues the need for further infrastructure development in the Barents Sea, since few oil discoveries mean a present lack of facilities offshore. As such, Avinor ANS has no base for its own equipment. Avinor ANS points out that one can have some fixed facilities on the coast but since the drilling operations are quite dynamic this can be challenging. As of today, short-term helicopter operations have largely flown to mobile rigs far from land. For example, Goliat is an exception located close to shore, and radiocommunications are working properly. However, ADS-B is put on hold until satellite-based ADS-B becomes available. Air traffic control and class D airspace means that one must have redundant coverage, i.e. satellite *and* ordinary ADS-B, alternatively *two* ADS-B's. As long as the airspace is not controlled, there is no requirement for redundancy. Moreover, future offshore UTM airspace for UAS operations is also something that needs to be addressed soon, both in the Barents region and elsewhere on the NCS.

Remote Tower Center (RTC) in Bodø
The CAA-N is closely following how the relocation of ATS units (particular Vardø AFIS and Kirkenes ATC with respect to offshore helicopter transport in the Barents Sea) will be handled at the remote tower centre in Bodø by Avinor ANS. This involves safeguarding local knowledge, "situational awareness", etc. The relocation must also be approved eventually by the CAA-N. From an EASA point of view, it is indicated that an appropriate procedure needs to be implemented for when both the "alternate aerodrome" and "destination aerodrome" is under the same RTC. In case of operations to several aerodromes from one RTC, RTC is identified as a possible single point of failure.

Need for QNH areas

In the Norwegian Sea and the North Sea there are QNH areas and a system for altitude setting in helicopters. In the Barents Sea, only two locations report atmospheric pressure. According to Avinor ANS, this will result in very high uncertainty about the helicopter flight height. Avinor ANS will introduce QNH areas in the Barents Sea in March 2022.

Information en route

In order to improve information en route, the following should be made available:

- HTI maps / wave forecast – the NCS features this, but insufficiently so in the Barents Sea.
- Improved SIGWX charts – Due to a limited number of airfields and a hostile flight environment, better charts should be made for the area east of 27° E.
- Autometar – available to all pilots regardless of opening hours of the airfield.

Exploiting the BaSEC collaboration

The fact that offshore operators have joined forces into a special collaboration regarding operations in Barents Sea, indicates that this area merits special considerations. The collaborative structures established should be exploited further, and the BaSEC reports should become recommended practice for activities in the Barents Sea (cf. 3.6.4).

4.2.3 Space-based ADS-B

In 2018 Avinor ANS established a project to look into the use of space-based ADS-B to reduce the separation between high-level airline traffic in Bodø Oceanic FIR (OFIR). In parallel, the Committee for Helicopter Safety on the NCS established a working group to look into the safety of helicopter operation in the Barents Sea, which recommended Avinor ANS to establish satellite-based surveillance over the Barents Sea to improve the information and alerting service for offshore helicopters. The space-based ADS-B-project tested together with satellite provider Aireon in 2019 the low-level coverage over the Barents Sea to investigate whether helicopters operating over the NCS could be provided with spaced-based ADS-B surveillance service. The test was a success and the surveillance of low-level helicopter traffic in the Barents Sea became part of the project.

One of the results of the pandemic in 2020 (and later the closure of Russian Airspace in 2022) was a big drop in numbers of high-level Atlantic crossing airline traffic, and this industry withdrew their support to the space-based ADS-B project. However, the petroleum industry (via Offshore Norge) accepted to finance the project by the Offshore Cost Base as a spaced-based ADS-B Offshore project only, and after technical set-up and testing, a spaced-based ADS-B surveillance service became operational in June 2022, provided by Avinor ANS Polaris ACC Bodø.

The polygon for surveillance coverage is limited within Bodø OFIR, with an addition to the eastern area of the NCS below Murmansk FIR. The spaced-based ADS-B is certified for information and alerting service only, so the surveillance coverage is filtered out in the CTAs along the Norwegian coast.

4.3 Industry fora and regulations

The Committee for Helicopter Safety on the NCS

There is a general agreement between industry players that the Committee for Helicopter Safety on the NCS (CHS) must continue to exist. The committee serves several purposes and is an active player in the helicopter community. One of the most important functions of CHS has been to follow-up the implementation of proposed safety measures. However, the activity in the committee is lower than before, and financing is an issue. The members have made suggestions to revitalize the committee, but it has proved challenging to come up with concrete measures. For example, Off would like to see changes, and the CAA-N is also not content with the way it works today. It is necessary to discuss how CHS can be developed further. What should the committee focus on? How should the committee work? How is progress secured? Who should be the driving force? How to follow up various assignments? As a first step a new mandate and statutes for CHS have been established by the Director General of CAA-N in November 2020.

New weather regulation (BSL G 7-1) and new weather service
A new pan-European weather regulation (for aviation in general) was introduced in 2020, replacing the existing one. It is incorporated in regulation (EU) 2017/373, and the implementing regulation BSL G 1-3 implements this regulation in Norway – with national additional requirements. BSL G 7-1 was subsequently amended and is now a dedicated Regulation on weather service on the NCS. To clarify the importance of the weather service in offshore helicopter operations, and to set requirements for the business, it was decided that existing Norwegian weather regulations would be transformed into offshore weather regulations (which is nationally regulated as the NCS is not included in the EEA agreement), as national additional requirements.

EASA amendment regarding CAMO
The CAA-N recently sent for consultation EASA's proposed amendments to Commission Regulation (EU) No 1321/2014, i.e. to change today's regulation governing CAMO in relation to an air carrier's AOC by way of allowing for moving CAMO out of the AOC, and to a third party. The industry response to this proposal is overall negative. The concern is that this is just the beginning when it comes to fragmentation of the AOC and that subcontracting CAMO will imply less responsibility, competence and audits within Norway – thereby threatening safety.

The change entered into force in the EU with the publication of Commission implementing regulation (EU) 2022/410 in March 2022 and the associated EASA ED Decision 2022/017/R in September 2022.

The situation is quite similar to the HOFO discussion a few years back, which ended up with additional national requirements being introduced to ensure national control. CAMO in this discussion was assumed to remain integral to the AOC. Nobody could foresee such a development, which is probably the reason why this is not specifically addressed in the national implementing regulation in BSL D 1-1 § 4a.

Helideck supervision
The authority role for helidecks is already described in NOU 2001:21 (and also proposed as a measure under HSS-3) and has now been taken up again - to prevent helideck supervision from falling between several regulative authorities. In a consultation letter, it has been suggested again that the CAA-N should have primary responsibility for helideck oversight.

4.4 Framework conditions for safety

The following section considers the extent to which key development trends in the period 2010–2020, as well as expected trends in the next ten-year period, will affect helicopter safety offshore. The assessments are based on collected data (empirical material) and are discussed in the context of selected safety theoretical perspectives.

4.4.1 Organizational fragmentation and re-fragmentation

Organizational fragmentation and re-fragmentation involve splitting an organizational entity into more entities – or the opposite through consolidation of an organization's elements – be it structural features at the corporate level, such as dividing a company into multiple units, or outsourcing tasks to external players, such as hiring various services. Moreover, fragmentation is also about change internally within an organization through, for example, changing (splitting up) competence requirements or role responsibilities for the performance of various tasks.

When it comes to the helicopter companies, both Bristow and CHC have been through chapter 11 processes since HSS-3, which resulted in reorganizations and new corporate-level structures, for example fewer regions in the group for CHC's part, i.e. a re-fragmentation of the corporate structure. Heavier helicopter maintenance is also seen outsourced, for example to the UK, something which might result in reduced maintenance competence within the helicopter companies as well as nationally. It is envisaged that geographical and organisational distance will reduce the understanding and control as to what has actually been performed technically. This may in turn result in uncertainty related to the helicopter's real technical status when returning from maintenance performed by an external operator.

Another example of organizational fragmentation internally in the helicopter companies is the change in competence requirements associated with the performance of specific roles. An example is the current use of personnel without specific technical competence related to long-term planning. According to helicopter technicians there are quite a few personnel who do not possess the proper technical know-how, which can be at the expense of proactive maintenance work on the helicopters.

The establishment of Tampen HFIS and the possible transfer of services from Equinor to Avinor ANS can also be seen in the light of organizational re-fragmentation in the sense that Avinor ANS is the primary air traffic service provider in Norwegian airspace. However, strong skepticism exists concerning the lack of local knowledge if the service is to be delivered centrally by Avinor ANS controllers. Moreover, one can talk about organizational fragmentation related to the maintenance of helicopter-specific competence at the CAA-N, considering limited resources on the personnel side, including the lack of concrete follow-up of submitted reports from the operators in the helicopter industry. Limited collaboration internally and across sections within the CAA-N is a similar example of fragmentation of organizational competence.

Whether it is about organizational fragmentation or re-fragmentation this type of change at the organizational level means that different actors will experience changes differently. This may impact how risk and helicopter safety is handled; what constitutes a risk to some may be perceived completely differently by others. For example, it can be argued that the proposed changes in Tampen HFIS are *positive* for air traffic controllers who are given responsibility for a larger part of the airspace, which could result in an increased situational understanding, while at the same time *negative* for pilots, who may experience increased uncertainty related to local weather conditions under special circumstances. This is in line with Perrow's (1999) notion of complexity, where it can be argued that air traffic controllers can experience the system becoming less complex through increased system understanding, while pilots, on the other hand, can experience increased complexity linked to flying under special conditions.

Organizational changes understood as framework conditions for safety (Rosness et al., 2012) do not necessarily give unambiguous answers. Furthermore, organizational re-fragmentation can also be challenging for safety if viewed in light of HRO (Weick & Sutcliffe, 2015) and as such a loss of redundancy that might challenge safety (Reason, 2001).

4.4.2 The Civil Aviation Authority's (CAA-N) power and powerlessness

Power can be understood in various ways (Rosness, Blakstad & Forseth, 2011) and can, for example, be seen in the context of what actions an actor takes to influence others, or through an actors' available resources, or through collaboration and networking. Furthermore, power can also be explored via symbolism and language discourse. We will now discuss how changed framework conditions can influence the regulatory impact of the CAA-N, especially the power to be able to influence both how regulations are drafted internationally, as well as how to fulfil national supervisory tasks.

The CAA-N points out that available resources for use on offshore helicopters are limited, which can be seen in the context of the ABE reform and may affect how the CAA-N performs its supervisory role. One can argue that there is a link between limited helicopter resources in general and the perception of a less visible CAA-N, including for example less stringent audits and follow-ups as experienced by the helicopter technicians. The CAA-N has limited personnel resources available, and particularly few people with explicit offshore helicopter experience. Challenges related to collaboration with EASA, for example regarding rule making tasks, are also seen in the context of the current resource situation for the CAA-N. At the same time, it should be remembered that this is complex – for example, there may be processes and framework conditions anchored outside Norway's borders that affect Norwegian certification and oversight work.

Although the current resource situation may seem somewhat inhibitory for the work of the CAA-N, we also see that the CAA-N actively seeks to influence regulatory frameworks within EASA, exemplified by previous work on HOFO regulations internationally. Moreover, the Ministry of Transport's acceptance of offshore requirements for the route between Bodø and Værøy shows how the CAA-N (on the basis of its own available resources) exhibits power when influencing national regulations, at the same time as the CAA-N also shows power when approving and using, for example, specific requirements in BSL-D. One can argue that these types of regulations also constitute important (external) framework conditions for the CAA-N's safety work, when following up actors in activities based on regulatory frameworks the CAA-N has played an active role in developing.

The CAA-N is influenced by, and at the same time also influences, other industry actors based on the various resources available to them. Consequently, access to sufficient resources is one of several key factors for the CAA-N's ability to exercise the supervisory power that is expected. For example, unions argue that since the CAA-N visits helicopter companies less frequently than in previous years, including less stringent audits and follow-ups, there is a possibility that audits do not necessarily reveal the whole and full truth. If this argument is tenable, it can for example be seen in the context of an "*Efficiency-Thoroughness Trade-Off*" (Hollnagel, 2004; 2009), i.e. a goal conflict between requirements for efficiency versus thoroughness (read: safety). This can potentially lead to the development of local technical variability, or adaptability. The research literature shows that results of such adaptability need not always be beneficial to safety and may also result in changed framework conditions for other actors, for example pilots. If a supervisory authority does not have the competence to ask the right technical questions where it is crucial, an important safety critical barrier will be missing, i.e. one lacks redundancy (Reason, 2001). This type of situation can also result in undesirable organizational drift as Vaughan (1996) describes.

4.4.3 New technologies and their affordances

New technology can be experienced differently by various users. A technology is either enabling or restrictive, and Hutchby (2001) argues that technology can be viewed based on its *affordances*, meaning to enable or limit certain forms of (intended) use. Importantly, a technology's affordances can only be identified by exploring the context in which the technology is being used. Therefore, it is important to properly consider the end users' actual needs when introducing novel technology, especially when this technology is to be part of a safety critical system.

According to technicians HUMS has improved progressively, and the system has become more intuitive and easier to understand. HUMS is now treated as an integrated system in the helicopter, so any deviations in parameters are treated similarly to other system deviations, which according to technicians makes more sense. However, it is still a task for specialists to interpret HUMS data including identifying trends. Through FDM data helicopter operators also have a system that monitors how the helicopters are flown, including grading of events based on pre-defined parameters. FDM technology has e.g. contributed to identifying unwanted low nose pitch during takeoff, thus enabling corrective measures at an early stage. Hence, HUMS is an important system for monitoring primarily the technical parameters of the helicopter during flight, while FDM also registers how the pilots fly, providing the opportunity to also analyze human performance.

It is important to bear in mind that pilots and management may view FDM data differently. The former can potentially see any individual follow-up based on FDM data as intrusive to privacy, while the latter may view this as a good tool for monitoring and controlling the operation of the company's helicopters. In order to achieve the intended safety affordances, it is required that the users have proper system insight through training, and that they preferably have the opportunity to influence the system design from the beginning. Moreover, FDM parameters are also defined differently between countries, which can have varying effects on the utilization. However, the example of low nose attitude identification during takeoff can be seen in the context of FDM's potential to prevent undesirable drift, as described by Vaughan (1996).

At the same time, the introduction of ACAS II prevents adverse situations between aircraft if pilots and air traffic controllers receive adequate training in the system. Similarly, ADS-B provides air traffic controllers with increased situational understanding, which is imperative for delivering efficient and safe flight and information services, including to SAR. These two technologies potentially reduce complexity within the air traffic services, while one could also argue that system couplings can loosen (Perrow, 1999), i.e. that more system redundancy is introduced (Weick & Sutcliffe, 2015) if user's know-how and needs are acknowledged.

4.4.4 Concluding remarks: The importance of understanding framework conditions when working with helicopter safety

This chapter has coupled development trends in the industry with the notion of framework conditions for safety (Rosness, et al. 2012) and discussed how these changes can affect helicopter safety offshore. It is important to recognize that these are thematic issues that do not produce definite answers. Rather, it is our ambition that the material presented motivates further reflections on key aspects related to helicopter safety. Based on developments and changing framework conditions for safety, we outline three key learning points related to an applied use of framework conditions – aspects we believe are important to recognize as prerequisites for further work related to maintaining safe helicopter operations offshore.

Framework conditions for helicopter safety need to be understood at different levels (society, organization, individual): By looking at framework conditions for safety against globalization aspects, it will be possible to see that framework conditions must be understood from different levels - for example how ACAS II through regulations entails technological change which in turn entails changing requirements for competence among pilots related to how the system is used safely.

Various framework conditions for helicopter safety are interconnected: This implies that preconditions that actors have for managing risk are interconnected. Changed framework conditions will affect an actor, which in turn will lead to changed framework conditions for other actors. An example related to helicopter companies is contracts featuring penalty clauses due to market conditions, which in turn can affect technicians and pilots and their risk management.

Various framework conditions for helicopter safety have varying impact on actors' ability to manage risk: Some framework conditions provide preconditions for safety that other actors may experience differently. This is played out on a horizontal organization/group/individual level. For example, one can hypothesize that air traffic controllers located onshore have other preconditions and might need to develop other strategies for mitigating risks related to local rig conditions compared to people actually working offshore on the rig.

5 Statistics 1999–2019

This chapter gives an overview of relevant statistics for helicopter safety focusing on the NCS for the period 1999–2019. The information presented here can be seen as an extension of the material found in the HSS-3/3b reports. The following sources have been used for obtaining new data post HSS-3/3b:

- Traffic volumes on the NCS from CAA-N
- Traffic volumes on the UKCS from CAA
- Reported incidents to CAA-N
- Accident investigation reports from NSIA
- Accident investigation reports from AAIB UK

5.1 Summary of accidents and serious incidents on the NCS

In the period 2010–2019 there have been two accidents and two incidents classified as "serious" on the NCS. Considering the extended period from 1999, three accidents and twelve serious incidents have been registered. Table 5.1 gives an overview of accidents and serious incidents for the period.

Table 5.1: Accidents and serious incidents on the NCS 1999–2019. Accidents are depicted in boldface.

No.	Date	Helicopter	Accident category	Description
1	01.03.2000	AS332L2 LN-OHG / S-61N LN-OSJ	A4 Mid-air collision	Loss of separation between departing and approaching helicopters at Bergen airport
2	26.06.2001	AS365N2 LN-ODB	A5: Controlled flight into terrain	Loss of visual references and control when attempting landing at the Hod installation in fog
3	**05.11.2002**	**AS332L2 LN-ONI**	**A2: Emergency landing**	**Damage to main rotor blade during approach to Stavanger airport, emergency landing on ship**
4	19.08.2002	S-76C+ LN-ONZ / AS332L LN-OLB	A4 Mid-air collision	Loss of separation between two helicopters near Heimdal (installation)
5	08.01.2004	AS332L2 LN-ONI	A1 Helideck/heliport	The tail rotor guard caught the helideck net during take-off from Transocean Searcher (installation)
6	13.05.2004	AS332L G-TIGV	A2 Emergency landing	Inspection hatch detached and damaged tail rotor in flight, emergency landing at Grane (installation)
7	09.07.2004	AS332L2 LN-ONI	A4 Mid-air collision	Approach to Stavanger airport, loss of separation to a helicopter on a test flight (AS332L2 LN-OHK)
8	21.01.2005	AS332L LN-OLB	A1 Helideck/heliport	Near collision with obstructing crane during landing at Kristiansund Airport
9	10.06.2006	AS332L2 LN-ONH	A1 Helideck/heliport A7 Person outside	Tail rotor close to personnel and obstacles during take-off (hover) from Snorre B (installation)
10	21.04.2007	S-76C+ LN-ONZ	A1 Helideck/heliport	Blocking of pedals for yaw control during landing at Stavanger airport

No.	Date	Helicopter	Accident category	Description
11	28.04.2009	Bell 214ST LN-OMM	A2 Controlled emergency landing	Exhaust pipe detached during shuttling at Tampen area, minor damage to tail rotor
12	01.04.2010	S-92 LN-OQE	A2 Controlled emergency landing	Pilot's seat became detached during approach to Gullfaks B (installation)
13	12.01.2012	H225 LN-OJE	A2 Controlled emergency landing A1 Helideck/heliport	Partial loss of hydraulics, emergency landing at Åsgard B platform, loss of wheel brakes on helideck
14	**29.04.2016**	**H225 LN-OJF**	**A3 Uncontrolled collision with terrain**	**Crash at Turøy after main rotor detachment, 13 fatalities**
15	**05.07.2016**	**S-92 LN-OND**	**A8 Ground collision**	**Damage to main rotor from collision with parked vehicle during taxi**

The table above refers to the different accident categories described in section 2.4. A distribution of the accidents/incidents based on accident categories are presented in Figure 5.1. Note that those events (9 and 13) that are placed in two categories also count as double in the figure below, thus the total is not accurate. This is subordinate since the purpose is to describe frequency/importance among the accident categories themselves.

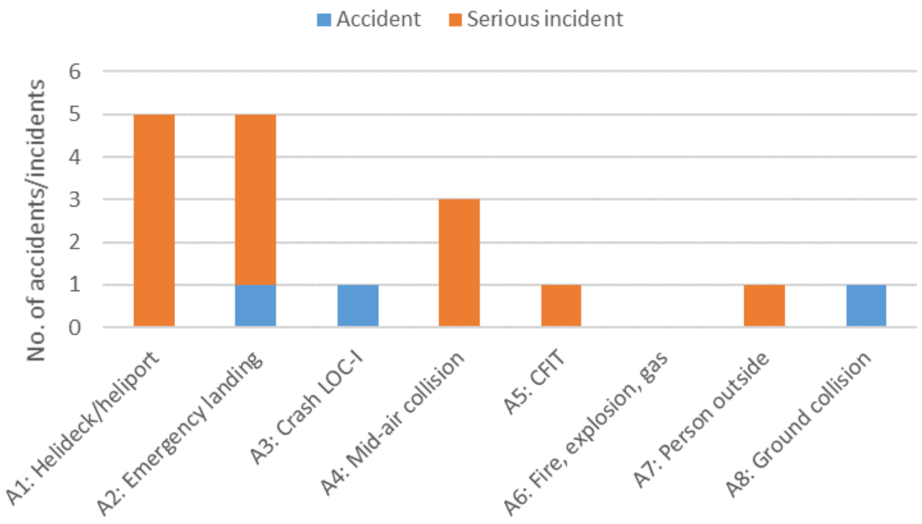

Figure 5.1: Distribution of accidents and serious incidents based on accident category; NCS 1999–2019.

Figure 5.2 presents how accidents and serious incidents are distributed per year for the period 1999–2019. We observe a clear reduction in the number of serious incidents over the last years. However, it should be noted that recent data from 2020 (not shown) features two serious incidents – the first since 2012.

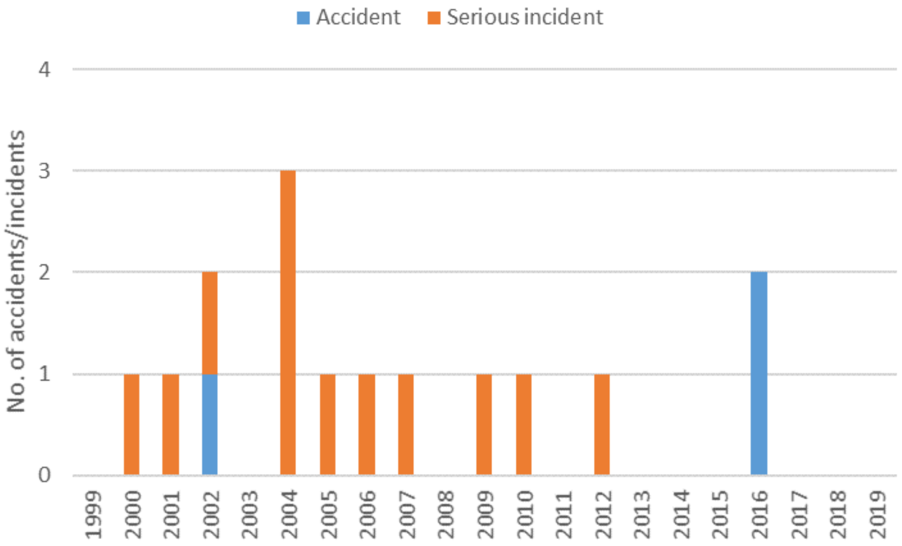

Figure 5.2: Accidents and serious/major incidents per year; NCS 1999–2019.[4]

5.2 Traffic volume

Table 5.2 and Figure 5.3 presents the traffic volume for passenger transport on the NCS for the period 1999 – 2019, based on data from CAA-N. The data relate to regular passenger transport, hence training, testing, cargo flights, medevac and rescue operations are not included. Similar data for the British sector are presented for comparison. The data are also used for calculating the accident statistics in Table 5.4 below. Note that some traffic data are missing; resulting statistics have been estimated and put in italics.

Table 5.2: Traffic volumes in the Norwegian and British sector 1999–2019. Number in italics are. estimates.

Year	Norwegian Sector				British Sector	
	Passenger transport	Shuttle	Flight hours	Person flight hours	Flight hours	Person flight hours[d]
1999	37 912	4 840	42 752	707 543	*78 208*[c]	*570 133*
2000	39 887	5 352	45 239	727 134	78 208	*570 133*
2001	40 670	5 692	46 362	775 708	82 180	*599 088*
2002	38 016	5 140	43 156	725 063	81 537	*594 401*
2003	38 877	5 356	44 233	705 953	73 139	*533 180*
2004	36 269	5 517	41 786	697 807	69 674	*507 920*
2005	38 280	5 279	43 559	720 368	76 919	*560 736*
2006	39 207	6 346	45 553	659 076	71 884	*524 031*
2007	39 848	5 092	44 940	671 337	76 254	*555 888*
2008	38 577	4 510	43 087	725 790	76 900	*560 597*
2009	47 110	121[a]	47 231	717 541[b]	71 865	*523 893*

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[4] Note that there are small deviations from the overview presentation in the HSS-3 report due to a later reclassification of incidents.

2010	46 299	4 352	50 651	709 587	72 557	*528 937*
2011	49 132	4 730	53 862	747 186	77 611	*565 781*
2012	53 095	4 065	57 160	759 862	86 134	*627 913*
2013	56 422	3 246	59 668	859 000	77 257	*563 200*
2014	58 178	2 346	60 524	879 000	78 984	*575 790*
2015	44 805	1 100	45 905	690 818	69 052	*503 386*
2016	35 158	1 547	36 705	468 027	*55 213*	*402 503*
2017	32 553	2 030	34 583	514 531	*52 021*	*379 233*
2018	36 082	2 323	38 405	559 474	*57 770*	*421 145*
2019	38 857	2 376	41 233	564 310	*62 024*	*452 156*

Note a: Shuttle volume in 2009 is low due to missing reporting. The total number of flight hours is assumed to be correct.
Note b: The number for NCS in 2009 is estimated as the average of 2008 and 2010.
Note c: Flight hours for the British sector for 1999 is estimated to be the same as for 2000.
Note d: Person flight hours for the British sector in 2010–2019 are estimated based on the same seat utilisation as for the period 1999–2009.

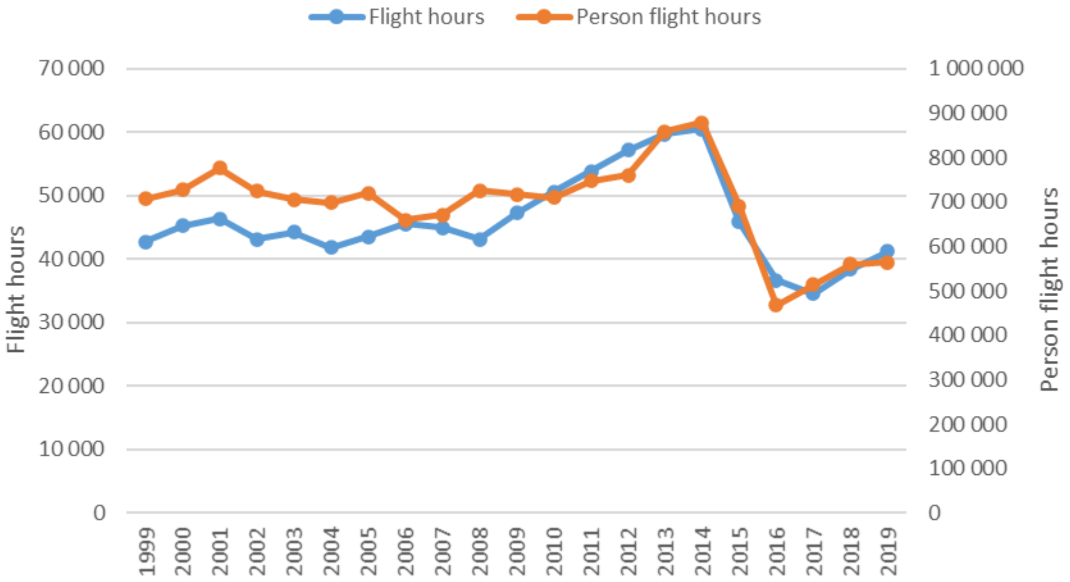

Figure 5.3: Traffic volume in the Norwegian sector 1999–2019.

Figure 5.3 depicts a relatively stable traffic level for the first part (1999–2009) of the period, after which it increases steadily and peaks in 2014. After 2014 there is a considerable drop in volume back to a level lower than before the increase. This coincides with the business downturn in 2015. After 2016–2017 the traffic volume is slowly increasing again.

The figure also shows that the ratio *Person flight hours* / *Flight hours* is lower in the second half of the period, indicating that the average number of passengers per flight has gone down a little.

It should be noted that traffic data for 2020 (not shown) indicate a steady level of flight hours but a notable drop in *person* flight hours. The latter is a specific effect of the Covid-19 pandemic, causing reduced activity (fewer workers) on the NCS. However, as the seat utilization has decreased too due to cabin separation demands, the number of flight hours has been maintained.

Moreover, Table 5.2 above shows that the British sector has significantly more flight hours compared to the NCS, but at the same time far fewer *person* flight hours. This implies a lower average number of passengers on British flights, which may be explained by more frequent use of smaller helicopters and a lower seat utilisation (due to e.g. more extensive use of shuttling).

5.3 Accidents in the Norwegian and British sector

In the period 2010–2019 there have been six accident (two fatal) in total in the Norwegian and British sector: two in Norway and four in the UK. Looking at the whole period from 1999, there are in total 19 recorded accidents (5 fatal); 16 of these accidents occurred on the UKCS and 3 on the NCS. The accidents are summarised in Table 5.3. A more detailed presentation and analyses of the accidents are presented in chapter 6.

Table 5.3: Accidents in the NO and UK sector in the period 1999–2019.

No.	Date	Helicopter	Place	Fatalities	Survivors[a]
1	2000-02-15	AS332L	UK	-	-
2	2001-07-12	S-76A	UK	-	-
3	2001-11-10	AS332L	UK	-	-
4	2002-02-28	AS332L	UK	-	-
5	2002-07-16	S-76A	UK	11	0
6	2002-11-05	AS332L2	NO	-	-
7	2006-03-03	AS332L2	UK	-	-
8	2006-10-13[b]	AS332L	UK	-	-
9	2006-12-27	SA365N	UK	7	0
10	2008-02-22	AS332L2	UK	-	-
11	2008-03-09	SA365N	UK	-	-
12	2009-02-18	H225	UK	-	-
13	2009-04-01	AS332L2	UK	16	0
14	2012-05-10	H225	UK	-	-
15	2012-10-22	H225	UK	-	-
16	2013-08-23	AS332L2	UK	4	14
17	2016-04-29	H225	NO	13	0
18	2016-07-05	S-92A	NO	-	-
19	2016-12-28	S-92A	UK	-	-

Note a: Survivor numbers are given only for the fatal accidents.
Note b: Accident no. 8 was not included in the HSS-3 report as the investigation report from the AAIB was not published and the classification not set.

5.4 Statistical risk

In Table 5.4 accident data and traffic data for both the Norwegian and British sectors are summarised for the period 1999–2009 (HSS-3), 2010–2019 (HSS-4) and the combined period 1999–2019 (HSS-3 and 4). There are no quality assured data for traffic volume for 2009 for the NCS, so this number is estimated as an average of the 2008 and 2010 data. For the British sector, data for 1999–2009 stem from the HSS-3 report, while data for 2010–2019 are estimated based on registered flight hours and an assumed average number of persons per flight equal to that of the previous period (1999–2009). Since some (the lesser part) of the traffic data are estimated, parts of the statistics shown in the table are to some degree uncertain. Estimated numbers are in italics.

Table 5.4: Traffic and accident statistics for the Norwegian and British sectors 1999–2019. Numbers in italics are estimates.

Parameter	**HSS-3: 1999–2009**			**HSS-4: 2010–2019**			**HSS-3/4: 1999–2019**		
	NO	UK	NO+UK	NO	UK	NO+UK	NO	UK	NO+UK
Million-person flight hours	*7,8*[a]	6,1	*13,9*	6,8	*5.0*[b]	*11,8*	*14.6*	*11.1*	*25,7*
Number of accidents	1	12	13	2	4	6	3	16	19
Number of fatal accidents	0	3	3	1	1	2	1	4	5
Rate of fatal accidents	0	0,25	0,23	0,5	0,25	0,33	0,33	0,25	0,26
Number of fatalities	0	34	34	13	4	17	13	38	51
Accidents per mill. person flight hours	*0,13*	1,97	*0,93*	0,30	*0,80*	*1,09*	*0,21*	*1,35*	*0,70*
Fatalities per accident	0	2,8	2,6	6,5	1,0	2,8	4,3	2,4	2,7
Fatalities per mill. person flight hours	**0**	**5,6**	***2,4***	**1,9**	***0,8***	***1,4***	***0,9***	***3,4***	***2,0***

Note a: The number for NCS in 2009 is estimated based on 2008 and 2010.

Note b: Person flight hours for the British sector in 2010–2019 are estimated based on the same average number of persons per flight as in the previous period (1999–2009).

For the NCS, the number of fatalities per million-person flight hours is **1,9** for the HSS-4 period (2010–2019), based on one fatal accident with 13 fatalities. This is an increase from **0** in the previous HSS-3 period (1999–2009), as there were no accidents with fatalities in that period. The average for the combined HSS-3/4 period is **0,9**.

For the British sector, the corresponding results are **0,8** fatalities per million-person flight hours for the HSS-4 period (one fatal accident with 4 fatalities), **5,6** for the HSS-3 period (three fatal accidents with 34 fatalities) and **3,4** for the combined HSS-3/4 period 1999–2019 (four fatal accidents with 38 fatalities).

For the NO and UK sectors combined there were **1,4** fatalities per million-person flight hours for the HSS-4 period (2010–2019). This is a reduction from **2,4** in the previous HSS-3 period (1999–2019). For the combined HSS-3/4 period (1999–2019) the average is **2,0** for the NCS and UKCS combined.

Figure 5.4 illustrates the development in the number of fatalities per million-person flight hours over the various HSS periods in the Norwegian and British sector, as well as combined. In the figure the first four column groups are results from the four previous HSS studies, while the last column group show results from the combined HSS-3/4 period.

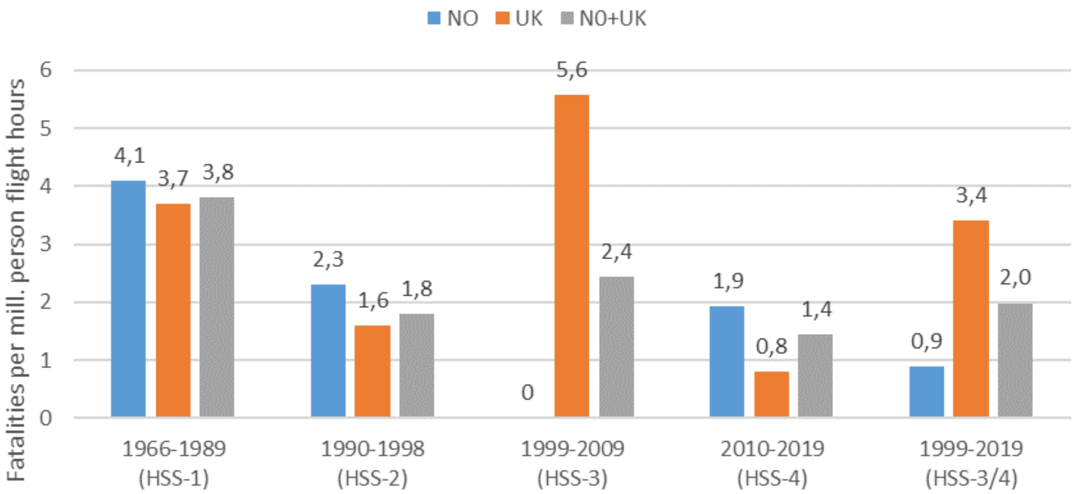

Figure 5.4: The number of fatalities per million-person flight hours on the Norwegian and British sectors and combined. Results are shown for the four different HSS periods as well as for the combined HSS-3/4 period.

Furthermore, Figure 5.4 demonstrates the following:

- The statistical risk for the NCS shows a clear positive trend through the HSS periods 1–3 but increases in HSS-4 due to the Turøy accident.
- There is no particular trend in the development of statistical risk in the British sector.

It must be stressed that the statistical risk as calculated here is highly sensitive to single fatal accidents like e.g. the Turøy accident. Hence, great caution must be taken when attempting to draw conclusions based on such a thin data material.

Figure 5.5 depicts the number of fatalities per million-person flight hours in the Norwegian and British sector combined for the period 1975–2017 (5-year moving average). A large and stable improvement after around 1990 is indicated, with some variation from 2004 and onwards. However, the global trend from the 1970-ies is showing a notable reduction.

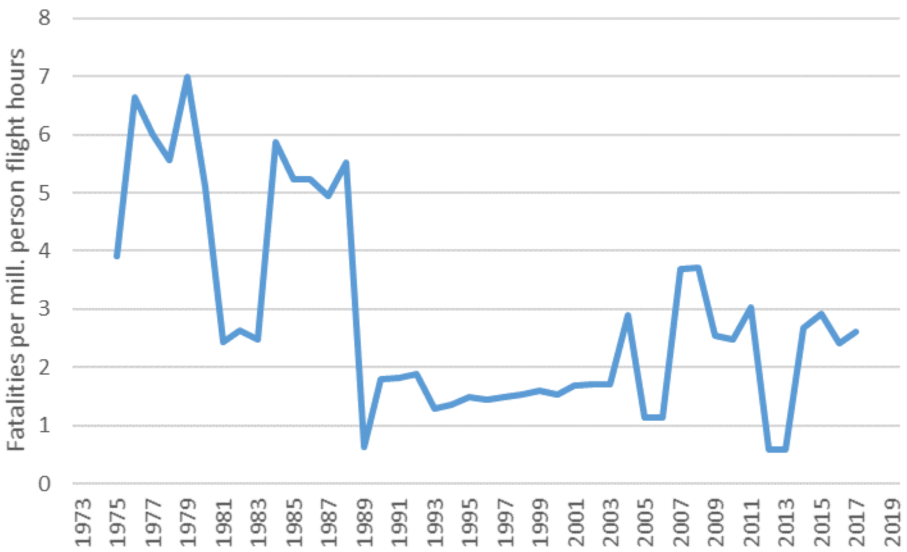

Figure 5.5: The number of fatalities per million-person flight hours in the NO and UK sector combined for the period 1975–2017; 5-year moving average.

6 Accident analysis

In this chapter, we have analyzed the accident picture for offshore passenger transport by helicopter in the Norwegian and British sectors. The main purpose has been to examine what can be learned and what we already have learned from these accidents. We also discuss, hypothetically, what preventive measures may have prevented possible accidents in the Norwegian sector. Furthermore, this is a basis to discuss possible future focus areas for accident prevention.

6.1 Accidents in the Norwegian and British sectors

There have been several accidents in the Norwegian and British sectors in the period 1999–2019. The majority of these accidents (16 of 19 accidents) have occurred in the British sector, while the latest fatal accident (Turøy, 2016) took place on the NCS. The Turøy accident had some striking similarities with a UK accident in 2009. Given that the two sectors have the same type of helicopters and comparable operating conditions, it is relevant to discuss to what extent the UK accidents could have occurred on the NCS.

Table 6.1 lists the accidents that are registered for offshore helicopter transport in the Norwegian and British sector for the period 1999–2019. For each accident, the course of events, contributing factors, and the extent of damage are described in brief, based on excerpts from investigation reports and interviews with relevant experts (pilots and technicians). The final investigation reports are available for all the accidents.

The accidents are classified in relation to the accident categories A1–A8, which are used in the HSS model. An assessment has also been conducted of which RIFs for frequency are the most important factors for each accident. SINTEF has based its assessments on expert judgments regarding the accident's relevance for the Norwegian sector, both at the time of the accident and for the current situation (2021). For each of the accidents we have raised the following questions:

- **A.** Could the accident have occurred in the Norwegian sector at the same time?
- **B.** Could the accident have occurred in the Norwegian sector today (2021)?

For each of the questions we have the following possible answers:

- **Yes**: Could have occurred in the Norwegian sector, with approximately the same probability
- **Yes***: Could have occurred in the Norwegian sector, but with a substantially lower probability
- **No**: Could probably not have occurred in the Norwegian sector

The comments column in Table 6.1 elaborates on whether the accident could have occurred in the Norwegian sector at the same time or today, what the industry may have learned from the accident, and which barriers are in place in the Norwegian sector which could reduce the probability or limit the consequence of a similar accident.

Table 6.1: Overview of helicopter accidents in the Norwegian and British sector for the period 1999–2019.

No.	Date	Place	Heli-copter	Course of events	Contributing causal factors	Extent of loss/damage	RIF	Acc. cat.	Same time? (A)	Today? (B)	Comments (A/B)
1	2000-02-15	UK	AS332L	Lightning strike. No subsequent failures in instruments or other systems.	The captain saw a cumulus cloud, contacted Scatsta and received a message that there was no lightning activity at that time.	No fatalities	1.10	A2	Yes	Yes*	Lightning strike. Improved system for forecasting lightning/discharge conditions.
2	2001-07-12	UK	S-76A	The captain decided that the co-pilot should turn the helicopter 90 degrees so it would be easier for the passengers to embark. After the helicopter had been turned, the pilot was not paying attention and pulled the wrong lever (the collective stick instead of the parking brake). The helicopter was lifted rapidly and the pilot lowered the collective at once. The helicopter landed tail first.	Human factors. Unfortunate placement of lever for parking brake.	No fatalities	1.5 1.3	A7	Yes	**No**	Human factors and cockpit HMI design (for S-76). Would probably not have occurred on the NCS today due to new design and improved CRM training (*Crew Resource Management*).
3	2001-11-10	UK	AS332L	The helicopter on the drill ship West Navion was refueling while the rotors were running. The captain remained on board while the co-pilot assisted the helideck personnel with the disembarking. Five minutes after landing, the ship's DP system changed to MANUAL. The ship started rotating and the helicopter rolled over.	The rig's DP system changed to MANUAL and the ship started to rotate. Big change in relative wind gave strong aerodynamic power which had an effect on the helicopter and made it roll easier. In addition the ship itself had roll movements. Lack of procedures: - for the ship crew to transmit the change in the alert status to the pilots - for the pilots if control of the ship is lost/degraded	One person seriously injured (the co-pilot, who was the only person outside the helicopter on the helideck was hit by flying parts from the helicopter's main rotor, which had been damaged in connection with the collision with the helideck.	1.8	A7	Yes	Yes	Somewhat better procedures today, but similar events could happen again. Helideck monitoring systems have been developed that measure helideck movement (pitch, roll, heave) on floating helidecks. On the UKCS a single *Motion Severity Index* (MSI) is also calculated. Helideck repeater lights are made mandatory both in UK and NO (2021), increasing the situational awareness in the cockpit.
4	2002-02-28	UK	AS332L	Bad weather (waterspout). During landing, the tips of the tail rotor blades touched the tail pylon.	Waterspout not visible to the deck personnel. Even though it was relatively far away and the pilots avoided the bad weather, there was severe turbulence.	No fatalities	1.10	A1	Yes	Yes	Could happen anytime, anywhere as long as the waterspout is not registered on the radar or by other means.

No.	Date	Place	Heli-copter	Course of events	Contributing causal factors	Extent of loss/damage	RIF	Acc. cat.	Same time? (A)	Today? (B)	Comments (A/B)
5	2002-07-16	UK	S-76A	During approach, people on the platform heard a loud bang, and then saw the helicopter fall into the sea. A witness also saw the main rotor head with the blades fall into the sea after the helicopter had hit the sea.	Loss of separation between the rotor blade sections led to imbalance and to the gearbox tearing away from the fuselage.	11 fatalities (out of 11)	1.1 1.2	A3	Yes	**No**	This accident type is not relevant for the newest generation proven helicopter technology (S-92 and H225).
6	2002-11-05	NO	AS332L2	During the descent to 1,000 feet for visual approach to Sola, severe vibrations occurred. The pilots sent a MAYDAY call and informed Sola that they set course for two ships they saw near land. They landed on the helideck of the ship nearest land.	Loss of a main rotor head vibration absorber pendulum weight due to fatigue in the attachment shaft. Weakness in the certification data for design. Other corresponding cases with this type of helicopter. The design for vibration damping is now modified.	No fatalities. Severely damaged main rotor blade.	1.1 1.2	A2	Yes	**No**	Introduced new maintenance procedures and the newest generation proven helicopter technology which prevents this type of incident from happening.
7	2006-03-03	UK	AS332L2	Lightning strike. No vibration or damage visible for the pilots, but there was a temporary disturbance on the instrument screens. Hydraulic system failure occurred, but the helicopter landed safely.		No fatalities. Damage to a main rotor blade and a tail rotor blade.	1.10	A2	Yes	Yes*	Lightning strike. Improved system for forecasting lightning/discharge conditions.
8[a]	2006-10-13	UK	AS332L	Five seconds into the take-off from Aberdeen a loud bang followed by severe vibrations was observed. Take-off was aborted and the helicopter landed safely on the runway.	Crack in one of the spindle attachments due to wear and incorrect torque of a bolt.	No fatalities	1.1 1.2	A2	Yes	**No**	New procedures issued from manufacturer for maintenance of spindle.
9	2006-12-27	UK	SA365N	During approach to the North Morecambe platform at night and in poor weather conditions, the co-pilot lost control of the helicopter. The helicopter passed the platform, crashed into the sea and sank.	No correct transfer of control between co-pilot and captain. The approach profile angle flown was non-standard, possibly due to limited visual cues.	7 fatalities (out of 7)	1.10 1.5 1.4	A5	Yes*	Yes*	Approach to offshore installation during reduced visibility. The probability for occurring on the NCS is considered lower due to training and improved CRM training (*Crew Resource Management*).
10	2008-02-22	UK	AS332L2	Lightning strike during flight. No system failures or impact to the helicopter's performance.		No fatalities. Damage to main rotor blade.	1.10	A2	Yes	Yes*	Lightning strike. Improved system for forecasting lightning/discharge conditions.

No.	Date	Place	Heli-copter	Course of events	Contributing causal factors	Extent of loss/damage	RIF	Acc. cat.	Same time? (A)	Today? (B)	Comments (A/B)
11	2008-03-09	UK	SA365N	During landing on a helideck, the helicopter's tail hit a crane.	Choice of approach profile, limited performance ability of helicopter, approach technique and possible fatigue.	No fatalities	1.5 1.8 1.1 1.2 1.4	A1	Yes*	Yes*	On the NCS the requirement for helideck diameter (after 2008) is 1.25D (compared to 1.0D in the UK sector). A larger diameter provides better visual reference and clearance to obstacles, especially for large helicopter types and on installations with much turbulence and difficult flight conditions. The accident could happen on the NCS, but with less probability because of greater helideck diameter.
12	2009-02-18	UK	H225	Collision with sea during approach to the ETAP platform during darkness and poor visibility.	Poor visibility, more clouds and fog than forecasted. No automatic warnings in cockpit that the helicopter was close to the surface. This was because the pilot had disconnected the auto warning function.	No fatalities	1.10 1.4 1.5	A5	Yes	Yes*	Approach to offshore installations during reduced visibility. In this case several human errors were committed. Would most likely not have occurred on the NCS today due to new design and improved CRM training.
13	2009-04-01	UK	AS332L2	The helicopter crashed on the way from the Miller platform to Aberdeen.	A failure in the main gearbox caused the main rotor to separate from the aircraft.	16 fatalities (out of 16)	1.1 1.2	A3	Yes	Yes	Even though procedures and maintenance practices are different in the UK and Norway, it is not more likely that this type of technical fault would have been discovered in Norway, not even for new machines. The Turøy accident (no. 17) is virtually identical and an example of this.
14	2012-05-10	UK	H225	The helicopter made a safe emergency landing on sea 34 nm east of Aberdeen following a warning in the main gearbox lubrication and emergency lube system.	A vertical drive shaft in the main gearbox (driving both oil pumps) cracked due to fatigue in the welding between two sections of the shaft.. The manufacturers FE model underestimated max tension in the weld. Bad design and welding of shaft plus some corrosion (due to moisture).	No fatalities	1.1	A2	Yes	**No**	After 2009 HUMS data are checked between flights. This was not the case with the accident helicopter. The shaft itself has been reinforced. It is claimed that cruise power outtake is lower in the NO sector than in the UK, implying less wear on dynamic components. This failure is specific for Super Puma helicopters.
15	2012-10-22	UK	H225	The helicopter made a safe emergency landing on sea 32 nm southwest of Sumburgh following a warning in the main gearbox lubrication system and emergency lube system. (Same as accident 14)	Same as accident 14.	No fatalities	1.1	A2	Yes	**No**	Same as accident 14.

No.	Date	Place	Heli-copter	Course of events	Contributing causal factors	Extent of loss/damage	RIF	Acc. cat.	Same time? (A)	Today? (B)	Comments (A/B)
16	2013-08-23	UK	AS332L2	Controlled flight into the sea during non-precision approach to Sumburgh Airport.	Low cloud layer and fog. The instruments were not monitored adequately during the latter part of the approach. Autopilot modes were not used optimally for a non-precision approach and the operator's procedures were similarly not optimised. No positive actions taken to level off when no visual references at MDA.	4 fatalities (out of 18)	1.4 1.5 1.10	A5	Yes*	**No**	Not followed SOP in relation to use of autopilot during approach, possibly due to complexity of system. It is claimed that procedures are more rigorously followed in the Norwegian sector. L2 not in use on the NCS today, and new helicopters have improved technology for approach.
17	2016-04-29	NO	H225	Helicopter crashed at Turøy on approach to Bergen airport.	A failure in the main gearbox caused the main rotor to separate from the aircraft.	13 fatalities (out of 13)	1.1 1.2	A3	Yes	Yes	See accident 13. The helicopter type is currently not in use on the NCS.
18	2016-05-07	NO	S-92	Helicopter main rotor impacted parked vehicle during taxi.	Construction work on site, insufficient separation between vehicles and helicopters. Bad planning of activities, unclear roles.	No fatalities	1.7	A8	Yes	Yes*	Procedures for project risk assessment have been improved
19	2016-12-28	UK	S-92	Loss of yaw control on landing at West Franklin Platform. Heavy landing and the helicopter rotated half turn after landing.	Tail rotor pitch change shaft bearing failure causing damage to pitch control servo. Detected by HUMS, but not recognized by maintenance.	No fatalities	1.1 1.2	A2	Yes	Yes*	Better HUMS HMI and procedures, so failures will be detected earlier today. But the root cause is still not known.

Note a: Accident no. 8 was not included in the HSS-3 report as the investigation report from the AAIB was not published and the classification not set.

We have identified and assessed a total of 19 accidents in the period 1999–2019. There are several aspects of the data material worth attention:

- Most of the accidents (16 of 19) occurred in the UK sector. The traffic volumes are comparable for the UK and Norwegian sectors.
- There has been a remarkable reduction in the number of accidents in the UK sector over the last years.
- Different versions of the Super Puma have been involved in most of the accidents (13 of 19). This type of helicopter is also utilised the most in this period.
- Roughly one quarter of the accidents (5 of 19) were fatal with 51 fatalities in total. In most of the fatal accidents (4 of 5) all or almost all on board perished.
- Almost half of the accidents (8 of 19) have a technical (i.e. airworthiness related) root cause. Of the 7 most recent accidents, 5 are "technical" – most linked to failures in the main gearbox.
- It is not very uncommon that the main rotor detaches from the helicopter (accident no. 5, 13 and 17).
- For the remaining 11 accidents which do not have a technical root cause, we find the following distribution:
    - Lightning strike / static discharge / extreme weather: 4 accidents (no. 1, 4, 7, 10).
    - Collision with sea: 3 accidents (no. 9, 12, 16).
    - Helideck conditions: 2 accidents (no. 3, 11).
    - Heliport conditions: 1 accident (no. 18)
    - Other: 1 accident (no. 2)

We emphasize that the categorization made above in "technical" and other accidents is very simplified, since normally several factors contribute to an accident. Human factors as such play an important role in many types of accidents. For example, a relatively harmless incident with a technical root cause can develop into an accident following an unsuitable human response. Human judgment and decisions also play a role in accidents related to landing/parking on helideck, although it is often easy to point at causes related to external physical conditions (obstructions, weather, etc.). For collision accidents with sea, human factors obviously have a dominating role, but technical factors (like man-machine interface) may be influential, and weather conditions may act as a triggering factor. Lightning strike is an external factor, but the decision to fly in areas with risk of lightning is obviously taken by humans. Further, lightning or static discharge may sustain permanent non-visual structural weaknesses that may later develop into a technical failure.

Finally, "technical" accident related to sub-opimal helicopter design or continuous airworthiness also clearly has a human element. Examples may be insufficient material knowledge, engineering miscalculations, production errors, faulty maintenance, lack of oversight, insufficient regulation, poor standards, etc. Hence, humans and their shortcomings are arguably present in all links in the chain of events leading up to an accident. Nevertheless, it is still useful to employ accident labels like "technical", "operational", "environmental", etc.

Concerning the two questions whether the accidents could have occurred in Norway at the same time (A) or today (B), the analysis gives the following answers:

A. All the UK accidents could *in principle* have occurred in Norway at the time. However, the *probability* for the different accidents occurring is not necessarily the same for the British and the Norwegian sectors. For a minority of the UK accidents (3 of 16) we consider the probability to have been significantly lower in the Norwegian sector.

B. In the current situation (2021) we assess that 7 of the 19 accidents will not occur again in Norway, while an additional 8 accidents have a significantly lower probability today than at the time of the accident. The improvement is mainly due to technical developments and learning form the accidents. For the remaining 4 accidents no significant change in likelihood have been identified.

Figure 6.1 gives a visual summary of central information and assessments of the accidents.

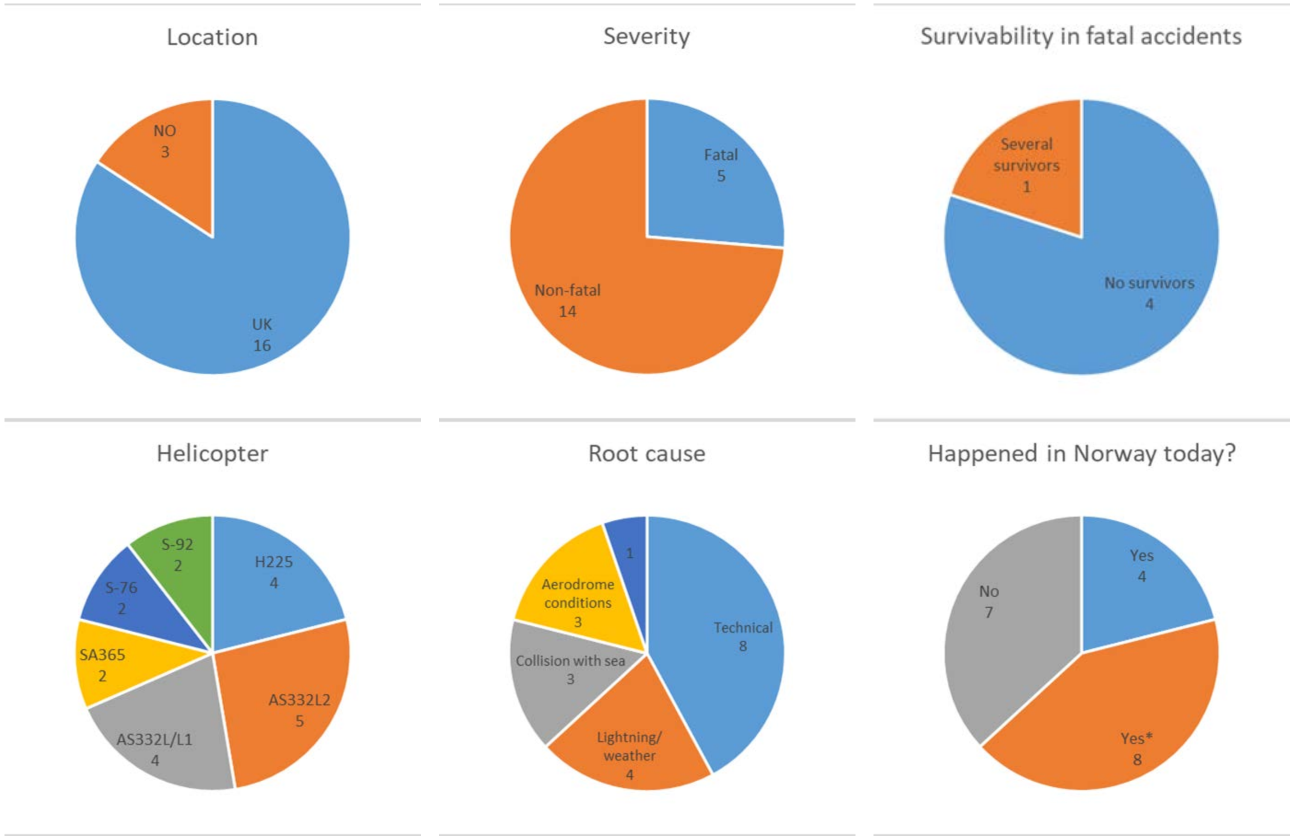

Figure 6.1: Summary of information about accidents in the Norwegian and British sector for the period 1999–2019.

Those accidents that are still likely – more or less (Yes/Yes*) – to reoccur today are grouped as follows:

- Lightning strike / static discharge / extreme weather
- Visual approach to offshore installations in reduced visibility
- Helideck/heliport conditions
- Technical failure in the drivetrain

For these types of accidents there are measures that may be implemented to reduce the probability of an accident. Each of the accident types are discussed below.

6.2 Discussion of accident types

6.2.1 Accidents caused by static discharge (triggered lightning)

Three of the accidents in Table 6.1 are related to lightning strike (static discharge), a phenomenon which is just as likely to occur in the Norwegian sector as in the British sector. Lightning can strike a helicopter by two different mechanisms. First, the helicopter may happen to be located in the path of a lightning in the environment (earth to ground or between clouds). Second, the helicopter itself can accumulate a static charge during flight and trigger a discharge with the environment.

Helicopters will always be exposed to this type of risk. The ability to predict lightning or static discharge conditions has improved over the last years, and dedicated forecasting tools are used both during planning and execution of flights. However, there is currently no satisfactory method to detect lightning conditions to such an extent that they may be avoided completely. The only way to avoid lightning is to not fly in exposed areas (e.g. snowy weather, cumulus and cumulonimbus clouds and areas with a temperature from -3 °C to +3 °C). To this end, the notice routinely published by MET is useful (see section 3.4.3).

The extent of damage caused by lightning may have increased after the introduction of composite materials in blades and parts of the airframe. Composite materials are not very good conductors compared to metal, and various bonding issues may arise as a consequence. Rotor blades are also more prone to damage due to delamination of the composite materials and anti-ice heating blankets when subjected to large electrical currents. Helicopters should be made more resilient to lightning strikes, and the technology needs to be developed further, also concerning hidden damages. Past accidents have led to some improvements in design and regulation, but there is still a way to go.

On average, there are 2–3 reported lightning incidents on the NCS per year. However, there are no *accidents* related to static discharge on the NCS for the period covered (1999–2019). A possible explanation to the absence of lightning accidents in the Norwegian sector, may be that flying in unfavourable weather conditions to a greater extent is avoided. Another explanation, given the low number of accidents, is that this is coincidental and reflects normal statistical variation.

6.2.2 Accidents during visual approach to offshore installations in reduced visibility

Three of the accidents in Table 6.1 are related to approach to helideck (accidents no. 9, 12) or airport (accident no. 16) in reduced visibility conditions (darkness, fog or bad weather). This accident type is considered likely to occur in the Norwegian sector as well. There have been incidents in the Norwegian sector where the helicopter came too close to the sea during approach, and collision was avoided due to the warning system (HTAWS/GPWS). Pilots, like most people, tend to trust and act based on what they can see with their own eyes (which in some situations can be misleading due to lack of visual cues) instead of trusting what the instruments show.

The Crew Resource Management concept (CRM) has been given an increased focus in the recent years. As an example, oil companies have required (via ON-066) additional recurrent simulator training for several years, and the regulations have recently followed suit (BSL D 2-3, 2019). Today, Norwegian pilots perform a high-quality training scheme in both monitoring and challenging the other pilot. How the CRM concept is utilised during flying and the methods for training air crew properly in the CRM concept is seen as one factor that might separate the British and the Norwegian sectors, at least in the past. The Norwegian culture supports a non-hierarchical cockpit where it is encouraged to challenge the captain (or the other crewmember) if something seems to be wrong. Accident reports indicate that cockpit relations might differ between the two sectors, as some British accidents indicate that the co-pilot has (apparently) failed in challenging the captain when he should have.

In addition to robustness of CRM training and practice, the introduction of automatic approach procedures is another important risk reducing measure for this type of accidents. These procedures will reduce the risk of misinterpretations during the approach. Other risk reducing measures are to reduce night operations and increase the amount of simulator training in darkness or bad visibility conditions.

Proper aircraft knowledge, the use of SOP and a good HMI is of the greatest importance for a good CRM in the aircraft. Use of automation should be possible in all phases of flight.

6.2.3 Accidents caused by critical failures in the drivetrain

As many as five of the seven most recent accidents (Table 6.1) are related to technical failures in the drivetrain, most of them in the main gearbox. Two of these accidents (no. 14 and 15) have led to technical improvements (new design features and strengthening of components) that will most likely prevent the exact same type of accidents.

For the remaining three accidents (no. 13, 17 and 19), some minor modifications and improvements in design, inspection and maintenance have been made to prevent any reoccurrence, but the effect seems unclear. Accidents 13 and 17 look very similar, both featuring a fatigue fracture in the second stage planetary gear in the main gearbox. However, a notable difference is that detectable metal chips were present in the gearbox prior to the 2009 accident (no. 13), while no chips were found before the 2016 accident (no. 17).

6.3 Analysis of the accidents

The main purpose of the accident analysis is to investigate what can be learned and what we already have learned from the helicopter accidents. Figure 6.2 depicts the distribution of accidents by categories. The distribution is for the British and Norwegian sectors combined for the period 1999–2019.

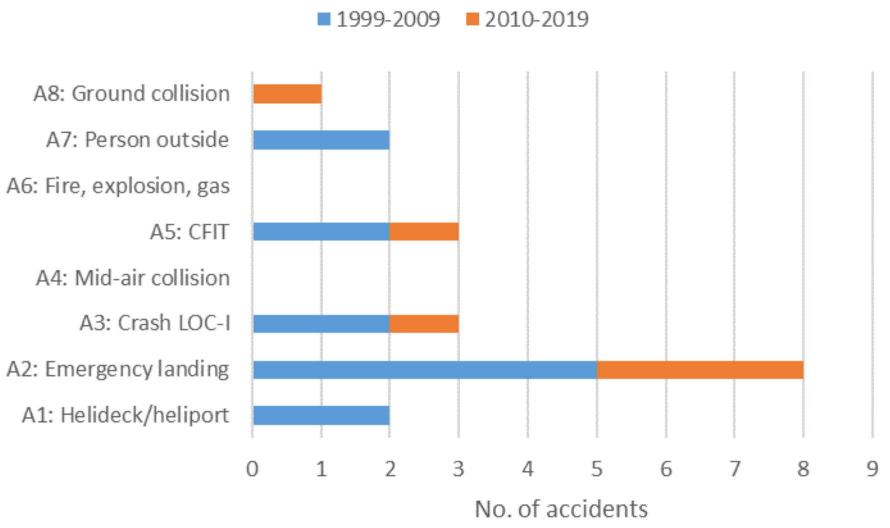

Figure 6.2: Accidents by accident category; NCS + UKCS 1999–2019.

From Figure 6.2 we observe the category A2 *Emergency landing* dominates with 8 accidents. However, the analysis shows that 4 of the 8 accidents could have been prevented today.

Figure 6.3 presents all the accidents distributed by the defined RIFs for the two periods. We observe that the RIFSs *Weather and climate* (RIF 1.10) and *Helicopter design* (RIF 1.1) hold the largest contribution to accidents since 1999. The accidents linked to *Helicopter design* are for a large part type *A3 System failure*, and the reduction of this type of accidents will also result in a decrease in this RIF's contribution.

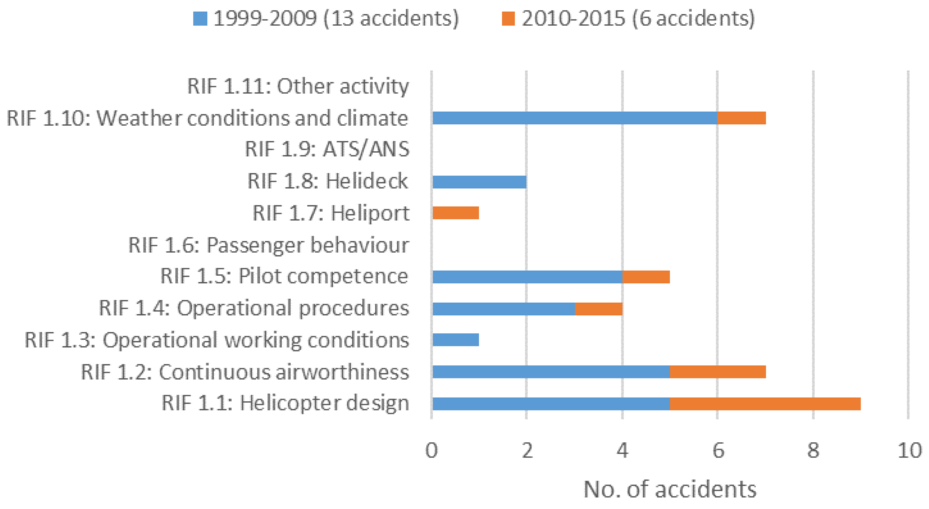

Figure 6.3: Accidents by RIFs for frequency; NCS + UKCS 1999–2019.

In HSS-3 the biggest contribution to risk was from RIF 1.10 *Weather and climate*. HSS-3 predicted that RIF 1.10 together with RIF 1.2 *Continuing airworthiness* would see a reduction in the period 2009–2019 due to the introduction of new helicopter types, last generation proven technology and new maintenance procedures. Furthermore, a reduction in RIF 1.4 *Operations procedures and support* and RIF 1.5 *Pilot performance* was also predicted based on new procedures and automated approaches. The few accidents occurring after 2009 do not support this prediction, so further analyses are needed to possibly verify this expected improvement.

For a number of the accidents (especially those in 2009 and 2012 that had a technical cause), the root causes have been addressed and improvements have been implemented in order to prevent reoccurrence of the exact same type of accident. The assessment of recent accidents shows that it is important to learn from accidents seen over a long time span, and not only act on the most recent ones. This is especially true when the same type of accident has occurred several times.

7 Quantification in the HSS model

This chapter presents the quantification of the HSS model and the main results from the associated analyses. The RIFs and the accident categories are quantified based on event data, expert judgements, and results from HSS-3. Additional information regarding assumptions, analyses, and data are given in Appendix A.

7.1 Data sources

The following event data have been used as input in the quantification of the HSS model:

- *All* events reported to CAA-N during the period 2010–2019.
- Events reported to RNNP[5] from the period 2010–2018 assessed (in RNNP) to have 0 or 1 residual barrier to prevent from accident.
- UK accidents in the period 2010–2019 considered as relevant for the Norwegian Continental Shelf, ref. chapter 6.

The accident and event data from 2010–2016 includes many H225 Super Puma events. As this helicopter has not been in operation on the Norwegian Continental Shelf since the Turøy accident in 2016, two separate data sets have been established for the quantification assessment:

- A dataset including *all events* and all helicopter types.
- A dataset including *only S-92* events.

Frequency and consequence contributions from the eight accident categories are presented in sections 7.1 and 7.2. The combination of the frequency and consequence contributions results in the risk contribution from the accident categories (presented in section 7.3). Contributions from frequency RIFs and importance of consequence RIFs are presented in sections 7.4 and 7.4, respectively. Section 7.5 presents the contribution from the organizations RIFs.

7.2 Frequency contributions from the accident categories

Table 7.1 presents the frequency contribution from the eight accident categories. Frequency distribution 1 is based on *all events* and frequency distribution 2 is based on *S-92 events only*. The results are also presented in Figure 7.1 and Figure 7.2. For both frequency distributions, accident category A1 (Accident during take-off/landing) is the main contributor the accident *frequency*. Also, accident categories A2 (Controlled emergency landing) and A3 (Collision with terrain/sea) contributes significantly.

Table 7.1: Frequency contributions from the accident categories.

	A1 Landing / take-off aerodrome	**A2** Controlled emergency landing	**A3** Collision terrain/sea (LOC)	**A4** MAC	**A5** CFIT	**A6** Fire / Explosion/ Gas	**A7** Personal accident / behavior	**A8** Ground collision
Frequency distribution: *All events*	31 %	24 %	17 %	3 %	9 %	3 %	5 %	7 %
Frequency distribution: *S-92 events*	46 %	14 %	15 %	4 %	3 %	3 %	8 %	7 %

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[5] Trends in risk level in the Norwegian petroleum activity. Published annually by the Norwegian Petroleum Safety Authority.

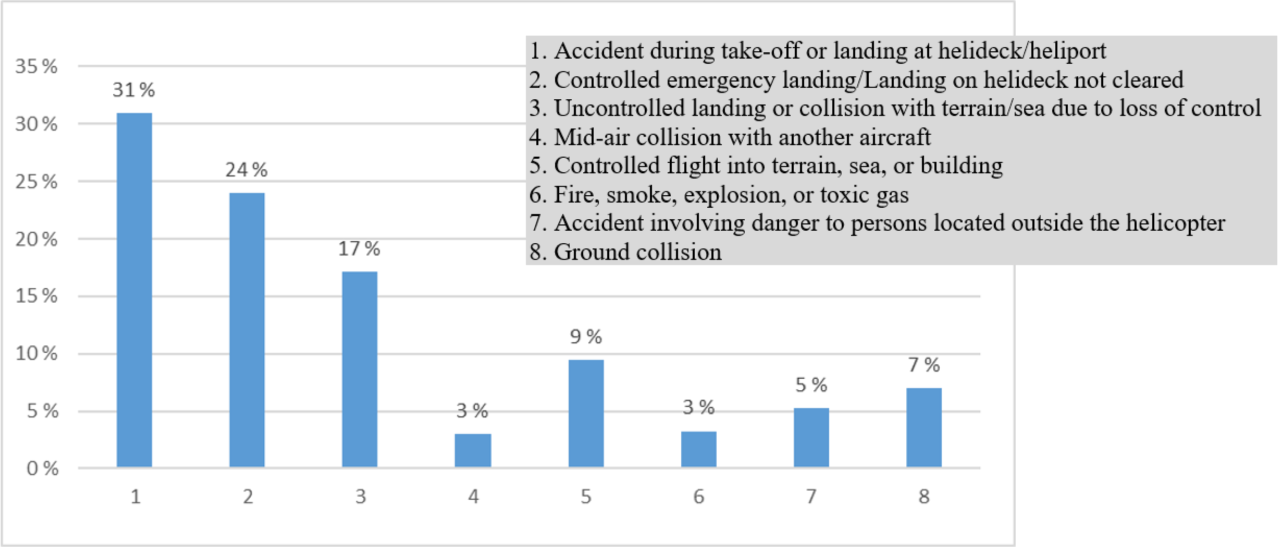


Figure 7.1: Frequency contributions from the accident categories – based on *all events*.

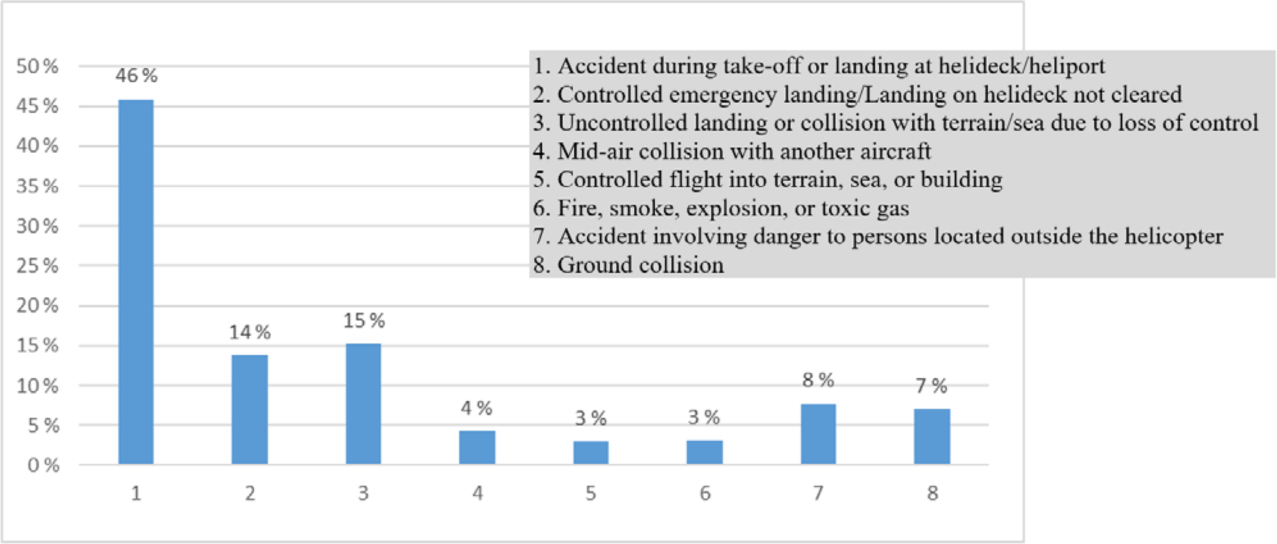


Figure 7.2: Frequency contributions from the accident categories – based on *S-92 events only*.

7.3 Consequence contributions of the accident categories

The number of facilities in an arbitrary helicopter accident depends on the accident category. The *consequence* – measured in the number of fatalities – for each accident category is estimated by combining:

a) Mean fraction of fatal accidents in the category
b) Mean fraction of fatalities in a fatal accident

Due to very limited statistics of fatal accidents, expert judgements have been used to estimate consequence of accidents (see Appendix A). The results are summarised in Table 7.2.

Table 7.2: Consequence contribution (number of fatalities per accident) from the accident categories.

	A1 Landing / take-off aerodrome	**A2** Controlled emergency landing	**A3** Collision terrain/sea (LOC)	**A4** MAC	**A5** CFIT	**A6** Fire / Explosion/ Gas	**A7** Personal accident / behavior	**A8** Ground collision
Fatal accident fraction *Example:* 1:5 – one out of five accidents is fatal	1:5	1:10	4:5	1:1	2:3	1:5	1:3	1:20
Fraction of fatalities in a fatal accident *Example:* 50 % - half of the people on board die	50 %	20 %	90 %	150 % [1]	75 %	50 %	10 %	20 %

Note 1: Given a MAC, the probability that the second aircraft involved is a passenger transport helicopter is estimated to 50 %. Hence, the fraction of eligible fatalities in a MAC is expected to be 100 % in the first helicopter and (average) 50 % in the second helicopter, which totals to *150 %* relative to the number of persons onboard a single helicopter. The remaining 50 % probability associated with the second aircraft may be attributed to fixed-wing, military, GA, drones, or a helicopter on other missions (SAR, training, testing, aerial work etc.).

7.4 Risk contribution from the accident categories and statistical risk

The risk contribution from each accident category is estimated from the combination of the frequency contribution (Table 7.1) and consequence contribution (Table 7.2) together with the expected number of persons onboard a helicopter. Based on today's activity level (2010–2019), the mean number of persons onboard one helicopter flight is 14.

To quantify the (statistical) risk, we need in addition the estimated total accident frequency for all accident categories. This accident frequency is based on statistics from the Norwegian Continental Shelf from the period 2010–2019, During this period it has been experienced 2 accidents per 6 751 795 person flight hours (ref. chapter 5), i.e. *0.3 accidents per million-person flight hour*.

Table 7.3 presents the risk contributions given by:

- Expected number of fatalities per accident category
- Risk distribution from the accident categories by percentage
- Statistical risk (number of fatalities per million-person flight hours) for each accident category based on all events and S-92 events, respectively.

A4 (MAC) has the highest number of fatalities per accident given that an accident has occurred. Here it is assumed that in about 50 % of the MAC accidents, the helicopter collides with another passenger helicopter such that the expected number of fatalities is higher than the number of persons on board a single helicopter (ref. Table 7.2). A3 (LOC) and A5 (CFIT) are also assessed to give a high number of fatalities.

Table 7.3 also shows that the total number of fatalities per million-person flight hours is approximately 1 (sum of risk attached to each accident category) with today's activity level. A3 (LOC), A4 (MAC) and A1 (Landing/take-off) are the three accident categories contributing the most to the risk.

Table 7.3: Risk contribution from the accident categories.

	A1 Landing / take-off aerodrome	**A2** Controlled emergency landing	**A3** Collision terrain/sea (LOC)	**A4** MAC	**A5** CFIT	**A6** Fire / Explosion/ Gas	**A7** Personal accident / behavior	**A8** Ground collision	**Total**
Fatalities per accident	1,4	0,7	8,4	21,0	7,0	1,4	0,5	0,1	**3,4**
Fatalities per accident (normalised)	3,5 %	1,7 %	21 %	52 %	17 %	3,5 %	1,2 %	0,3 %	**100 %**
Fatalities per million-person flight hours (all events)	0,13	0,05	0,43	0,19	0,19	0,01	0,01	0,00	**1,01**
Fatalities per million-person flight hours (S-92 events)	0,19	0,03	0,38	0,27	0,06	0,01	0,01	0,00	**0,95**

7.5 Contributions from technical and operational RIFs to accident frequencies

The relative contribution from the 12 technical and operational frequency RIFs to the accident frequencies, is presented in Table 7.4 (based on all events) and Table 7.5 (based on S-92 events). The tables include both the total contributions and the contributions to each accident category. The main results are shown in Figure 7.3 and Figure 7.4.

Table 7.4: Contributions from RIFs to accident frequencies – based on all events.

RIF		**Accident category**								**Sum**
		A1 Landing / take-off aerodrome	**A2** Controlled emergency landing	**A3** Collision terrain/sea (LOC)	**A4** MAC	**A5** CFIT	**A6** Fire / Explosion/ Gas	**A7** Personal accident / behavior	**A8** Ground collision	
1.1	Helicopter design	2,4 %	4,7 %	12,3 %	0,1 %	2,2 %	0,8 %	0,2 %	0,8 %	**23 %**
1.2	Continuing airworthiness	3,2 %	8,6 %	1,9 %	0,2 %	2,6 %	1,2 %	0,8 %	0,7 %	**19 %**
1.3	Operational working conditions	2,4 %	0,1 %	0,1 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	**3 %**
1.4	Operational procedures&support	2,2 %	2,0 %	0,1 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	**4 %**
1.5	Pilot performance	2,1 %	0,7 %	0,6 %	0,5 %	3,4 %	0,0 %	0,9 %	0,2 %	**9 %**
1.6	Passenger performance	0,1 %	0,2 %	0,0 %	0,0 %	0,0 %	0,1 %	0,5 %	0,0 %	**1 %**
1.7	Helideck	5,5 %	2,4 %	0,6 %	0,0 %	0,0 %	0,5 %	2,2 %	0,1 %	**11 %**
1.8	Air navigation services (ANS)	0,5 %	0,2 %	0,0 %	0,9 %	0,9 %	0,0 %	0,0 %	0,4 %	**3 %**
1.9	Heliport	7,9 %	0,8 %	0,2 %	0,0 %	0,0 %	0,5 %	0,4 %	4,3 %	**14 %**
1.10	Other airspace activities	0,1 %	0,0 %	0,0 %	1,1 %	0,0 %	0,1 %	0,0 %	0,2 %	**2 %**
1.11	Weather conditions	4,1 %	4,2 %	1,2 %	0,1 %	0,2 %	0,1 %	0,2 %	0,4 %	**10 %**
1.12	Intentional adverse events	0,5 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	**1 %**
Sum		**31 %**	**24 %**	**17 %**	**3 %**	**9 %**	**3 %**	**5 %**	**7 %**	**100 %**

Note that there are some differences between the results in the two tables. Based on all events, the RIFs 1.1 *Helicopter design*, 1.2 *Continuing airworthiness*, 1.7 *Helideck* and 1.9 *Heliport* contributes the most. Besides, 1.5 *Pilot performance* and 1.10 *Weather conditions* also have significant contributions. However, based on S-92 events only, the most significant RIF contributions are from 1.2 *Continuing airworthiness*, 1.7 *Helideck* and 1.9 *Heliport*, in addition to 1.10 *Weather conditions.*

Table 7.5: Contributions from RIFs to accident frequencies – based on S-92 events.

RIF		Accident category								Sum
		A1 Landing / take-off aerodrome	**A2** Controlled emergency landing	**A3** Collision terrain/sea (LOC)	**A4** MAC	**A5** CFIT	**A6** Fire / Explosion/ Gas	**A7** Personal accident / behavior	**A8** Ground collision	
1.1	Helicopter design	1,0 %	1,2 %	1,1 %	0,1 %	0,3 %	0,3 %	0,1 %	0,1 %	**4 %**
1.2	Continuing airworthiness	5,0 %	7,9 %	7,4 %	0,4 %	1,1 %	1,8 %	2,0 %	0,2 %	**26 %**
1.3	Operational working conditions	5,4 %	0,0 %	0,5 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	**6 %**
1.4	Operational procedures&support	0,3 %	0,1 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	**0 %**
1.5	Pilot performance	2,1 %	0,3 %	1,3 %	0,4 %	1,1 %	0,0 %	0,4 %	0,2 %	**6 %**
1.6	Passenger performance	0,2 %	0,2 %	0,2 %	0,0 %	0,0 %	0,0 %	0,7 %	0,0 %	**1 %**
1.7	Helideck	9,1 %	1,3 %	1,4 %	0,0 %	0,0 %	0,3 %	3,8 %	0,1 %	**16 %**
1.8	Air navigation services (ANS)	0,5 %	0,1 %	0,0 %	1,3 %	0,4 %	0,0 %	0,0 %	0,2 %	**3 %**
1.9	Heliport	17,4 %	0,7 %	0,7 %	0,0 %	0,0 %	0,4 %	0,4 %	6,1 %	**26 %**
1.10	Other airspace activities	0,1 %	0,0 %	0,0 %	1,9 %	0,0 %	0,1 %	0,0 %	0,1 %	**2 %**
1.11	Weather conditions	4,1 %	2,0 %	2,7 %	0,1 %	0,0 %	0,0 %	0,3 %	0,1 %	**9 %**
1.12	Intentional adverse events	0,8 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	**1 %**
	Sum	**46 %**	**14 %**	**15 %**	**4 %**	**3 %**	**3 %**	**8 %**	**7 %**	**100 %**

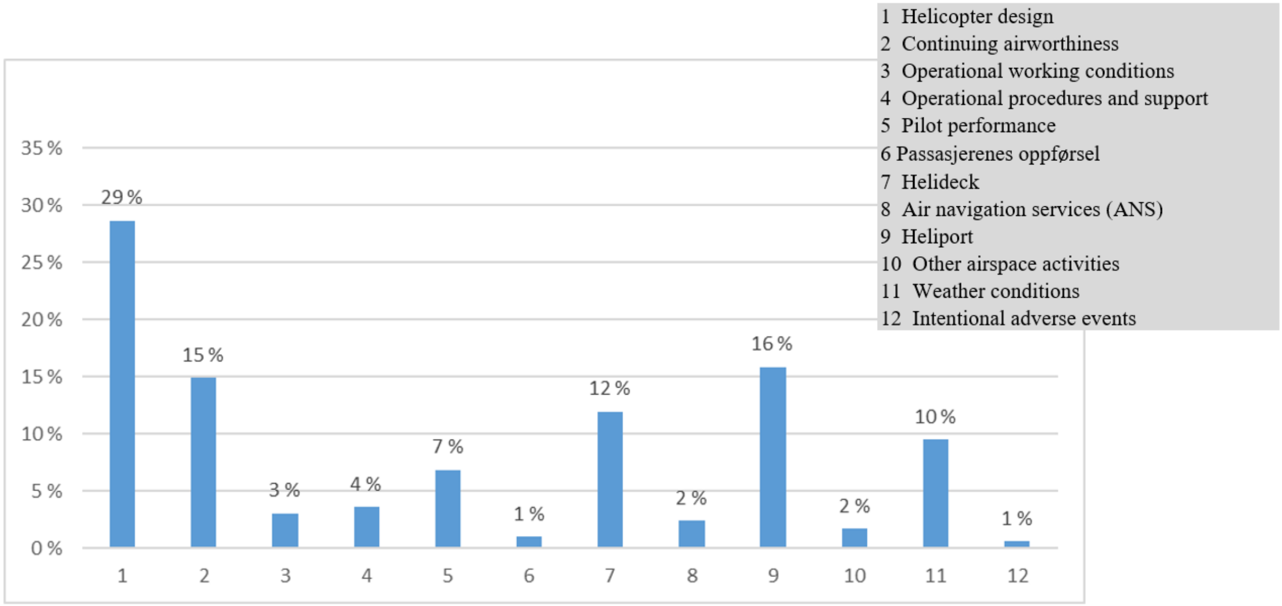


Figure 7.3: Contributions from RIFs to accident frequencies – based on all events.

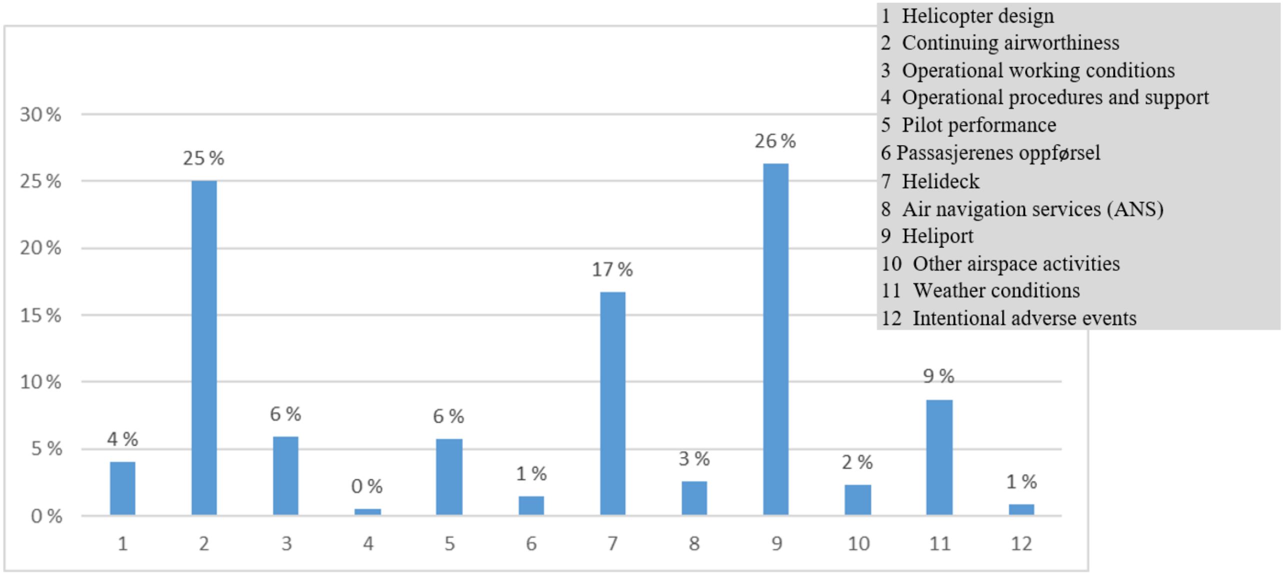


Figure 7.4: Contributions from RIFs to accident frequencies – based on S-92 events.

7.6 The importance of the technical and operational RIFs for consequence

The technical and operational consequence RIFs reflects the importance of each RIF to the number of fatalities for each accident category compared to the other RIFs. Each RIF has a value on the scale from 0 to 10, where 0 corresponds to a RIF without importance and 10 corresponds to a RIF with high importance. The results are presented in Table 7.6 and are established based on expert judgements and the HSS-3 results combined with development trends in the period 2010–2020. The rightmost column gives a total value for each RIF and corresponds to a mean risk contribution (consequence value combined with frequency distribution from Table 7.1). It should be noted that a high importance of a consequence RIF corresponds to a "safety contribution" as well as a "risk contribution", while the contribution from a frequency RIF only refers to a "risk contribution".

Table 7.6: Importance (0–10) of technical and operational RIFs for consequence.

RIF		**Accident category**								**Total**
		A1 Landing / take-off aerodrome	**A2** Controlled emergency landing	**A3** Collision terrain/sea (LOC)	**A4** MAC	**A5** CFIT	**A6** Fire / Explosion/ Gas	**A7** Personal accident / behavior	**A8** Ground collision	
1.1	Impact absorption and cabin safety	9	4	4	2	9	6	0	5	**5,9**
1.2	Stability on sea	7	5	5	1	9	5	0	0	**5,4**
1.3	Survival equipment	6	5	5	2	8	6	0	0	**4,7**
1.4	Emergency location equipment	3	5	5	2	8	3	0	0	**3,8**
1.5	Pilots competence	7	5	5	3	7	10	8	5	**6,2**
1.6	Passenger competence	8	6	6	2	6	9	8	5	**6,5**
1.7	Emergency procedures	8	5	5	2	7	8	5	5	**5,9**
1.8	Helideck emergency preparedness	7	2	2	2	2	4	7	0	**3,5**
1.9	Heli-/Airport emergency preparedness	2	2	2	2	4	4	6	10	**2,8**
1.10	SAR helicopters	8	5	5	4	9	5	4	0	**5,6**
1.11	Other emergency preparedness	2	3	3	1	4	1	1	0	**2,2**
1.12	Weather conditions	5	5	5	3	7	4	3	0	**4,5**
Sum		**66**	**48**	**48**	**25**	**80**	**65**	**45**	**30**	**57**

More interesting than the absolute values, are the relative importance from each consequence RIF as shown in Table 7.7. From the table we see that the most significant RIFs are 1.6 *Passengers competence*, 1.7 *Emergency procedures* and 1.10 *SAR helicopters*. For the rest of the RIFs there are limited variation of their importance.

Table 7.7: Relative importance of technical and operational RIFs to consequence.

RIF		**Accident category**								**Total**
		A1 Landing / take-off aerodrome	**A2** Controlled emergency landing	**A3** Collision terrain/sea (LOC)	**A4** MAC	**A5** CFIT	**A6** Fire / Explosion/ Gas	**A7** Personal accident / behavior	**A8** Ground collision	
1.1	Impact absorption and cabin safety	2,5 %	1,1 %	1,1 %	0,4 %	2,3 %	1,6 %	0 %	1,5 %	**10 %**
1.2	Stability on sea	2,2 %	1,5 %	1,5 %	0,3 %	2,6 %	1,5 %	0 %	0 %	**9 %**
1.3	Survival equipment	1,6 %	1,2 %	1,2 %	0,5 %	2,1 %	1,6 %	0 %	0 %	**8 %**

1.4	Emergency location equipment	0,9 %	1,2 %	1,2 %	0,5 %	2,1 %	0,8 %	0 %	0 %	**7 %**
1.5	Pilots competence	1,6 %	1,1 %	1,1 %	0,6 %	1,5 %	2,1 %	1,7 %	1,1 %	**11 %**
1.6	Passenger competence	1,9 %	1,3 %	1,3 %	0,5 %	1,4 %	2,1 %	1,8 %	1,2 %	**11 %**
1.7	Emergency procedures	1,9 %	1,1 %	1,1 %	0,5 %	1,6 %	1,9 %	1,2 %	1,2 %	**10 %**
1.8	Helideck emergency preparedness	1,8 %	0,5 %	0,5 %	0,4 %	0,5 %	0,9 %	1,7 %	0 %	**6 %**
1.9	Heli-/Airport emergency preparedness	0,3 %	0,2 %	0,2 %	0,3 %	0,6 %	0,6 %	0,9 %	1,6 %	**5 %**
1.10	SAR helicopters	2,0 %	1,1 %	1,1 %	1,0 %	2,3 %	1,3 %	1,0 %	0 %	**10 %**
1.11	Other emergency preparedness	0,6 %	0,8 %	0,8 %	0,2 %	1,0 %	0,2 %	0,2 %	0 %	**4 %**
1.12	Weather conditions	1,2 %	1,1 %	1,1 %	0,8 %	1,8 %	1,0 %	0,8 %	0 %	**8 %**
Sum		**18 %**	**12 %**	**12 %**	**6 %**	**20 %**	**16 %**	**9 %**	**6 %**	**100 %**

7.7 Organizational RIF contributions to frequency and consequence

The following organizational RIFs on level 2 in the influence diagrams influence the technical and operational RIFs on level 1, and thereby influence the risk:

- Helicopter manufacturers & Design organizations – *influencing both frequency and consequence*
- Maintenance organizations – *influencing frequency*
- Helicopter operators – *influencing both frequency and consequence*
- Customers – *influencing both frequency and consequence*
- ANS organizations – *influencing both frequency and consequence*
- Search & Rescue organizations/Norwegian rescue service – *influencing consequence*
- External organizations – *influencing frequency*

Note that trade unions implicitly influence the risk by influencing organizations such as maintenance organizations, helicopter operators, and customers. CAA-N and other authorities are to be found in level 3 in the influence diagrams and influence the organizations on level 2.

The simplified influence diagrams in Figure 7.5 and Figure 7.6 illustrate the influence from the organizational RIFs to the technical and operational RIF for frequency and consequence, respectively. The results are assessed by expert judgements and is common for all accident categories. Each arrow from an organizational RIF to a technical and operational RIF has a value in the area from 1 to 10, where 10 corresponds to significant contribution from the organizational RIF and 1 corresponds to limited contribution from the organizational RIF to the technical and operational RIF. The influences are also illustrated by the arrow thicknesses. It should be noted that the numbers are not normalised for each technical and operational RIF, since the contributions from the organizational RIF has been assessed by comparing contributions.

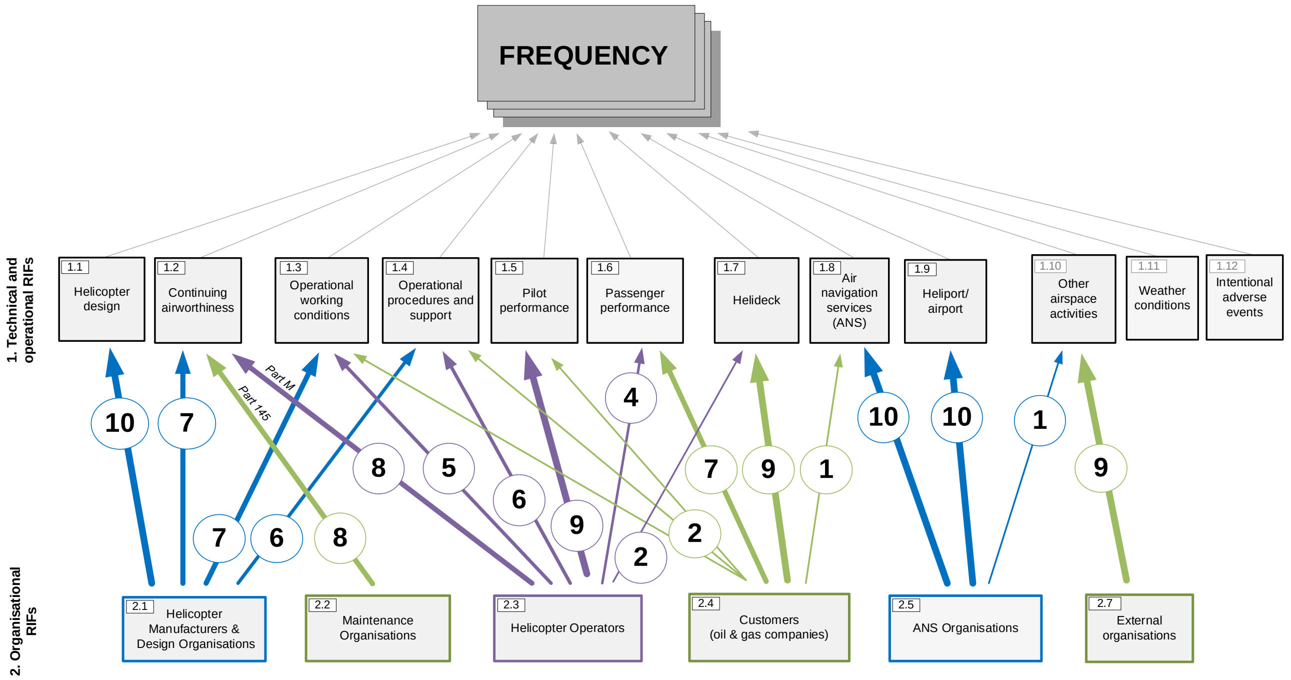


Figure 7.5: Organizational RIFs contribution to technical and operational RIFs for frequency. (Arrow thickness reflects the significance of the contribution. Colours are used to increase readability).

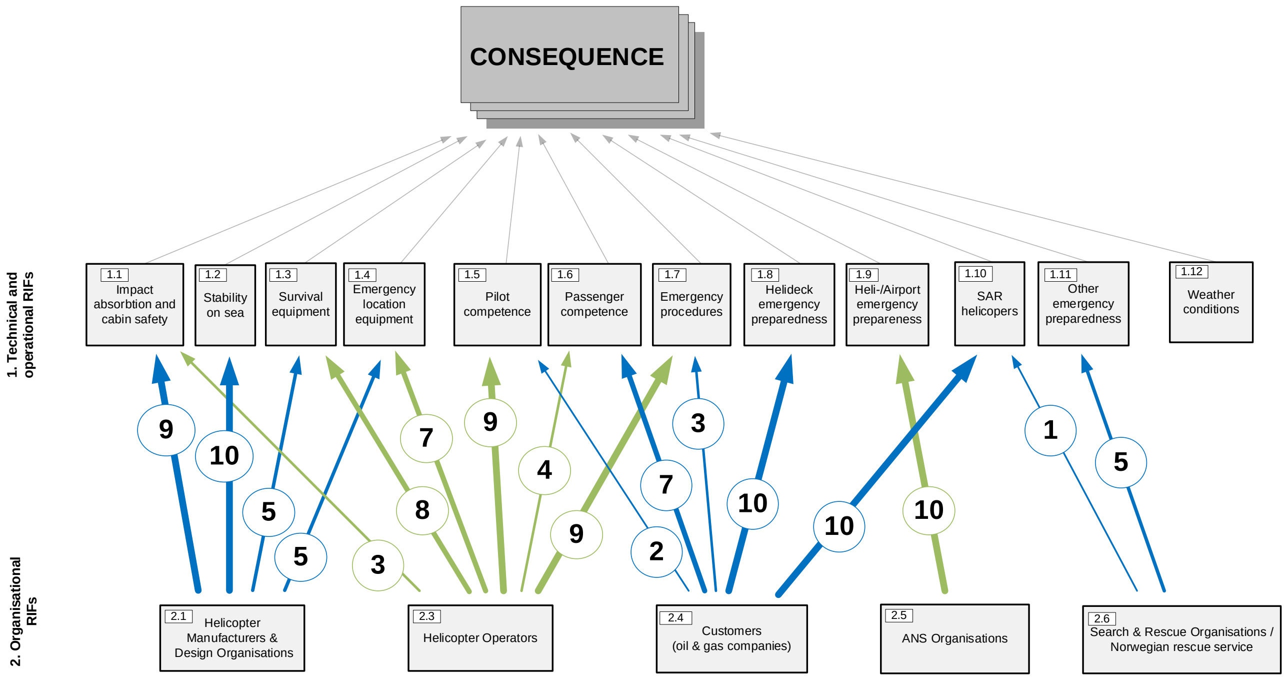


Figure 7.6: Organizational RIFs contribution to technical and operational RIFs for consequence. (Arrow thickness reflects the significance of the contribution. Colours are used to increase readability).

The relative risk (frequency and consequence) influences of the organizational RIFs are quantified by combining the risk contribution from the technical and operational RIFs (on level 1) with the influence from the organizational RIFs. The result is presented in Figure 7.7. The helicopter operators and the manufacturers/design organization are the organizations with the most significant influences. Also, the customers, ANS organizations and the maintenance organizations influences significantly. Search & rescue organizations influences the consequence to some extent. The external organizations have limited influence on the frequency.

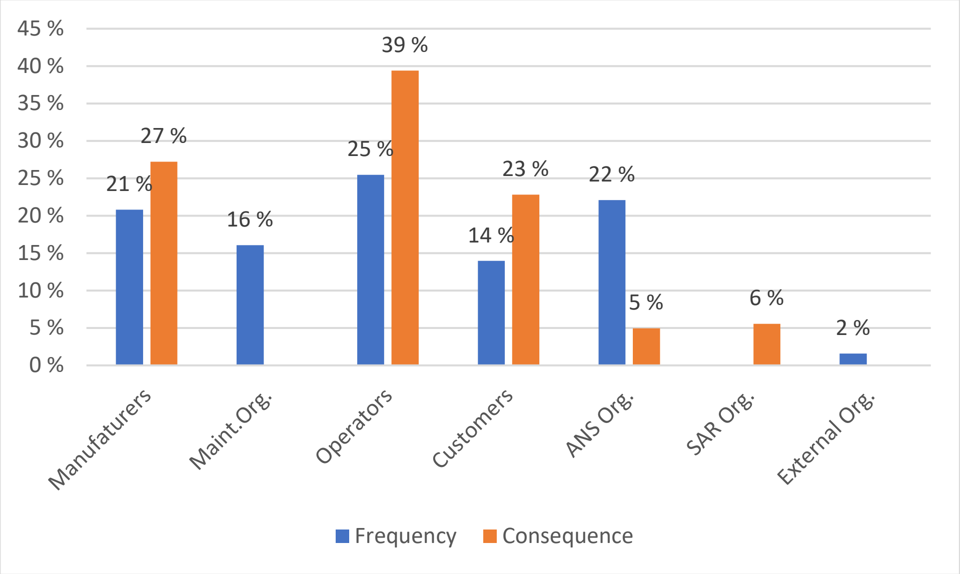


Figure 7.7: Organizational RIFs influence on frequency and consequence.

– PART II –

8 Maintenance of helicopters

The study activity on maintenance of helicopters is documented in this chapter. Due to a limited scope, focus have been on experiences and concerns raised at the "sharp end" of maintenance, i.e. technical personnel, technicians' unions and maintenance management (Part-145/CAMO) in the helicopter companies. Information has been obtained mostly through interviews, supported by document studies and prior knowledge.

8.1 Introduction

Many of the global accidents and incidents involving helicopter operations offshore in recent years have been rooted in technical conditions. Proper maintenance is key to the safety of offshore helicopter operations. However, technical maintenance has, to a limited extent, been the focus of previous HSS studies.

Maintenance of Norwegian offshore helicopters have traditionally been performed in Norway by Norwegian maintenance organizations that are approved by the Norwegian authorities. Maintenance of helicopters is a small industry where the players are closely linked, and where educational institutions and authorities usually recruit competence and personnel from the helicopter operators.

In recent years, heavy maintenance has been moved to organizations outside Norway, or that foreign actors (from the EU) are establishing branches in Norway. Examples are SAAB's workshop for maintenance at Sola, and HeliOne's performance of heavy maintenance in Poland. Such practices are permitted under current technical regulations (EU 1321/2014). Relevant actors must, however, be approved (certified in accordance with EASA requirements) and will be subject to the oversight from the certifying national aviation authority.

Contracting of maintenance is more common and proven in the fixed-wing segment, as well as in other industries. Offshore helicopter operations, however, are quite specialized, and there is reason to raise questions about the possible safety consequences of reducing the proximity to maintenance operations. The concern is mainly about *competence* and its management, with special focus on:

- competence of maintenance organizations - both administratively and in the executive section
- technical competence about the helicopters and typical loads they are subjected to from the environment in which they are used
- technical competence of overseeing authorities
- competence within educational organizations

Such competence will necessarily be lacking for new actors, and necessary competence is something that can take time to acquire. At the same time, there may be organizational differences in the way the competence is expressed through real maintenance work, including the impact that the sharp end of the maintenance work experiences with regard to managements' maintenance decisions on the helicopters.

A parallel can be seen in connection with the implementation of the aircraft operational HOFO regulations and the Norwegian main concern about the possible loss of national control of helicopter operations on the Norwegian continental shelf. No conclusion was reached on this issue since the Norwegian government stated that the regulations are not EEA-relevant (the NCS falls outside the geographical scope of the EEA Agreement). The solution was to regulate the requirement for Norwegian AOC (BSL D 1-1 § 4a). Maintenance of helicopters was discussed in that process, both in the Committee for Helicopter Safety on the NCS (CHS) and in dialogue between CHS and the Ministry of Transport and Communications.

Currently, the contracting of heavy maintenance abroad is limited, but since the regulations allow for this, one can imagine a spectrum of possible future maintenance models. The extreme case is that all maintenance is performed by foreign organizations with foreign workers, either at a foreign workshop or in Norway with contracted personnel. It is also conceivable that this will involve a foreign country without its own helicopter industry, with associated competence challenges as argued earlier.

This chapter presents empirical material related to outsourcing, i.e. contracting of maintenance work. Focus is on experiences from operative technical personnel in Norway who also have experience in working abroad. The first part is based on a document study outlining specific framework conditions for maintenance, that is regulations and organization of working life. The empirical part highlights distinct aspects related to contracting of maintenance. Focus is particularly on aspects related to technical (professional) competence. The chapter concludes with reflections regarding implications for safety, and lessons learned.

8.2 Document study

The focus of the document study has been to explore whether contracting of maintenance within offshore helicopter operations impacts flight safety per se, and if so, how. For that reason, it is useful to shed light on two key aspects relevant for contracting and in particularly the execution of maintenance, i.e. the current European technical regulations, and the organizing of working life from a national perspective. The latter two aspects are about prerequisites for how the maintenance is carried out in practice, i.e. framework conditions for maintenance across national borders.

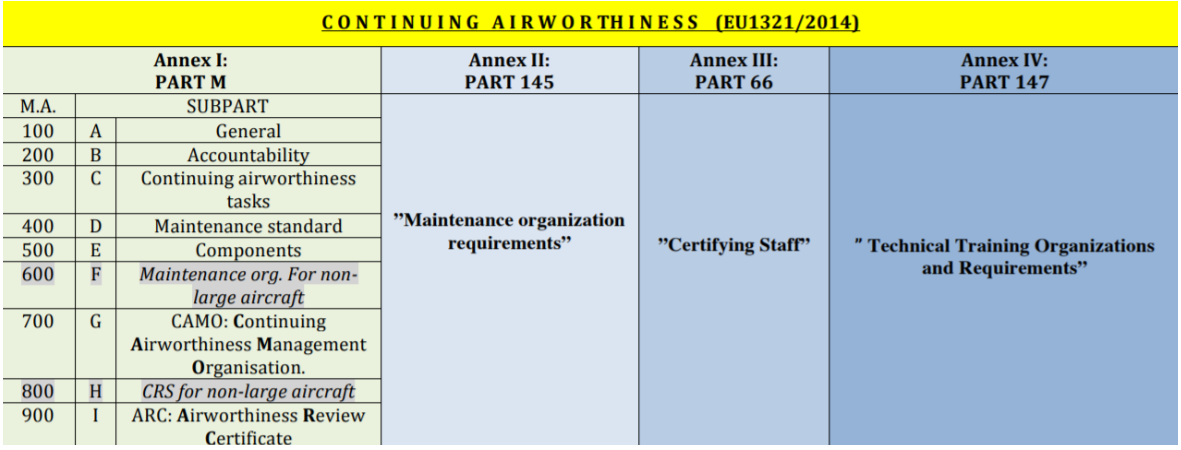
8.2.1 Current regulatory framework for maintenance of helicopters

EU 1321/2014 is a joint European legislation that meets the requirements related to the continuous maintenance of airworthiness, including the requirements for approval of organizations and personnel. Table 8.1 shows the regulatory structure with annexes with its associated "PART".

Part-M consists of various SUBPARTS and specifies which requirements apply to the maintenance program – for example how maintenance data is to be stored. Part-M also specifies the prerequisites that apply to keeping a helicopter airworthy, which also means the basis for approval of maintenance manuals and associated documentation. CAMO means a Continuing Airworthiness Management Organization, where one finds the certification requirements for Part-M organizations – which *roles* are necessary and associated *responsibilities*, which *qualification requirements* apply to certified personnel, and standardization of quality systems. It also defines how the annual ARC inspection is to be carried out, which applies to maintaining the Certificate of Airworthiness.

Part-145 covers the maintenance organization itself and contains the requirements for being able to perform maintenance on helicopters, i.e. requirements for personnel, equipment, planning of production and how the organization reports incidents. In relation to the regulatory structure, it is worth noting that these are regulations that apply across national borders within EU/EEA. This means that regardless of whether maintenance is carried out in Norway or for example Poland, the same regulatory statutes form the basis for the actual technical work in the respective countries.

Table 8.1: EU 1321/2014 regulatory structure (adopted from NFO, 2017).



CONTINUING AIRWORTHINESS (EU1321/2014)					
Annex I: PART M			**Annex II: PART 145**	**Annex III: PART 66**	**Annex IV: PART 147**
M.A.		SUBPART	**"Maintenance organization requirements"**	**"Certifying Staff"**	**" Technical Training Organizations and Requirements"**
100	A	General			
200	B	Accountability			
300	C	Continuing airworthiness tasks			
400	D	Maintenance standard			
500	E	Components			
600	F	*Maintenance org. For non-large aircraft*			
700	G	CAMO: **C**ontinuing **A**irworthiness **M**anagement **O**rganisation.			
800	H	*CRS for non-large aircraft*			
900	I	ARC: **A**irworthiness **R**eview **C**ertificate			

8.2.2 The value of tripartite cooperation

The "Norwegian model" for working life is characterised by close cooperation, dialogue, and trust between owner (management) and employees, where participation and co-determination over work performance are key factors. This means that employees' everyday work entails equality and trust, and that individual competence is valued, which in turn has a positive effect on job satisfaction. The Norwegian model involves rules of the game and tools that provide predictability for the parties, and the idea is to handle conflicts of interest as early as possible to prevent labour disputes and possible strikes. The model has been developed over a period of more than a hundred years (Alsos et al., 2019). The term "tripartite cooperation" is also used, which alludes to the cooperation between trade unions, employers as well as the Norwegian state.

A recent Norwegian public report (NOU, 2019) on the topic of Norwegian aviation in change, highlights the good tripartite cooperation between the actors on the Norwegian continental shelf as an important enabler of the very good flight safety statistics within offshore helicopter operations. This applies to all parts of the activity, including maintenance.

8.2.3 New ways of organizing and potential impacts on safety

According to the "Globalization Report" (2016) there is no basis for a connection between new forms of organization and negative effects on safety – including outsourcing of heavy maintenance – in the US. However, it is pointed out that authorities must pay close attention to the restructuring processes at the operators. Similarly, Tang (2012) argues in a CRS report for the US Congress that although some experts believe that airline flight safety is being compromised due to outsourcing of maintenance, analyzes of recent trends do not support that outsourcing affects airline safety negatively.

EASA (2017) has published a guide related to risk in new business opportunities where EASA points out that outsourcing of safety-critical functions can also have benefits, e.g. purchase of services from another organization with better knowledge and quality. However, there is a risk associated with the buyer losing control and influence. The "Ghent report" (Jorens et al., 2015) describes how the liberalisation of the European aviation marked gave rise to new business models, e.g. low-cost airlines and contemporary employment relations for pilots and cabin crew members (Jorens et al., 2015). The report identifies various forms of atypical employment for aviation professionals, such as self-employment, fixed-term work, work via temporary work agencies as well as zero-hour contracts and pay-to-fly schemes (Jorens et al., 2015:XII). The report explicitly points to Flags of Convenience as challenging arguing that this can result in a race to the bottom including social dumping similar to the maritime sector, which might impact aviation safety. The report raises concerns regarding contracting of personnel in the light of a just culture approach, highlighting proper reporting mechanisms, a non-blame culture and the acknowledgement of whistleblowers. The report also describes that some airlines' management styles are in contradiction with provisions and regulations on CRM as well as Safety Management Systems (Jorens et al., 2015).

Moreover, the SINTEF report "aviation safety during restructuring processes" (2005) concludes that aviation safety may be threatened under certain conditions, for example related to:

- Organizational fragmentation within a system with tightly coupled activities, ref. Hatfield accident (railway) in the UK and organizational fragmentation of maintenance responsibility.
- Impairment of an organization's ability to detect danger signals - seen in connection with e.g. loss of competence with regards to identify and interpret symptoms of vulnerabilities. Also, line managers who do not pay enough attention to safety issues.

8.3 Maintenance today

This section presents some central themes based on interviews with key stakeholders from operational maintenance work, both employees, unions and technical management. All the informants also have some experience from maintenance abroad.

8.3.1 Maintenance practice

An ordinary working day for technical personnel will vary depending on the role held. For personnel working with maintenance on the helicopters, the day usually starts with checking whether one is qualified in accordance with the maintenance manual for the planned work. On each shift, there are several people working on the same helicopter; in Norway there are most often a minimum of three people per shift. However, it will vary which shift scheme the technical personnel are part of. Different companies practice this differently, which one of the interviewees also pointed out was one of the reasons behind his own recent job change.

Maintenance checks and contingencies

A helicopter undergoes varies types of maintenance, from daily line inspections to heavy maintenance where the helicopter is taken out of operation for a longer period of time. Maintenance involving hangar work follows the helicopters specified maintenance program. For the S-92A the program follows a schedule divided into sections. These sections are maintenance divided into groups every 1500 hundred hours, as well as smaller checks on 750, 375 and 50 hour intervals. During maintenance work, the maintenance instructions (drawings etc.) do not always correspond to real life issues, and when such situations arise, it is standard practice for the technical personnel to contact the Part-M department in the company for updating and / or clarification on how to proceed further.

Prescribed versus performed work

Our informants report that maintenance in Norway is characterized by a desire to be careful and dedicated in all aspects of work on the helicopters. The starting point is that work is allocated the time necessary for it to be acceptable in terms of quality and safety, where the personnel working on the helicopters in the hangar have also the opportunity to influence technical decisions at the managerial level. It is pointed out that helicopter maintenance has some distinct challenges that are not found in the fixed-wing segment. Helicopters are arguably more complex machines than airplanes, considering the large quantity of rotating and vibrating parts. This increases the risk of crack formation, calling for regular critical inspection and maintenance tasks at a much higher frequency than is the case in fixed-wing. Experience and continuity among the technical personnel are thus emphasized as particularly important. At the same time, there is always an ideal desire for more employees to be present at work, preferably related to the efficient implementation of maintenance work.

It is explicitly emphasized that on the NCS it is important to follow the maintenance instructions, i.e. the standards, procedures, and guidelines in force at any given time. Our informants also describe a working day out in the hangars where technical personnel do not experience pressure to stretch or utilize the regulations from their superiors. Technical management points out that in Norway technical personnel are less likely to use the tolerance limits completely during maintenance. It is emphasized that safety is always prioritized first. If, contrary to expectations, an error is made during maintenance, it is perceived from the operational side that it is important to be allowed to report - there is no need to hide anything from the management. A culture of openness is also something the professions are aware of communicating the importance of internally. Our informants highlight that the reporting culture and just culture is strong in Norwegian working life. Specifically, technical management points out that they experience that there is a very good reporting culture in their own respective helicopter organizations.

With regards to the relocation of heavy maintenance out of Norway, HeliOne's relocation to both Canada and Poland are one of several examples, which meant that HeliOne in Norway experienced competition from its own company located abroad. However, the activity in Canada was eventually shut down, which resulted in the Norwegian business being provided with extra resources.

8.3.2 Varying levels of bureaucracy

Our informants point out that own experience related to working in Norway compared to other countries is about different ways of organizing and practicing maintenance. For example, it is perceived that Canadian maintenance work is more uncomplicated in terms of formalization and bureaucracy compared to Poland and the UK. The experience was also about a better technical basis and the trust shown by management in connection with the implementation of maintenance work. Another example from maintenance work in Poland involves the aforementioned bureaucracy, and many local middle managers who were involved in the work. This type of involvement was perceived by the Norwegians as disruptive, at the same time as it took the focus away from the actual work. Involvement from local management was often about questions related to when the work would be completed, which often led to the experience of time pressure.

8.3.3 Varying levels of competence

Our interview informants, who have experience from maintenance abroad, point to challenges regarding varying competence among technical personnel as an element of uncertainty when outsourcing heavy maintenance. It is claimed that the competence in some countries is more varied than, for example, in Norway, i.e. that in addition to very skilled and dedicated professionals, there are also people who do not have a sufficiently high professional level to work on the helicopters. In addition to technical competence, the challenge also lies in language skills and sometimes a lack of understanding of English, i.e. everyday speech in addition to helicopter-specific words and expressions. However, our informants representing technical managerial roles point out that there is a particularly high quality of competence and quality among technical personnel in Norway.

Another aspect of relocating maintenance is whether the organization you are moving to has similar competence as the organization you are moving away from. In this context, Poland is mentioned as an example where it took time to build up the necessary technical competence - frequent replacements of personnel made it challenging in the beginning to ensure good continuity with regard to technical personnel. However, there is a perception that in Poland, for example, there are more employees at work per shift compared with Norway. An expressed concern from Norwegian technical personnel is nevertheless related to whether, in an imaginary case, one is able to uncover in advance serious errors and deficiencies during maintenance and inspections, which is seen in connection with the mentioned perceived variation in competence within the various disciplines at some foreign maintenance organizations.

8.3.4 Contracted maintenance in Norway

Today, there is relatively little contracted labor when it comes to maintenance in Norway, both within maintenance organizations and within the helicopter operators. However, the situation was somewhat different five to ten years ago. Norwegian workers' unions argue that contracted labor may be unfortunate for helicopter safety. Arguments relate to increased time pressure associated with contracting, as well as the notion that contracted labor does not necessarily experience a strong ownership of job performance compared to permanent employees. The same arguments are given when it comes to *subcontracting* as well.

When it comes to contracted labor, it is often seen that workers come from the UK, where hierarchy is made visible in that technicians have a tendency in overriding skilled workers. Concern has also been expressed from permanent employees related to the fact that contracted personnel are more occupied with getting the job done, than the actual quality of the work. At the same time, contracted labor may refuse to report unfavorable working conditions or anything of a technical nature, because one thinks that it may make it more difficult to extend one's own current employment contract or the possibility of receiving new contracts in the future.

8.3.5 On current work practices within maintenance and impact on helicopter safety

When asked what it is about current maintenance practices that one thinks could potentially have a negative impact on helicopter safety, the picture our informants provide is in unison related to tight time frames on maintenance jobs, including a generally experienced time pressure. However, it is worth pointing out that even if time pressure is experienced, technical personnel are clear that this is something they try not to be influenced by in their daily work. An example from a Norwegian context is when the technical manager hangs over the shoulder of the responsible technician to complete a job that allows the helicopter to be released, where the involved technician resists and argues and explains that the ongoing work needs more time to finish, which the technical manager then accepts. It also varies which disciplines are in question in view of perceived time pressure – a sheet metal worker will not experience the same time pressure as a mechanic, because the former is much earlier involved in maintenance processes than the latter. However, according to our informants who also have maintenance experience from abroad, reluctance to comply with managerial pressure to get things done quickly is not always acceptable in working cultures internationally.

8.3.6 The role of regulators, CAA-N and EASA

How technical personnel relate to the CAA-N depends on the role individuals have in their respective organizations. However, none of our interview informants have anything to complain about in the CAA-N´s performance of its own responsibility related to maintenance follow-up. Particularly, technical management points out that they experience a very good cooperation with the CAA-N, with open dialogue and professionally skilled inspectors.

EASA, for its part, has tightened the current regulations with regards to competence, for example, it is no longer allowed to carry out maintenance and repairs based on own experience (grandfather's rights). This must now be done after consultation with the manufacturer. As previously mentioned, there is now also proposed amendments to Commission Regulation (EU) No 1321/2104 allowing to separate CAMO from an AOC, i.e. to subcontract CAMO to a third party. The industry response to this proposed change has been overall negative. The main concern in the short term is related to reduced responsibility, competence and audits within Norway, while the fear in the longer term is that this represents the beginning of a fragmentation of national AOC. This topic should preferably be investigated further in a separate study.

8.4 Discussion: Technical competence in motion

This section contains a discussion on regulations, maintenance practices and technical competence across nations, followed by some reflections on safety. As background for this, we first recapitulate the main empirical findings from the interviews:

- Cultural differences are experienced – in Europe, the most important thing is to get the job done efficiently, e.g. more shortcuts.
- Contracted labor is claimed to be more restrictive in reporting – seen in connection with new contracts or not.
- High authority gradient in e.g. Poland – middle managers who interfere taking the focus away from actual work performance.
- Experienced competence abroad is varied – replacement of personnel, which means that it takes a long time to ensure continuity and build competence.
- Technical management points out that heavy maintenance in e.g. Poland is done well, but takes longer time. Weaker documentation abroad – helicopters returning home are examined in detail by technicians at home.
- Operationally, it is commented that EASA has tightened regulations – previously experience-based repairs were allowed.
- The main challenge (from the hangar) related to safety involves time pressure to get a helicopter ready – however, technical management in Norway comments that "if the helicopter stands, it stands".

8.4.1 Regulations, maintenance practices and technical competence (across nations)

A joint European legislation through EASA related to the requirements for maintenance means that it should in principle be possible to carry out maintenance in a similar way across European national borders. However, we see that this is not necessarily what happens in real practice. Lack of spare parts is often a challenge, something which can be related to planning processes per se. For example, EASA Part-145 states regarding personnel requirements that an organization shall employ or contract staff that is "competent". Planning involves competence, and it is therefore important to ensure the proper technical competence when for example hiring of planning personnel. The regulation does not go into detail about what constitutes competence per se, which provides a space of opportunity with regards to who will hold such positions – competence is also something that can be defined differently across national borders, but also within and between organizations. There is, of course, thus a room for manoeuvrability as to how regulations can be utilized between and within various nations. This may be related to local market conditions, but also how working life is organised, including whether one is concerned with consensus or conflict, and the extent to which working life and organizations are characterised by what organizational theory describes as machine bureaucracies etc. The question is nevertheless how and to what extent different stakeholders including technical personnel will be able to influence the actual maintenance practice and decisions, and whether one actually desires to, something which is also culturally conditioned and varies across nations.

8.4.2 What about safety?

The research literature does not provide a clear and unambiguous answer related to outsourcing and subcontracting of maintenance and implications for helicopter safety, be it strengthening or weakening. If one delimits towards the preservation of technical competence (across national borders), the picture is such that competence is managed somewhat differently, which can be seen in connection with how various nations organize working life, and how cultural features are expressed through work practice, e.g. maintenance performed in the hangar. However, from a technical operational point of view, the recognition of, for example, individual competence is imperative, i.e. technical personnel must be confident that their own professional assessments related to a helicopter's technical condition is heard and at the same time recognized by local as well as central management in the organization. This does not imply that "the technician is always right" regarding decisions on how to proceed next – what is important is for employees to be confident that they are able to express and voice concerns impartially without this potentially having a negative individual consequence afterwards. A *just culture* approach is thus one key aspect related to ensuring safety within helicopter organizations characterized by inherent tight couplings and complexity.

As a summary, it is important to note that the interplay between what is optimally efficient and what is optimally safe, and whether it is possible to have both at the same time, is complex and not possible to answer unambiguously. It is also not necessarily the case that outsourcing will automatically contribute to more efficient work processes, which is often seen in connection with lower costs and is as such an important driver for moving maintenance per se. Outsourcing of maintenance can also have the opposite effect, e.g. that maintenance processes take longer to complete, even if the level of safety is maintained. Again, these are complex issues. Conclusively, it is worth noting that Norwegian and Widerøe have recently decided to move back heavy maintenance on their aircraft to Norway, where building up the necessary technical competence within Norway is a main argument, while maintaining cost efficiency and flight safety.

8.5 Concluding remarks – lessons learned from studying outsourcing of maintenance from a safety perspective

The following points summarizes the findings into lessons learned in relation to helicopter safety. As such, the points should be viewed as areas needing more in depth-studies in the future:

- Facilitate and ensure a **just culture approach** rooted throughout the entire maintenance organization. Experiences from fixed-wing have shown that this can be challenging due to liberalization and increased market competition.
- Importance of **clear responsibility and reporting routines** within maintenance organizations and helicopter companies should not be underestimated. New ways of organizing, e.g. subcontracting and organizational fragmentation renders this particularly relevant.
- **Adequate access to resources**, operational as well as managerial, including technical expertise and competence. Changed (and increasingly tougher) competitive conditions and requirements for

efficiency per se in the industry mean that local technical competence must not be underestimated. In this context, independent inspections are also relevant to discuss.

- **Tripartite cooperation** is an important contributor to safety through safeguarding dialogue and exchange of opinions, as well as facilitating trust among the various industry stakeholders.
- The possible consequences of **subcontracting CAMO** to a third party (outside the AOC) should be investigated in a separate study.

9 Crew Resource Management (CRM)

The study activity on Crew Resource Management (CRM) is documented in this chapter. Due to a limited scope, focus have been on experiences and concerns raised at the "sharp end" of CRM, i.e. operational personnel (pilots) and pilots' unions. Information has been obtained mostly through interviews and expert discussions, supported by document studies and prior knowledge.

9.1 Introduction and delimitation

CRM is an approach to understand what characterizes effective collaboration imperative for safety. Helicopter pilots must have a good understanding of what CRM entails, i.e. principles, methods, and practical use. CRM is intended to act as a barrier in all conceivable situations, whether it is normal operations or situations where emergency procedures are needed. If procedures and standards fail or do not exist, good CRM practice should be able to provide a crew with the best starting point for regaining control and minimize the consequences of a critical situation.

The discussion in this chapter is based on the fact that CRM deals with both specific skills, as well as the prerequisites that must be used as a basis, something that is achieved through training. For analytical purposes, we choose to use CRM instead of, for example, non-technical skills (NTS) as described by Flin et al (2003). Our argument is that the applied practice of CRM skills in relation to collaboration involves technical as well as non-technical competence, in a mutually dependent relationship.

Causes of fatal accidents in the oil industry globally in the period 2013 to 2021 are distributed as shown in Figure 9.1. The figure is taken from HeliOffshore Safety Performance Report 2013–2021. Almost half of the accidents are categorized as either collision type events (CFIT/CTOL/ARC) or loss of control (LOC-I). A closer look shows that many of the accidents have their direct cause in missing or poor CRM. Furthermore, deficient CRM is involved in many of the accidents with other primary causes (technical, weather, etc.).

In recent years, there have been a number of serious near misses where CRM aspects have been involved. Two examples of collision with sea (CFIT) in the UK sector are the approaches to the ETAP platform (2009) and Sumburgh (2013) (ref. chapter 6). An example of a near-collision with sea (10 ft) is the interrupted approach to a platform outside Halifax in 2019. There were also two incidents on the Norwegian continental shelf in 2019 and 2020 where the crew did not follow procedures during departure from the platform which resulted in the helicopter ending up below the helideck level before control of the situation was regained.

In addition to fatal technical failures, inadequate use of CRM skills is the major risk the offshore industry sees for helicopter operations at NCS. This is the background for CRM as a separate activity in HSS-4. This activity explores the following research questions:

- How is CRM used in today's offshore helicopter operations?
- What are the benefits and disadvantages of today's CRM?
- What implications does this have for CRM of the future?

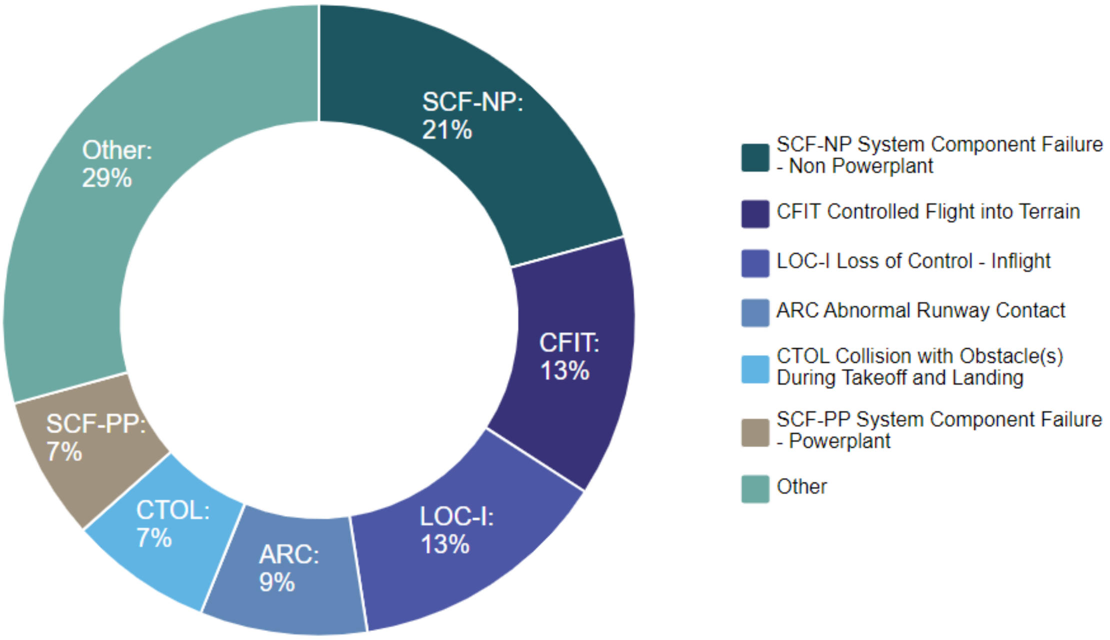


Figure 9.1: Categorization of fatal accidents in the oil industry globally; 2013–2021 (HeliOffshore, 2022).

This chapter begins with an introduction to the concept of CRM in aviation with special emphasis on the traditional skills of CRM. As a framework for an increased understanding of the importance of CRM within offshore operations, selected incidents and accidents from aviation are reviewed. Part two presents CRM topics based on interviews with key operational CRM professionals. CRM is limited to dealing with the collaboration between the crew in the cockpit, i.e. the pilots and cockpit resource management. At the same time, it is important to point out that CRM can also involve focusing on an entire crew through "crew resource management", as well as companies as a whole through "company resource management".

Our analytical approach involves studying what it is about the CRM concept that facilitates pilots to be able to handle unexpected situations, i.e. how unexpected situations also can entail some predictability. The chapter concludes with suggestions related to further development of CRM including future CRM training within offshore helicopter operations.

9.2 Theoretical part: Background

Crew Resource Management (CRM) implies a flight crews' use of all available resources to ensure safe and efficient operations including reducing errors, avoiding stress together with increasing efficiency (Skybrary, 2021). CRM is traditionally viewed as a set of principles, or procedural ways of interacting motivated by the need to reduce human error. The origins of CRM can be traced back to the late 1970-ies. After the 1977 Tenerife disaster, where two Boeing 747 aircraft collided on the runway under foggy conditions, CRM began to emerge as a conceptual framework to understand how pilots collaborate in the cockpit. This was further reinforced by the 1978 United Airlines Flight 173 crash and the subsequent National Transportation Safety Board (NTSB) recommendations. In 1979 NASA psychologist John Lauber introduced the term CRM based on own studies of pilot communication. Motivated by the need to facilitate a less hierarchical and authoritarian way of interacting, first officers were for example encouraged to question decisions made by captains if errors were detected or one was uncomfortable with any situation.

In 1981 United Airlines became the first airline to provide CRM training to pilots, and a decade later CRM based training was standard in the aviation industry. In addition to pilots, United Airlines also trained its flight attendants in using CRM concepts to facilitate better collaboration among the entire crew. This is standard practice today in the aviation industry, including offshore helicopter operations, e.g. SAR-crews. The idea is to improve safety and efficiency through reducing barriers associated with interpersonal communication.

The introduction of the "black box", i.e. flight data recorder (FDR) and cockpit voice recorder (CVR) also meant that accident investigators had at their disposal new and powerful tools to gain insights into the causes of aircraft accidents. These novel technological resources uncovered that many of the accidents at the time did not have technical root causes per se, nor poor aircraft handling by pilots. Instead, focus was directed towards *how* pilots responded to escalating situations, i.e. inadequate responses were seen in conjunction with poor quality of cockpit communication between the pilots. For example, one often saw a chain of causes where initial weak communication between the pilots resulted in a loss of situational awareness, thereafter unfortunate decisions followed by a serious incident or an accident.

9.2.1 CRM training

CRM training initially started out as classroom training. Today, the prominent resource for training pilots is the flight simulator. The flight simulator when it was introduced, allowed for theories and assumptions related to for example accident causation to be tested experimentally, which further sparked the way for various techniques that focused on improving flight deck teamwork. These collective embraced techniques, i.e. CRM training, is today well recognized and used in almost all parts of the aviation industry, with the main goal to strengthen aviation safety.

CRM based training is also in widespread use worldwide in varying industries where personnel need to make rapid and time-critical decisions within work environments characterized by inherent complexity and risk. These settings range from e.g. firefighting, ship bridge management together with medicine having adopted CRM for use within medical operating rooms.

Skybrary (2021) presents several factors that are viewed as causes for pilots not being able to manage crew resources effectively. Some of the mentioned causes are:

- Lack of proper CRM training – crews may exhibit poor resource management and have an inadequate understanding of the value of CRM.
- Not having proper technical knowledge can affect performance adversely – can result in confusion and lack of confidence.
- Over-emphasis on technical expertise cannot replace good resource management skills - some situations require teamwork as well as technical skills.
- Organizational culture can also affect CRM when professionals are discouraged from expressing their opinions - for example, some cultures may also be characterized by a high gradient of authority and challenges related to challenging decisions and actions of seniors.
- Operational pressure from management can hinder sound decision making.
- Emotional status, fatigue as well as past experiences can hinder ones CRM skills.

Skybrary (2021) also describes the following approaches to counter some of the mentioned causes:

- An understanding of human factors and how people work and interact as a prerequisite for managing crew resources.
- A well-designed CRM training course that covers for example situational awareness, decision making, teamwork (communication, cooperation, leadership and followership), as well as human-machine interaction and automation.
- Improved technical competence – it will help professionals to manage situations in a more confident an open manner.
- Proper planning and briefing are important including not deviating from standard operating procedures (SOP's) in order to reduce the chances of misunderstanding.
- Acknowledge that other people can have different thought processes, opinions or cultural leanings than oneself. Professionals are different - be assertive, nevertheless remain open and recognize the potential for legitimate differences.

9.2.2 The traditional skills of CRM

CRM involves several elements, which even before CRM was conceptualized were recognized through for example issues of crew cooperation as well as airmanship. These terms, however, are today viewed as CRM competencies, i.e. knowledge, skills and attitudes coupled to distinct aspects like for example situational awareness, decision making and problem solving. CRM has as such structured and formalized various competencies which have in part been a known phenomenon in aviation from the early beginnings. CRM is generally understood (and defined) as a systematic approach to facilitate the optimal use of all available and relevant resources, i.e. involving the human, the technical and organizational to ensure safety and efficiency of flight operations. From a safety perspective, this necessitates the importance of recognizing people, equipment, and procedures as mutually depending. This implies that for example distinct skills required by the professionals overlap with each other as well as overlapping with needed technical skills.

A traditional focus for CRM is professionals' abilities to demonstrate interpersonal skills related to teamwork communication. Cognitive as well as social skills are emphasized as necessary preconditions for desirable collaboration. Focus is on the importance of mental processes as a prerequisite for achieving and sustaining sufficient situational awareness, as well as further making the right decisions. The technical skills needed to manage flying are an important CRM focus area. Cognitive, social as well as technical skills are interdependent key skills within CRM.

A key aspect of CRM is to facilitate a collaborative climate where it is expected that questions are asked when for example a situation is perceived as confusing or that one experiences that something is wrong.
How expectations are formed are also central to CRM since one of the key indicators that something is not right is the acknowledgment that there is a discrepancy between what is actually happening with what one expects to happen. In some cultures, it can be more challenging to challenge authority when the co-pilot needs to question the captain's order. Therefore, systems were needed to objectively assess performance on CRM skills, and one such system is NOTECHS (van Avermaete, 1998).

NOTECHS assesses crew members *non-technical skills*, both cognitive and social and is widely used in aviation to select professionals who meet the required CRM skills. In addition to assessing, NOTECHS also provides feedback on specific social and cognitive skills that are related to human error and hence aviation safety. However, the NOTECHS system is one of several methods that couples CRM training to actual enhanced effectiveness (Goeters, 2002). Table 9.1 shows the CRM skills in use based on the standardised NOTECHS taxonomy.

Table 9.1: Overview of non-technical skills (cognitive and social) in NOTECHS (van Avermaete, 1998).

Category	Elements
Co-operation	- Team building & maintaining - Considering others - Supporting others - Conflict solving
Leadership & Managerial skills	- Use of authority and assertiveness - Providing and maintaining standards - Planning and coordination - Workload management
Situation Awareness	- Awareness of aircraft systems - Awareness of external environment - Awareness of time
Decision Making	- Problem recognition and diagnosis - Option generation - Risk assessment and option selection - Outcome review

The NOTECHS descriptive framework consists of three levels, i.e. category, element, and behaviours (van Avermaete, 1998). Elements are subsets to the categories and provide thematic examples of each of the categories' focus. For example, the category Situation Awareness involves the ability the crew has to perceive, monitor, and comprehend, thus be aware of the aircraft's surroundings. Each element is provided with indicative behaviours meant to enable identification and assessment of the extent an element reinforces or weakens the overall skill (category), i.e. through positive or negative behaviours. *Communication* per se is not a distinct category in the NOTECHS' framework – the argument is that communication skills are inherent in all the four non-technical skills categories and is also manifested in the elements as well as the associated behaviours.

The analytical starting point for Table 9.1 is both social and cognitive skills operationalized through the four categories. What characterizes social skills is primarily verbal action through how one communicates, which gives a crew the opportunity to, for example, jointly discuss situations that arise. Examples are briefings before departure and landing, as well as explicit exchange of information during the flight. Cognitive skills imply ones' ability to gain situation awareness (SA) and to make proper decisions, i.e. tasks like observing, planning, and prioritizing prior to making the decision. However, Flin et al. (2003) note that social skills (Co-operation, Leadership and Management) are directly observable, while the cognitive skills (Situation Awareness, Decision Making) are not, since they do not materialize through explicit behaviours or actions.

9.2.3 An extension of the CRM concept

CRM originally initiated with an emphasis on *Cockpit Resource Management*, i.e. pilot collaboration, while in recent years this has broadened to also encompass the entire crew, for example involving rescuers in SAR helicopters. There is also an expanded CRM concept through *Company Resource Management*, and the idea of *Team Resource Management* (TRM) as well as *Maintenance Resource Management* (MRM) illustrate that the general idea of improving key professionals' non-technical skills extend beyond the original pilot and cockpit approach. For example, the TRM approach is like CRM with regards to optimise safety and efficiency. However, focus is on the Air Traffic Services with a particular emphasis on involving safety management to safeguard aircraft operations from common system failure causes. The principal idea behind

TRM is to strengthen the functioning of ATC teams by focusing on professionals' acknowledging how and why human factors, including interpersonal behaviour influence operational safety.

Eurocontrol (2018) shows that approximately 70 % of the surveyed ANSPs have implemented TRM, and it is expected that almost half of those not yet having implemented TRM will do so in the future. Several of the ANSP's held joint sessions where other professions also participated, e.g. management and or pilots. The topics addressed in the TRM sessions originate mainly from internal reports, i.e. using ATC case studies, internal investigation reports and videos. Eurocontrol (2018) describes a TRM session to last one day involving around ten participants including two facilitators. Professionals having participated report TRM sessions to be generally effective, alternatively highly effective (Eurocontrol, 2018).

9.3 Empirical part I: CRM and lessons learned from aviation case studies

The following incidents and accidents are important in the sense that they illustrate how deficient CRM in some instances can have severe safety consequences. At the same time, some cases also show how distinct crew collaboration can have quite an opposite and positive effect on safety. Specifically, the Boeing 737 MAX is included because the accidents illustrate how the design of technological systems can also lead to clear limitations for the pilots' room for manoeuvre, even if CRM skills are well trained. This also illustrates the importance of understanding the framework conditions for good CRM in practice. The rationale behind presenting these cases is to explore some CRM aspects that were identified in the aftermath of the incidents/accidents.

9.3.1 Air France 447

In January 2009, an Air France Airbus A330 crashed in the Atlantic Ocean enroute between Rio De Janeiro and Paris. There were no survivors, and the two black boxes were first recovered two years after the accident. AF 447 had been flying for three and a half hours when ice crystals blocked the A330's speed sensors, which resulted in the flight computer automatically disengaging the autopilot. This it was designed to do in cases of inconsistent data from the outside sensors. The aircraft was flying at 33.000 ft., and when the autopilot switched off the pilots had to take over manually. The French accident board (BEA, 2009) notes that pilots do not train in simulators on manual handling of an aircraft while it is on cruising altitude. In the cockpit of flight 447 it was the least experienced flight officer who was the pilot flying, while the role of pilot monitoring was held by the senior flight officer. When the event initiated the captain was resting and outside of the cockpit. The co-pilot's response to the autopilot disconnecting was to overcompensate when trying to adjust a slight aircraft bank. Also, and without being aware, he pulled his sidestick back pulling the aircraft's nose upwards, which resulted in an aerodynamic stall one minute after the autopilot disengaged.

The excerpts from the CVR did not indicate that any of the pilots understood what was really happening to the aircraft, i.e. a stall, which also included the captain who was quickly called back to the cockpit. Since the pilots did not understand (until it was too late) that the aircraft had stalled, they were also unable to carry out actions to get the aircraft out of the stall until at the very last moment. The Airbus A330's aircraft computer did actually declare through voice commands "stall" 75 times over the four and a half minutes from the autopilot disengaged to impact with the ocean surface. However, it is worth noting that in the A330 the automation is designed so that a stall warning is automatically turned off when the speed is reduced to less than 60 knots. At the same time the angle of attack values also became invalid as a parameter to trigger a stall warning, something which also contributed to confuse the pilots.

Some of the major BEA (2009) findings are CRM related. For example, the report states that the Captain left the cockpit without clearly instructing the two co-pilots on their roles. Neither of the two co-pilots called for an "Unreliable Indicated Air Speed" procedure even tough having identified and called loss of airspeed indications. There was neither any explicit task-sharing between the two co-pilots, and they did not use any standard callouts on the disparities in pitch attitude and vertical speed. BEA (2009) further states that there was no CRM training provided for a crew consisting of two co-pilots where one of them was to act as a relief captain. Safety recommendations on operations were to train specifically on manual stall recovery handling at high altitudes, together with formally assessing qualifications needed for the role of relief captain to improve sharing of tasks (BEA, 2009).

9.3.2 Boeing 737 MAX

In 2018 and 2019, the Boeing 737 MAX experienced two fatal accidents that resulted in the aircraft type being grounded. In 2018, Lion Air Flight 610 crashed into the sea off Indonesia, while in 2019 Ethiopian Airlines Flight 302 crashed off Addis Ababa. Both accidents occurred immediately after departure. The accident investigations were carried out in several countries, respectively NTSC (2019) in Indonesia, AAIBE (2019) in Ethiopia together with NTSB (2019) in the US. Human Factor experts participated in the investigations. The investigations quickly revealed faults with the control system "Maneuvering Characteristics Augmentation System" (MCAS), which is an automated system designed to prevent stalls given specific flight parameters. MCAS took control over the aircraft and lowered the aircraft' noses to prevent stalling – the problem was that MCAS is only connected to one single angle of attack indicator (AoA), which in both accidents also reported incorrect sensor data to MCAS. The pilots in both aircraft were unable to correct the aircraft's automated and continuous downward movements due to a lack of system knowledge, including lack of training in how MCAS could be overridden.

The need for MCAS was a result of the new and larger engines on the Boeing 737 MAX, compared to previous versions of the aircraft. The engines' new design and the risk of stalling in specific situations are also emphasized in the NTSC report (2019), while the AAIBE report (2019) emphasized how MCAS was incorrectly designed. In the aftermath of the accidents, questions were also raised as to the suitability of the cockpit alarm design to support pilots in understanding what is really going on when situations tighten (NTSB, 2019). One of the safety recommendations was based on Boeing demonstrating insufficient understanding of pilot behaviour and responses to alarms during the design phase. A prerequisite from the authorities for lifting the flight ban was to redesign the MCAS as well as the requirement for the pilots to undergo simulator training. Endsley (2019) recently pointed out in a congressional hearing on the accidents that there is a need to include pilots, including the use of Human Factors standards related to task analysis in the design of automated systems. Endsley (2019) argued that novel automated systems must be tested by users themselves where human performance is also considered as part of the certification process.

9.3.3 Quantas Flight 32

In 2010, a Quantas Airbus A380 suffered a failure in one of the four engines four minutes after take-off from Singapore on its way to Sydney. The aircraft continued to fly for about two hours to assess the situation before making a successful emergency landing. There were no injuries to either passengers or crew. According to the investigation a turbine disc in the engine disintegrated resulting in extensive damage to the wing, fuel system, landing gear and both flight as well as engine controls. The Australian Transport Safety Bureau (ATSB, 2013) concluded that the root cause was an improperly manufactured oil pipe which broke as a result of fatigue. The report notes that a key aim of CRM is to minimise or manage crew workload, and the presence of additional flight crew in the cockpit on Flight 32 (one check-captain and one in training) provided the primary flight crew with extra support on tasks such as for example communication with the cabin crew. The ATSB (2013) relates the behaviour of the flight crew as well as the cabin crew to the CRM skills described by Salas et al. (1999). The report concludes that crew behaviours were consistent with the CRM skills, i.e. the whole crew performed to the level of a *competent team* (ATSB, 2013). The report highlights the following CRM-related behaviours that facilitated a safe landing:

- The captain (in conjunction with the rest of an experienced flight crew) made critical decisions regarding aircraft controllability, completion of the ECAM procedures, preparing for return and landing of the aircraft and passenger disembarkation.
- The purser dealt efficiently and effectively with a minor medical issue involving a passenger and his/her medication and ensured that all cabin crew were aware of the developing situation and what their duties entailed by personally visiting each station and briefing all crew.
- Communication between all crew members and between crew and the passengers was rapid, thorough, and provided the necessary information to keep all fully informed.

McCall (2017) explores four successful aviation cases to identify the characteristics of flight crew and ATC coordination, and the link to successful outcomes. Flight 32 is one of the cases explored. McCall (2017) argues that coordinative practice facilitates shared understanding of a situation, which is essential for crews to be able to develop joint plans to handle unexpected in-flight events. Four themes are elaborated that enhanced coordination during the in-flight emergencies, i.e. reluctant heroes, trust in roles, coping with crisis and embracing training. The latter is particularly relevant in terms of CRM – the interviewed flight captains highlighted the importance of dedicated CRM training for successful flight crew coordination. The presence of extra pairs of eyes (two check-captains) were valuable in a CRM perspective through how they helped assess decisions made in the two hours the A380 circled before the emergency landing.

Donoghue (2012) notes that training is never able to address all possible dangers associated with aviation, which makes it necessary to possess experience including traditional airmanship skill. The Quantas Flight 32 is also referred as a black-swan event. There were errors that the certification standards did not consider, which made this an event that had not been trained on in the simulator, i.e. the crew needed to understand a situation that was outside their realm of experience. The captain of Flight 32 stated afterwards that the success was because of good teamwork, and that todays' complex aircraft designs most likely contribute to make some unforeseen situations more confusing than needed. To be best equipped to handle future situations outside the realm of experience, the captain of Flight 32 pinpoints teamwork including CRM experience and a non-authoritarian command gradient as imperative.

9.3.4 The forced landing at Yme

In 2013 a Sikorsky S-92A operated by Bristow Norway made an emergency landing at the unmanned and shut down oil rig Yme. The helicopter was on its way to the Valhall platform with twelve passengers but had to abort the landing due to low visibility. On the way back to Sola airport, several warnings in the cockpit indicated that something was wrong with the main gearbox's lubrication system. The pilots observed that the oil temperature rose while at the same time the oil pressure dropped, a signal that this was not just an indication error. The pilots chose to set course for Yme since the oil pressure remained stable above the minimum level of 47 psi, i.e. the pilots perceived the situation so that they had to land as quickly as possible, but not immediately. The Norwegian Safety Investigation Authority (NSIA) concluded that the fault indications in the cockpit were due to a minor technical fault which caused an automatic circuit breaker to trip (NSIA, 2015b).

The NSIA report comments that the error messages the pilots had to manage were confusing – the oil pressure did not drop even though the warnings indicated a failure in the gearbox oil pumps. The pilots thus experienced a situation where the instruments provided conflicting information, which was not made easier by the fact that this type of situation was not described in the S-92A emergency checklist – there was no information related to both oil pumps failing at the same time, nor how to solve the problem. However, despite the uncertainty as to what happened, the situation was handled very well - the pilots took immediate actions that limited the risk that the situation would lead to a serious accident, i.e. reducing speed and low flight altitude towards Yme as well as informing ATC. The passengers were also informed and asked to prepare for an emergency landing at sea.

The NSIA comments that the emergency checklists did not support the pilots in making decisions, which is reflected in the safety recommendations asking Sikorsky for the complicated emergency checklists to be made easier to understand. Secondly, that the indications the pilots experienced explicitly are included in the emergency checklist.

9.3.5 Pilot incapacitation during landing on Gullfaks B

In 2010, the crew of an S-92A belonging to CHC experienced an unexpected serious aviation incident during landing on the Gullfaks B installation after a routine flight from Bergen Flesland (NSIA, 2015a). During the approach to the platform and while the helicopter had a flight altitude of 500 feet, the captain's pilot seat detached from the mounting rails, which led the captain having to hold on to the grip handles in the ceiling with both hands. Upon review of the incident, it was concluded that there was a risk associated with blocking the helicopter's flight controls. The reason why the seat came loose was the lack of slide stops and quick release pins that had not been properly reinstalled after maintenance the week before.

The NSIA report concludes that in addition to the risk for blocked flight controls, there was also an additional risk associated with the captain not being able to assist the co-pilot during the landing if needed. However, the NSIA report states that both pilots handled the acute danger well. The captain clearly informed the co-pilot that he had to hold on to the handles and would not be able to contribute to any actual flying during landing. The co-pilot conducted the landing without any further problems. CHC also stated afterwards that the incident ended well because the crew remained calm when the situation arose.

9.3.6 Inadvertent descent

In 2011 a Sikorsky S-92A operated by Cougar Helicopters departed from an offloading vessel on the Grand Banks about 200 nm east of Newfoundland, carrying five passengers. During departure, the helicopter engaged the automatic go-around mode while in instrument flying conditions. The helicopter's pitch attitude then increased to 23 degrees followed by a rapid loss of airspeed. After an initial climb to 541 feet above sea level, the S-92A began descending with its nose high and airspeed low. The pilots managed to stop the descent when the helicopter reached 38 feet above the water. After some seconds in hover the helicopter flew to the mainland, however during the recovery of the inadvertent descent the S-92A exceeded its transmission limits. There were no injuries (TSB, 2013). The captain was the PF while the first officer was PM. Both pilots had more than 18.000 flight hours, however the first officer's flying experience was primarily from fixed-wing and only 900 flying hours on helicopters.

Cougar Helicopters had implemented an in-house training program called CHARM, i.e. a holistic safety program that addresses CRM issues where one of the main tenets are that crew members must be ready to support each other including taking over the flight controls when flight safety is compromised (TSB, 2013). This is specified through the 2-challenge rule, which states that any deviations from the desired flight profile implies that the PM should advise the PF, which is to be repeated if the PF does not initiate proper action. If there is no response after the second challenge, the PM's responsibility is to take over control of the flight.

The TSB report (2013) notes that immediately upon noticing the helicopter's descent the first officer verbally made an attitude and airspeed deviation call to the captain (PF), something the first officer continued to do also after not receiving any actual flight control change from the PF. The report states that this was contrary to Cougar's guidance in the CHARM handbook and not in accordance with the 2-challenge rule in Cougar Helicopter's SOP's. The first officer *did not claim* actual control of the flight when the PF failed to take appropriate action to recover from the inadvertent descent. The probable cause of the PF's subtle incapacitation was spatial disorientation. The report further comments that this was the first time the first officer experienced that no response was provided based on deviation calls. Some conclusions from the TSB report (2013) are:

- Lack of standard callouts for pitch deviations increases the risk of miscommunication during unusual attitude recoveries.
- If there is no training on how to recognize and respond to subtle incapacitation, they may lack the confidence to take control from more experienced colleagues.
- If CRM strategies are not practiced during simulator and flight training, the risk increases that flight crews will experience CRM breakdowns resulting in reduced safety margins.

9.4 Empirical part II: Experiences with CRM in today's offshore helicopter operations

This section presents thematic findings from interviews with key CRM professionals, from an operational point of view. Focus is on current CRM practice, as well as challenges and benefits associated with CRM in practice.

9.4.1 Fundamentals of CRM

The interviews identified how important communication per se is for good CRM – if the communication collapses, everything else also collapses according to one of the informants. If the cockpit collaboration is not characterized by sensible communication, it does not help that the procedures are well formulated, including, for example, calls. Communication must work - for that reason it is very important for pilots also to be able to play a listening role. CRM cockpit training is about knowing and using the right tools to be able to identify good communication. For example, tools such as names or standard calls are used during training to get attention. Communication tools are also extremely important to be as well prepared as one possibly can to handle situations where the phenomenon known as the startle effect comes into play.

When training on CRM aspects, it is not based on specific events from real-life – lessons from events are obtained through internal investigations. The focus of CRM training is largely about raising awareness – right from the intention of flying arises, about the importance of briefings and focusing on the dangers that can arise during the flight. It is also necessary that a clear division of tasks exists, including what the pilot monitoring should explicitly focus on under the prevailing flight conditions.

9.4.2 CRM in practice

One of the helicopter operators has recently implemented an assessment program related to non-technical aspects where a tablet computer is used. In such assessments, it is the speed and perception associated with, for example, a radio call or malfunction that is registered. In the case of a low assessment score, this is a signal that one does not have good enough attention in relation to a specific task. The starting point for these assessments is about the need to map CRM skills which will be the starting point for evidence-based-training

(EBT) in the future. This is generally perceived to be a good tool but it requires that CRM instructors are well drilled in using the opportunities that the tool provides, and that they can assess correctly. However, there is still a way to go to streamline this towards EBT.

9.4.2.1 The ability to identify one's own mistakes

From a learning perspective, the above assessments are about wanting to understand why something went wrong – however, one should not necessarily point out that the wrong button was pressed. Instead, one wants pilots to ask themselves why this was done. Was there, for example, a reason for the unfortunate decision that was made including understanding any distractions. This requires that the CRM instructors are able to also carry out facilitation in addition to instruction per se. It is about getting the pilots to identify and understand their own behavior, including mistakes that are made. This is especially important in relation to strengthening the pilots' CRM competence, in the sense that it is seen as positive (also among the pilots) that one learns to identify one's own mistakes and thereby to correct one's own behavior.

9.4.2.2 Use of simulator

Today, there are EASA requirements, for example, related to night recency training, which means that the simulator often is used only for this type of training to comply with HOFO requirements. In such cases, the pilots spend one hour in a simulator with an instructor, although it is not necessary to use an instructor for this. Self-training can be the case, yet an instructor is still used to provide guidance if there are deficiencies that are considered important to address. It is important to guide pilots in the use of proper flight techniques, for example the use of the trim release, and follow up on the use of, for example, automation in the helicopter – the helicopter systems are designed to assist the pilots and therefore, from a safety perspective they need to be used during flight.

The pilots must be in the flight simulator for recurrent training every six months. This is a regulatory requirement. At the same time, there is flexibility in the system in that this can be done up to three months prior to the expiry date without any practical consequences to the pilot licences. This means that in theory it can take up to nine months between two recurrent training sessions. However, the helicopter companies strive to stay within plus or minus one month so that in practice training is carried out every six months. In general, the helicopter operators experience that the requirements for what is to be implemented as training increases. Pilots train for eight hours in total in the flight simulator, including the PC check, which contains clear requirements from the CAA-N about which requirements are to be met. In practice, there are six hours available where all training aspects must be included. Based on standardization, one of the helicopter operators has chosen six-months periods with the same content, which means six periods over three years, i.e. OPC one to six is used, which in turn means that after three years all the helicopter's systems have been covered.

It is challenging to maintain the requirement for recency related to night landings during the summer, which means that pilots must be sent in a simulator if they do not meet the requirement of three night-landings in the last three months, which in turn is challenging logistically for the helicopter operators. The objective for training on night landings is that there is no more risk involved when landing at night compared to day landings. The point is that the same techniques are used, including raising awareness of possible dangers, but that the same flight techniques regardless of the time of day is the best (and most effective) strategy. For example, at night the artificial horizon is used instead of the real horizon, yet the helicopter still needs to be flown similarly as during the day. In such a context, it also becomes visible which pilots handle instrument conditions, versus those who do not handle it that well. This is important and something the helicopter operators focus on in relation to pilot selection, i.e. choosing pilots who can fly well under instrument conditions in addition to just flying by looking out the cockpit window.

A few years ago, one of the helicopter companies learned that even though they recruited skilled pilots with several thousand flight hours, there were some pilots who did not handle the concept of flying under instrument conditions.

9.4.2.3 How to train the startle effect

As for the startle effect, this is trained by using scenarios where pilots need to reason outside the square box, i.e. events not manageable by adhering to procedural instructions. This type of training must be seen in relation to how the simulator training is set up. For example, training can be done specifically for low visibility operations, including night operations, where incapacitation becomes relevant. Incapacitation does not necessarily occur solely for medical reasons; there may be other reasons that result in one of the pilots not being able to perform a specific task. An example could be that one of the pilots stops giving call outs during an approach - a situation that needs to be handled immediately by the other pilot. Such a relatively simple exercise where one of the pilots stops talking is handled in various ways by pilots, something which is attributed to uncertainty regarding what is happening.

In the simulator, pilots can also experience that cockpit displays suddenly stop working during take-off, which can be experienced as particularly challenging by the pilot flying. As for developing scenarios, the simulator instructors need to be creative – for example, designing scenarios reflecting events that are not necessarily described in any of the pilot procedures or checklists. In relation to designing good training programs, there is according to our informants a positive collaboration with the providers of simulator services.

9.4.3 CRM related challenges

Training in CRM is also about making the pilots aware of their own attitudes. This is illustrated by challenges related to declaring mayday to air traffic control. There are pilots who are somewhat restrictive to using mayday – they simply experience it as a bit scary. CRM training focuses that mayday provides priority from ATC, and necessary assistance through, for example, other air traffic being diverted away. It is equally important to give ATC the opportunity to be prepared if the situation escalates rapidly. The point is to make the pilots aware of the benefits of using all available resources.

One of the pilots described how an incident appeared incomprehensible because the checklists did not correspond to perceived reality. The pilot reflected on a feeling of inadequacy when nothing seemed right, which resulted in the checklists being dropped and the focus being on dealing with the situation there and then based on the available information. It is emphasized that it is challenging to train for situations where the startle effect comes into play. The helicopter companies have experienced incidents where this effect had a negative impact on CRM, especially related to reducing the quality of pilot communication. An example was about how communication disappeared due to the startle effect, i.e. the crew stopped using procedural standard calls like my controls, your controls etc. The pilots did not have a sufficient understanding of the situation, which meant that they became scared with consequent loss of established communication processes as well as unfortunate handling related to flying the helicopter. In the mentioned example, the startle effect occurred because of weak CRM initially – e.g. threats and hazards were not discussed prior to the flight.

Time pressure in situations also entails a distinct CRM challenge related to the pilots' understanding of overall time usage. It is often the case that in situations characterized by stress, one's own experience of time becomes unreliable. One pilot commented that one looses the concept of time quickly in situations that require full concentration. It is therefore wise to simply write down the time so that you can easily keep track of time related to maintaining an overview of technical conditions – how long the helicopter has been flying with high oil pressure, low pressure, high temperature and so on.

The experience from incidents is the importance of a clear plan, including a briefing on which tasks are prioritised and who is responsible. It is also very important to be aware of potential dangers and risks associated with the flight. The importance of involving each other so that the pilots have a joint understanding of the situation and what will/can happen is the prerequisite for success.

9.4.4 CRM related benefits

CRM is considered a good tool to promote collaboration in the cockpit, but it presupposes that CRM training is carried out by well-trained instructors. One of the pilots stated that it is important to be able to appropriately evaluate CRM behaviour, such as proper evaluation of weak CRM practices, which can be a comprehensive and sometimes challenging task.

It is important that CRM practices and helicopter operations are viewed in the context of actual offshore safety statistics. Our pilots point out that the incidents the industry has experienced in Norway related to CRM make up a vanishingly small part of the overall picture. It is thus important to recognize that much of what is done today within CRM is qualitatively good work. It is particularly pointed out how valuable CRM is to increase the understanding and recognition of the importance of *standardization* for flight safety among operational personnel. An example of the importance of a standardization as a basis for helicopter operations is when pilots change bases and fly and collaborate without problems with pilots they have previously not met or flown with.

Another example related to CRM benefits illustrates how CRM training is considered by pilots as a prerequisite for being able to interact effectively during demanding and time-critical situations. One of the operators on the Norwegian continental shelf experienced a serious incident some time ago where one of the engines eventually had to be shut down. The helicopter continued flying on single engine while descending rapidly, a descent that culminated on 400 feet. The situation was aggravated, and the pilots had to act quickly. Eventually and when the pilots gained control of the helicopter, they experienced that this was a type of situation they recognized – they were almost forced into a way of thinking similarly to that in the simulator. In retrospect, this became a company recognition of the value of repetitive training on aspects concerning communicative practices, i.e. how to effectively interact, how to work with checklists, and the importance of good calls between the pilots when a situation escalates.

One of the benefits CRM provides is the opportunity to train on unexpected situations and or events. Examples are lessons learned from previous technical incidents where flight instructors in one of the helicopter companies have focused on how to prepare for the unexpected. It may be about being able to focus outside the box, e.g. not always to focus only on the checklist, which may also make it necessary to change pilots' traditional mentality about how to deal with surprising situations. The lesson has been particularly that CRM makes it possible to train to expand one's own (safety) room for manoeuvring. This can be about communicating to ATC that one needs extra air space, which will free up the crew's resources to use internally to solve the immediate technical challenges, instead of using the capacity to think about e.g. approach and other traffic.

9.5 Concluding remarks: Lessons learned and implications for CRM ahead

Based on the review of documents and the interview material, the following CRM learning points become relevant:

- **Communicative practices:** Increased focus on how CRM through training of communicative practices facilitate the handling of complex situations, particularly where checklists/SOPs are inadequate.
- **Handling incapacitation:** Specific focus on developing CRM training methods and tools to further ensure that pilots develop strategies to recognize situations involving own as well as each other's varying degrees of incapacitation.
- **Train critical task trajectories:** Train explicitly on the task trajectory and coordination involved when executing critical flight tasks during time-critical events.
- **Sufficiency of current CRM regulations:** Assess whether the current CRM regulations are sufficient to meet the need for flexible and thorough CRM training, as well as the need to ensure baseline CRM skills and identification of standard best practices.

One of the areas identified as important to focus on for CRM ahead is the importance of training the application of specific tools and strategies related to maintaining a shared situational *understanding* between pilots. The methods used must be able to expand situational understanding for the individual pilot. CRM training as well as real incidents have shown how individual situational understanding can vary, i.e. from somewhat narrow to a more broadened understanding of what is happening during flight. Consequently, it is important for all pilots to know *how* to expand each other’s understanding of what is currently happening.

As for future CRM training, pilots must be able to apply what are the most effective strategies and tools to regain control in any situation. For example, there may be simple things to practice such as explicit use of names during a briefing, which immediately fosters attention.

There is a danger that both crew members can lose track of a situation without either of them acknowledging it, an issue it is extremely important that crews are aware of. As such, and specifically based on the interviews, CRM should continue to focus on preventing a joint loss of situational understanding, as well as identifying such situations and how to restore overview when one or both pilots become incapacitated.

10 Comparing helicopter operations in the British and Norwegian sectors

This chapter investigates some main differences in offshore helicopter operations between the British and Norwegian sector. The analysis is done from a predominantly UK perspective, and the ambition is to both *describe* UK helicopter operations in general and to *discuss differences* between the UK and Norway. The extra emphasis on the UK perspective has been made possible by additional student work resources at Imperial College London. Note that the various issues highlighted in this chapter are accompanied by an extensive use of quotations from interviews.

10.1 Introduction

Norway and the UK both have a considerable petroleum activity, and helicopter transportation of personnel is essential for this activity. At first sight, there are many apparent similarities between the British and Norwegian sectors when it comes to the organisation and conduct of helicopter operations. Such similarities include helicopter types and equipment, helicopter operators, regulatory requirements, customer base, activity level, environmental conditions, etc. Furthermore, as close neighbours in Northern Europe we share much of the same history and culture and are likely to have the same view on e.g. the importance of safety work.

Looking closer at the two sectors, however, quite a number of differences and nuances can be identified. Some differences are objectively evident or documented, while others are substantiated by anecdotes and hearsays. Examples of the latter are claims of cultural differences between the sectors that might lead to differences in decision making and behaviour, possibly impacting safety. However, such claims have not been assessed in previous studies or academic work, at least not in the context of helicopter safety.

A main recommendation in the HSS-3b report was to conduct a broad comparative study of helicopter safety in Norway and the UK. This was also advocated in HSS-3. An important trigger for this initiative was the observed striking difference in the number of accidents between the two sectors.

This chapter outlines some major factors underlying the helicopter operational safety in both the UK Continental Shelf (UKCS) and the Norwegian Continental Shelf (NCS). Building upon previous parts of this report, this chapter in particular focusses on the following:

1. An examination of the recent safety situation in the UKCS helicopter operations by means of statistical data analysis that complements Chapters 5 and 6.
2. Investigation of the underlying factors in both the UKCS and NCS relating to the safety of offshore operations by means of semi-structured interviews with relevant personnel. This investigation is based upon the rationale that the accident analysis provides at times only a superficial explanation of the accident causation and there is therefore a need interview personnel involved in helicopter operations to better understand the factors underlying the safety of such operations.
3. Development of an explanatory framework for the safety of operation of the UKCS and NCS. This framework, based upon the interviews enables a structured discussion of the differences in operations between the UKCS and NCS.
4. Lessons learnt by the experience of each country and recommendations for the greater safety of helicopter operations in the UKCS and NCS.

The first section of this chapter will briefly recap the analysis of helicopter accidents in the UKCS. Further analysis of these accidents is then conducted to assess possible statistical insights. This is then followed by a methodology for both the conduct of interviews with relevant safety personnel and the subsequent analysis of the interview data. The analysis of the interview data reveals a number of relevant themes, and a framework is developed to explain these themes into high-level country specific factors and more detailed, specific factors relevant to the operation of helicopters. Based upon these specific factors, the final part of this chapter makes recommendations of the lessons learned for the safety of helicopter operations in both the UKCS and NCS. The sections relating to the analysis of the interviews use quotes from interviewed personnel to highlight the important factors.

10.2 UK offshore accidents 1997–2016

Given that the majority of accidents identified in Chapter 6 occurred in the UKCS, this section considers these accidents from 1997 to 2016. Using data provided by the UK's Aircraft Accident Investigation Branch (AAIB), and based upon an accident coding system developed by the US National Transportation Safety Board (NTSB), 19 accidents were investigated in this period. Five classifications were identified, as seen in Table 10.1.

Table 10.1 indicates the distribution of primary causes of the offshore helicopter accident in the UK between 1997 and 2016. It's evident that pilot-related operational failures accounted for the majority of the accidents, followed by weather conditions, which resulted in over a quarter of the accidents during this period.

Table 10.1: Distribution of primary causes of UKCS accidents (1997–2006).

Primary cause	No. of accidents	Percentage
Operational Failure (Pilot-related)	6	32 %
Operational Failure (Non-Pilot-related)	1	5 %
Weather	5	26 %
Airworthiness Failure	4	21 %
Maintenance Failure	3	16 %
Total	**19**	**100 %**

i) *Helicopter Types and Phase of flight of the accidents*

Five helicopter types were involved in the 19 offshore helicopter accidents in the UK: Airbus AS332 Super Puma, Airbus H225 Super Puma, Airbus AS365 Dauphin, Sikorsky S76 and Sikorsky S92. The main features of accidents associated with these helicopter types were:

- The AS332 was the most frequently involved helicopter in accidents during this period, being involved in ten such accidents with adverse weather conditions involved in nearly half of the accidents. The majority of these weather conditions refer to lightning strikes, indicating concern relating to the lightning protection of this helicopter.
- H225 and S76, each of which were involved in three accidents during the period.
- Two of the three accidents involving the H225, were caused by airworthiness failures, indicating potential problems with the design or manufacturing process of the helicopter.
- The AS365 was involved in two accidents, both of which were related to pilot errors, suggesting careful consideration of pilot training and assistance/warning system on the helicopter type.

Pilot training issues are of concern given the number of operational failures. The accident data suggests consideration of the phase of flight. During this period:

- pilot-related failures accounted for the most substantial proportion of accidents in the approach phase, and
- the arrival segment was demonstrated to be statistically associated with pilot-related accidents.

Hence there is a need for greater focus of the training on the arrival phase.

ii) *Cruise Phase-of-Flight Accidents*

Half of the helicopter accidents in the cruise phase were caused by technical failures. While no statistically significant association between the cruise phase and technical failures, the proportion of technical failure accidents were the largest in the cruise phase.

In this period, there were no pilot-related accidents in the cruise phase of flight. As Clifford (1996) explained, this is due to greater stress sustained by aircraft components in the cruise phase. Majumdar et al. (2009) also identified that the helicopters in the cruise phase were not prone to pilot-related failures in comparison with other phases in both countries and attributed this finding to low importance of pilot controlling skills for the safety of helicopter in the cruise phase.

Adverse weather conditions contributed to the other half of the accidents in cruise phase, and the statistical association between weather conditions and cruise phase of flight approached statistical significance. Considering the lack of accident data, it can be said that accidents in the cruise phase of flight is likely to be associated with adverse weather conditions.

iii) *Weather-related Accidents*

In this period none of the weather-related accidents were fatal. However, of the four fatal accidents in the UK, two involved factors related to visual conditions, and both accidents were caused primarily by pilot-related errors, as it was believed that the accident could have been avoided if the pilot has properly complied with standard operating procedures and flight manuals. There were also four non-fatal accidents caused primarily by pilot-related failures of which only one accident involved visibility issue. In conclusion, the probability of having visibility issues in fatal accidents is higher than having that in non-fatal accidents.

iv) *Rotor system accidents and airworthiness failure*

For accidents involving the occurrence of rotor system failure, the airworthiness problems appeared much more frequently as primary causes of the accidents than the maintenance problems. This reveals that the manufacturers’ design and production are more critical than the daily aircraft maintenance in terms of ensuring the stability of the helicopter’s rotor system.

Rotor system failure factors appeared in 7 out of 19 offshore helicopter accidents in the UK, but the factors representing the rotor system were found in 12 accidents in the database as some rotor system problems were not severe enough to give rise to failure of the rotor system. Surprisingly, the adverse weather conditions accounted for nearly half of the accident involving rotor system problems. As mentioned above, the majority of the adverse weather conditions in the accidents in this study refer to lightning strikes, it can be concluded that the rotor system of the helicopters should be specifically protected from the damage caused by lightning strikes. This has also come to the attention of Kråkenes et al. (2017), who identified that the rotor blade is particularly prone to lightning damage since it is made of composite materials that have limited conductivity, therefore suggesting to further develop the relevant material technology. Even though the offshore helicopter operations in both Norway and the UK are conducted in nearly the same environments, there was no accident caused by lightning strike in Norway in the past two decades as Norway might have frequently avoided flying into adverse weather conditions (Kråkenes et al. 2017).

v) *Maintenance failure and Loss of Control in Flight*

Maintenance failures were most often noted as primary causes in accidents involving loss of Control In Flight. The loss of control has been recognised as one of the occurrences that were most commonly seen in helicopter accidents with fatalities (de Voogt & van Doorn, 2007). This leads to the conclusion that the maintenance-related issues have a great potential of causing fatal accidents, suggesting that the helicopter operators for offshore service should take actions to improve the procedures and supervision of daily helicopter maintenance. Furthermore, factors related to the improper use of procedures were found only in the four maintenance failure accidents. Given the link maintenance failure accidents and the loss of control state which has a great potential of leading to fatal accidents, it is vital for the offshore helicopter service operators to take actions to improve and ensure the maintenance personnel's adherence to the prescribed procedures and standards in daily maintenance activities.

vi) *Planning and Decision Making*

Previous studies have identified that planning and decision problems were among the main contributors of helicopter accidents (Majumdar et al., 2009; Wiegmann et al., 2005; JHAST, 2007; EHEST, 2010). This is also the case in the UK offshore helicopter industry. Analysis of the 19 accidents revealed similar findings and were found in all pilot-related accidents. Hence a focus is needed in offshore helicopter transport operations in the UK to improve pilot training in terms of making proper decision and planning and to further consolidate their adherence to standard operating procedures.

vii) *Visibility*

The discussions regarding the injury severity, lighting conditions and ground coordination above jointly reveal the great importance of visibility to the safety of offshore helicopter transport in the UK. Therefore, refer to suggestions made by Kråkenes et al. (2017) regarding this issue, the offshore helicopter operators in the UK should introduce more pilot training with simulated low visibility conditions. In addition, the oil and gas companies could consider upgrading and redesigning the visual cues on the offshore installations. These problems have again reminded the manufactures or designers of the aircraft of the importance of onboard pilot assistance and warning systems.

viii) *Conclusions and limitations*

The accidents analysed in the UK between 1997–2013 are mostly the same as those analysed by Kråkenes et al. (2017), since most of the offshore helicopter accidents in the North Sea occurred in the UK. Consequently, the majority of the findings regarding the accident causes found by Kråkenes et al. (2017) were again identified in this analysis, though wider range of risk factors were considered. Many findings identified in this study mostly agree with those of the safety review conducted by the CAA (2014), especially the trend regarding pilot-related and technical failures.

While formal accident reports present narratives and causation in great details, the information collected from the accident investigation is neither entirely complete nor accurate. Rao and Marais (2017) suggest in Figure 10.1 below, that initially, the accident details are already not completely available to investigators during their investigation of the accident site as it is impossible to find out every single detail. Next, the investigators would be unable to obtain all the available accident details, partly because the witnesses might either not be found or provide an inaccurate and subjective interpretation of what they have seen or experienced to confuse the investigators' understanding of the accident. The investigators themselves could miss some important information during the investigation and add their own interpretation in accident reports. Consequently, the information of the accident presented to the public present a much-constrained picture in comparison with all actual details of the accident.

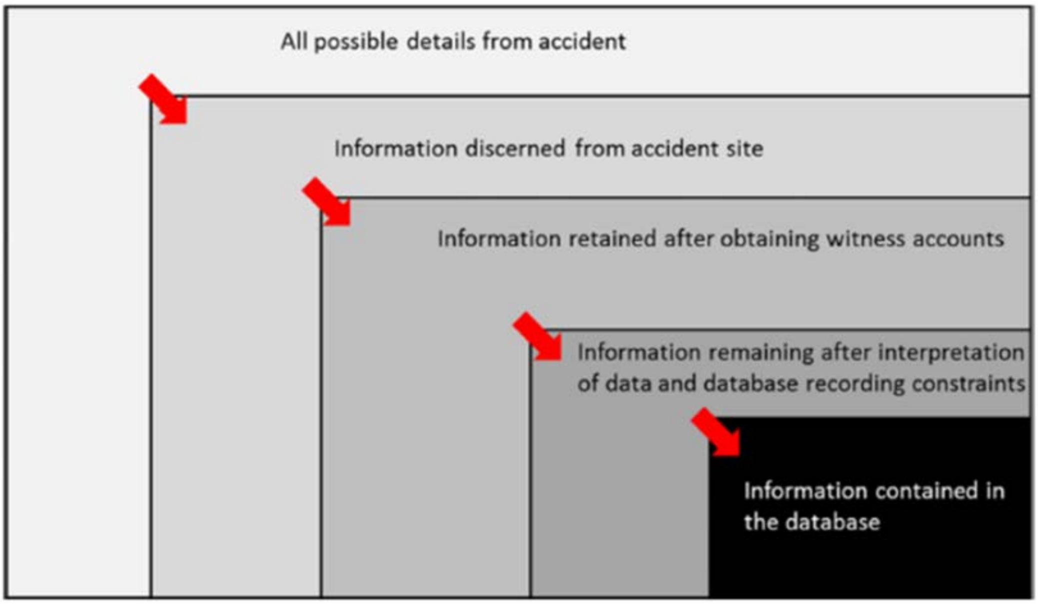


Figure 10.1: Levels of information available to accident investigations and safety analyses (Rao & Marais, 2017).

In order to overcome this limitation, there is a need to understand as much as possible about the context of the helicopter operations and safety in the UKCS. In order to do this, data sufficiently rich in detail from professionals involved in the UKCS helicopter operations, must be collected.

10.3 Methodology of interviews

The method chosen for data collection was semi-structured, individual face-to-face video interviews. Social distancing measures were in place while conducting this study so the closest alternative to in-person interviews are video interviews.

It should be noted that while individual interviews are time consuming, each interview is very rich with information so requires comprehensive analysis, and the diversity in individuals that can provide information is immense so knowing how many individuals to interview can be difficult. Moreover, the direction of the interview is dependent on the questions and follow-ups presented by the interviewer. Likewise, interviewer behaviour (non-verbal) can lead to the interviewee changing their responses (Opdenakker, 2006). Thus, this can lead to bias in the interview and quality of data is limited by the researcher's ability to remain neutral. Furthermore, the interviewee may not be completely truthful in what they say as they do not wish to share all the information (Cohen et al., 2007). This may create reliability and validity concerns. The choice of semi-structured interviews was to enable some flexibility in how and what order questions are asked, explain questions in more detail when required, and follow up on points of interest while ensuring the interview is kept relevant and all required topics are covered.

10.3.1 Interview questions

The interview questions focused on seven different categories. These categories were chosen as they cover a wide range of topics and based upon a literature review:

- personal details
- safety culture
- reporting and training
- typical flight details
- equipment and material
- regulatory factors
- contractual factors and future
- any other important factors

The interview questions were designed for each category in a very open way and where further information was required, additional questions were asked. An example of a question asked within the equipment and material category was: ‘What are your general remarks on the conditions of the helicopters and other equipment in your organisation?’. This is an indirect question which essentially is trying to determine whether the quality of helicopter and equipment is good or bad in the UK. Had this been phrased as a direct question, less information would have been extracted from the interviewee and they may have been less frank/ honest in their response (Cohen et al., 2007). Similarly, this is an opinion question but has been structured in such a way to minimise any biasness from the interviewee. All other questions were structured in a similar manner to maximise the information that can be extracted, ensure it is of the highest quality and is biasness is minimised. Appendix 2 outlines the interview questions.

10.3.2 Sampling method

The sample participants were selected either through selective sampling or snowball sampling. Selective sampling is when the researcher uses their judgement to select individuals who they believe would be most beneficial to the study. This technique is advantageous as time restrictions for the study means only a certain number of interviews can be analysed and this technique allows for the best suited individuals to be selected. The fear of lack of diversity and variation within the sample can be dismissed as individuals from all areas of the industry had been selected. Moreover, this approach allowed for the hardest to access groups to be reached and allowed selection of participants who would be ready to speak of sensitive topics and unravel current shortcomings within the system. The offshore helicopter industry is difficult to access and numerous interview questions require participants to reveal important information. (ConnetUS, 2019).

In addition to this, snowball sampling was used to further reach into the hard to access group, which created the possibility of discovering hidden populations and gain contacts which are at positions that can directly answer topics of interest (Johnson, 2014). This adds depth to the study and ensures time efficiency and an example of a hitherto latent population were those working on helidecks. The interviews with such personnel revealed the extent of helideck safety issues.

10.3.3 Participant selection

To ensure the correct individuals and inputs from all parts of the offshore helicopter industry were taken, it was crucial to create a stakeholder diagram. is based on the principles described by Silva et al. (2005) where there is a sharp end which is where the operations take place and there is also a blunt end which is where all the organisation inputs are and what indirectly affects the operations. This figure lists all the key stakeholders but is not a complete list. The pointed end of the arrow in Figure 10.2 indicates the organisations that report or are influenced by the company from which the arrow originates from. The stakeholders were partly identified by the report on *Guidelines for the Management of Offshore Helideck Operations* by UKOOA (2005).

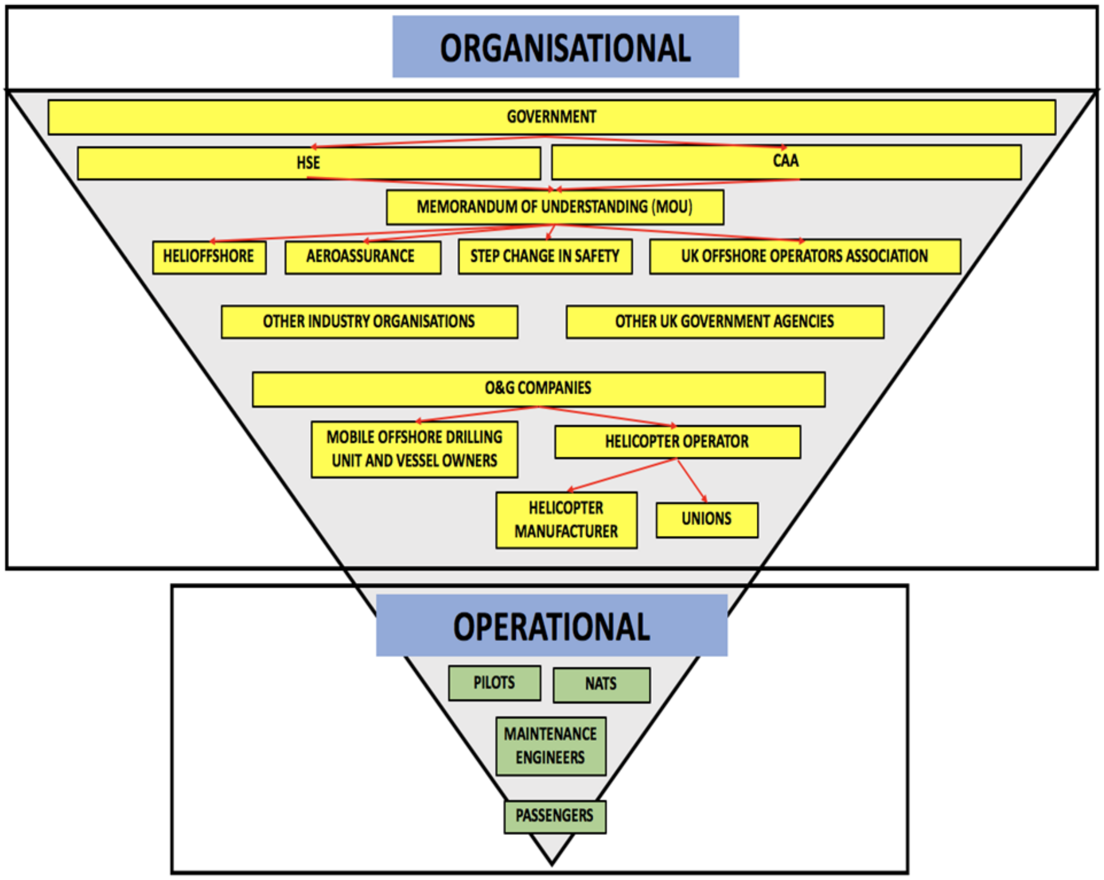


Figure 10.2: Stakeholders involved in the UK offshore helicopter industry.

All participants were approached to be interviewed via an email. The interviewees represented a range of stakeholders, including:

- CAA
- OGUK
- Unions
- Pilots and maintenance workers
- Helicopter operators
- HeliOffshore
- Safety organisations
- Expert consultancies

Close to 30 interviews were conducted, the majority on the UK side.

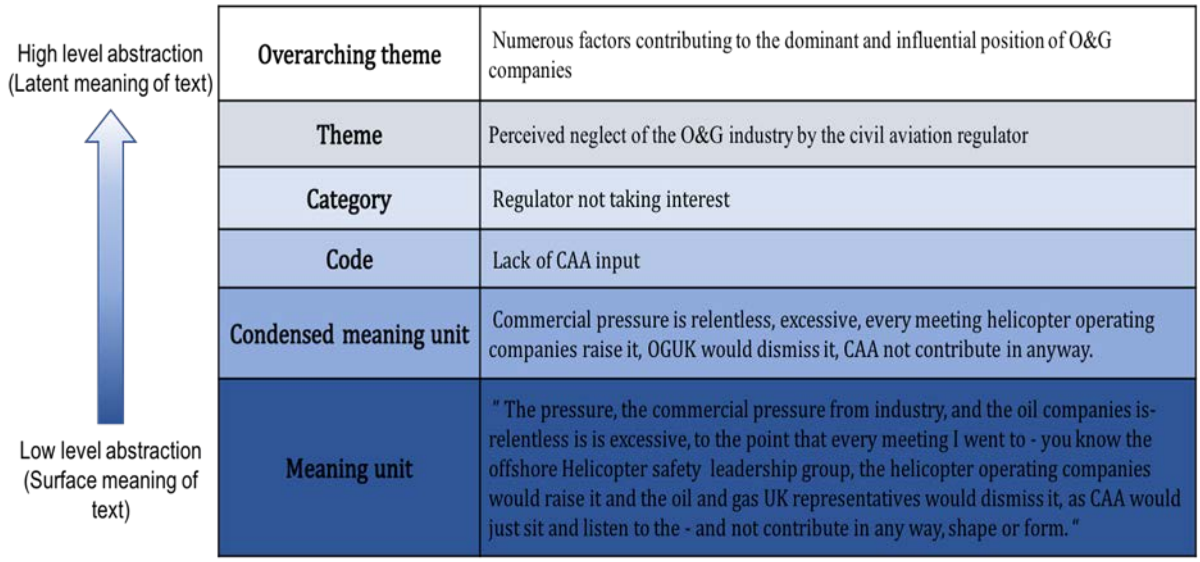
10.3.4 Analysis of the interviews

The interview recordings were processed using an online software called Otter.ai, which transcribed the recordings. These transcriptions were manually confirmed. Next, all transcripts were labelled with a random participant number to ensure interviewee confidentiality and to minimise chances of researcher bias. Thematic analysis was subsequently used to:

- convert the data into highly organised and concise summary of important findings (Erlingsson and Brysiewics, 2017);
- identify, analyse and report the patterns and unique findings within the data (Braun and Clarke, 2006).

First, the transcripts were read numerous times to gain an understanding of the interview records and initial thoughts about the data were noted. Then, the transcripts were divided into smaller parts, called units. These units were then condensed by removing words that did not add meaning while the original meaning was retained. This formed condensed units which were assigned a code or on some occasions multiple codes. A code is essentially a label which describes the meaning unit and helps identify links between different meaning units. To aid with the coding process, a software called NVivo was used. This was preferred over coding using no software as it was easier to organise the data, assign codes in a clean manner, help with code frequency counts, visualise analysis using mind maps and make changes to codes. This improved the quality of analysis and saved time. The assigned codes were then grouped to form categories. Codes were grouped together if they related to one another based on their content or context. The categories were then grouped to form overarching themes, themes and sub-themes. Themes identify underlying meanings of the data, they help summarise key findings related to the research questions, and they serve purpose to communicate with the reader on an intellectual and emotional level. The analysis will identify themes at both the semantic and latent level. This means the analysis will aim to discover themes that are stated explicitly in the text and identify underlying concepts, much beyond surface level findings.

Thematic analysis is a reflective process, hence after a certain step is performed, it will be repeated until the researcher is completely satisfied with their outputs.



Overarching theme	Numerous factors contributing to the dominant and influential position of O&G companies
Theme	Perceived neglect of the O&G industry by the civil aviation regulator
Category	Regulator not taking interest
Code	Lack of CAA input
Condensed meaning unit	Commercial pressure is relentless, excessive, every meeting helicopter operating companies raise it, OGUK would dismiss it, CAA not contribute in anyway.
Meaning unit	" The pressure, the commercial pressure from industry, and the oil companies is- relentless is is excessive, to the point that every meeting I went to - you know the offshore Helicopter safety leadership group, the helicopter operating companies would raise it and the oil and gas UK representatives would dismiss it, as CAA would just sit and listen to the - and not contribute in any way, shape or form. "

Figure 10.3: Illustration of going from meaning unit to overarching theme.

Figure 10.3 is inspired from Erlingsson and Brysiewics (2017) and shows the process of going from the raw data to the theme it belongs to.

During the analysis process, the researcher was aware of the biasness they can potentially introduce. Many of the steps involved were purely based on the judgement and decisions of the researcher. Such decisions can easily be influenced by pre-understandings or some other form of biasness. As suggested by Erlingsson and Brysiewics (2017), to prevent this issue, all data was approached with an open mind and any findings that were unusual were not dismissed. Similarly, the significance of the theme was based on whether it captured something important relating to the research questions or not.

10.4 Cultural themes

It is important at the onset of the review to highlight that all the interviewees noted the major improvements in safety in the UKCS helicopter operations over the past decade, with one describing the difference during the past decade as "chalk and cheese". In particular, the operators interviewed indicated the safety culture in the North Sea operations was relatively mature, and continuously evolving, with two factors contributing to this:

- Operators were global organisations which have operated in the North Sea and other oil producing regions over a number of years;
- Cooperation with personnel involved, especially Trades Unions, and good communications explaining just culture.

With this in mind, there are several important features regarding the UK, its "culture", legal system etc. that have a major impact on the operations of the helicopter industry in the UK sectors of the North Sea. The four most prominent with regards to the interviews conducted and can help to put them in context are given in Table 10.3.

Table 10.2: Feature of National Themes.

Theme		Description
I	**Government involvement**	The relatively little government involvement with oil and gas (O&G) operations in the North Sea
II	**Market**	The nature of the dynamic, competitive market in O&G operations
III	**Legislation**	Legislation in its various forms and their impact on the O&G sectors
IV	**"Greening"**	The "greening" of UK's energy sources, with reduced reliance on fossil fuels and decommissioning of oil rigs

These four features – regarded as "national themes" – offer a stark contrast to the situations faced by helicopter operators in the UK and in Norway and set the basis for understanding specific differences between the two countries. Each of these themes are considered in turn below.

10.4.1 Government involvement in the O&G sector

A major theme emerging from the interviews was that in the UK there is relatively little government intervention compared to Norway.

There are numerous reasons underlying the UK Government's reluctance to intervene in the operations of the O&G sector. Undoubtedly there are financial imperatives for the UK government arising from the O&G sector. Thomas (2021) states the O&G companies have brought in GBP 360 billion in tax revenue since 1970 which shows their critical role in the country's economy. This financial focus of the government has been observed by interviewees through the lack of requirements in issuing licenses as well. Though not mentioned in the interviews, Downie and Gosling (2019) note that the lack of government intervention in the industry maybe a result of its wish for O&G companies remain in the UK and indeed the UK government provides some of the "most attractive tax regime" in the World (a headline rate of 40 %, compared with the 70+ % for Norway) and financial relief for the decommissioning of oil rigs (Thomas, 2021)

> *But the safety rep(resentative) legislation was there. And it's never changed, since it was introduced, it's been reviewed a couple of times, but it's never ever been changed by any government. Despite the representations made by the trade unions, since its conception, we felt, then as we do know- that without some robust regulatory protections, and without that trade union backing and training, that the ability of a safety rep offshore to fulfil his rule in a really meaningful way, was being diluted.*

Consequently, O&G companies have a large degree of freedom in their operations free from government interference and regulations, allowing them to adhere to and further develop their own "brand". Inadvertently, it also signifies to the O&G companies how reliant the UK government is on their financial health.

> *Actually, my view is that that kind of goes across the board for the oil companies - that nobody really wants to upset them even when it comes to government.*

Interviewees believe the limited government input there is, that too is driven by financial gains:

> *And it comes back to what I said before, it appears to me that nobody wants to upset the oil companies that are there. Probably a lot due to the actual taxing coming out - it comes through from the actual offshore.*
>
> *And there's really no state influence, the only influence the state holds is in licencing, where they will sell licencing for different parts of the North Sea. But there's not even any conditionality on that, so they will sell it just for the money.*

The nature of the O&G industry is such that companies were described to be profit orientated companies by many of the interviewees, though given the vagaries of the oil price in recent years this is unsurprising.

> *I mean, their main goal is production and how do you get production - as much production as they can.*

Consequently, such freedom from government intervention allows them to focus on often short-term, cost-cutting measures and actions that may well have adverse effects on safety in the long term. This lack of intervention not only affects how O&G companies behave but also makes employees and helicopters operators vulnerable.

> *Quite a common thing is, all oil companies say safety is number one priority and we are seeing its number one priority after production. So, anything that's impacts on production comes first, then safety.*

In contrast, Norway sees greater government input as the government controls two thirds of the dominant O&G company in Norway, Equinor. It's worth noting that the UK government has no share in any O&G company.

> *I think it all goes back to the system that they have got. We call Equinor ...as the state oil company, with the unions being tied into their negotiations with the actual Norwegian government. And they've got a lot more influence there.*

Consequently, the Norwegian government is in a position to ensure best practices are upheld within the industry as this reflects upon the government itself. There is less fear from the Norwegian government of intervention as they are aware that Equinor cannot simply relocate elsewhere for financial reasons since the government is the biggest stakeholder.

> *But I'm told that the Norwegian government told the Norwegian Oil Company, which helicopter company they were to use, and all, you know, really regulated it properly.*

10.4.2 The Nature of the dynamic, competitive market

Part of the UK government's reluctance to involve itself in the operations of O&G operations in the North Sea is the nature of competitive, dynamic market in the UK. This is not only seen in the O&G operations but also in other sectors of the economy.

> *One might assert that maybe perhaps four helicopter operators in the North Sea is too many - because the business is not there. So that could be an assertion - but at the end of the day to some extent, you know, the fittest survive,. And maybe you just have to let market conditions prevail. And whoever survives over a period of time - that's what it is, and it will reach an equilibrium. The challenge for the helicopter operators would probably be, yeah, but if you want flexibility, if you want to be able to get helicopters at your beck and call at last minute, then you know you've got to have this number of operators – so you want competition, you've got to have this number of helicopter operators.*

Within the North Sea O&G operations itself, such a dynamic market has been seen since the oil price crash of 2014. This saw the beginning of the retreat of O&G "majors" and utilities and the introduction of private companies, often backed by wealthy private equity funds. Their collective share of production reached 30 % in 2020, from a base of 8 % in 2010 and 13 % in 2014 (Figure 10.4). These new entrants see an opportunity to reduce costs and extract more oil and gas from assets that were previously ignored by the majors and utilities, which have either pulled back from the North Sea oilfields or exited entirely, to focus on lower-cost regions, or to end fossil fuel production. Furthermore, many of these newcomers tend to focus either on the UK alone or a more limited number of countries.

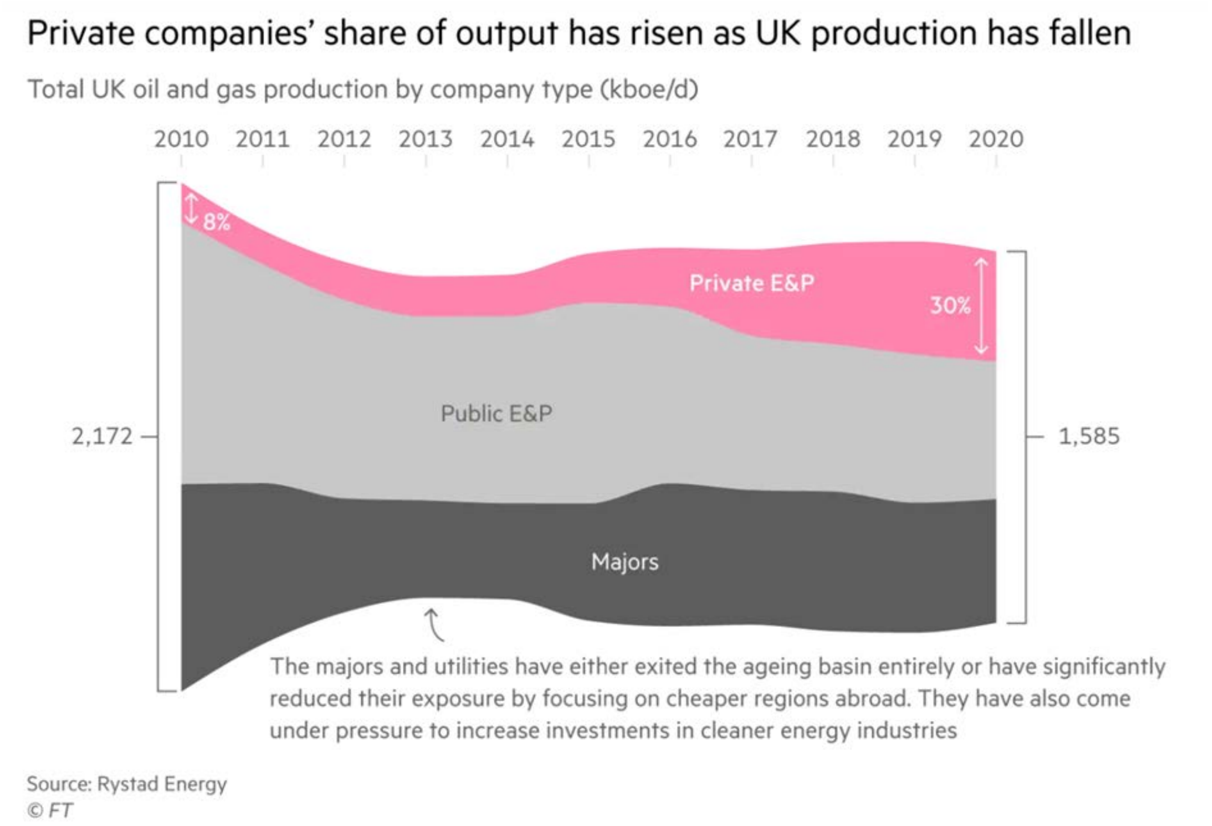


Figure 10.4: Production of O&G in the UK by company type.

> *You would probably start to argue in the early days, obviously the likes of BP and Shell, their footprint is starting to quite dramatically reduce these days I remember it and you've got the likes of Chrystal - they're probably starting to become the more dominant rep(resentative) - quite dominant in the area. Total still quite dominant. BP and Shell always going to carry a big sway but they have probably less and less sway these days than they did maybe 5 or10 years ago.*

The focus of the smaller, private companies is such that in terms of helicopter operations, they seek to have what several interviewees described as "Uber-type of services", i.e. a cheap and basic service without further commitment:

> *Whilst you would perhaps have the larger companies like Shell and BP that were prepared to pay a little bit more for a premium service, … what the new companies want is just the minimum that meets the requirements. And they just see they have helicopters as ….more of a commodity, rather than a service. It's a bit like an Uber, you will call it and it goes and you don't mind what type of car it is. It's just a way to take you from A to B.*

A consequence of such services is that this may lead to a reduction in the amount of investment in safety for the helicopter operators, though not necessarily in a reduction in safety per se:

> *I think safety will not tend to have declined because of the systems in place. But safety has slowed. For example some of the OEMs have begun to update their systems, we're not seeing those systems getting to the front line. And in most cases, it's just a software update, which I think costs something like $30,000.*

> *So we are not talking about massive sums, that is not getting to the front line, because of concerns about cost.*

In contrast, Equinor's domination of Norway's offshore operations is witness to a different market dynamic, where there is a dominant state owned O&G company:

> *Yeah, the market dynamics quite different there. And from what I see, you know, a decision that Statoil makes has a direct impact on Norway's economic model, you know…if Statoil makes a decision to invest or exploit or go in a particular direction, that will come back to the nation one way or another.*

Interviewees felt therefore that safety would be unlikely to be compromised given the Norwegian state's stake:

> *That's a major factor in region terms because a state-owned company is going to reflect the position of the state and therefore you've got that - input if you like, to ensure they are the top benchmark and continue to perform at that benchmark.*

10.4.3 Legal systems

The nature of the legislation in the UK and how it is implemented highlight a major area of difference with Norway. Put simply, English law is based upon "Common Law" principles, i.e. a body of unwritten laws based on legal precedents established by the courts. Common law influences the decision-making process in unusual cases where the outcome cannot be determined based on existing statutes or written rules of law. Note that in the UK, the law differs between England and Scotland. Scotslaw is a combination of "Common Law" and "Civil Law" principles (see the section on Norway below for further details of Civil Law).

United Kingdom
The UK government's desire for a competitive market, with little interference, offers what may seem to be considerable flexibility to the O&G companies and helicopter operators to dismiss their employees for reasons that can appear relatively trivial. The employee has the option to dispute the dismissal but the law as currently constituted favours the employers since the compensation they have to pay is quite small and they have no obligation re-employ the employee. Consequently, employees are hesitant to raise concerns in order to prevent themselves being dismissed. This problem is amplified by the competitive nature of the industry where there are more skilled people than jobs currently available. The recent pandemic is expected to eliminate 30 000 jobs in the industry which will further increase the competition for jobs (Thomas, 2021).

Another issue regarding the law is that in order to prove that negligence or unsafe behaviour of an O&G company has caused an accident, the legal bar is very high. This may well remove the deterrence effect of the law and may encourage an O&G company to take risks more frequently which can impact safety. There are understandable reasons for the law to be framed in such a manner because the UK wishes for no one to be incorrectly prosecuted so it must be proved beyond doubt that someone has done something wrong.

And finally, many helicopter operators have shared concerns about sharing data between themselves as it could put operators at risk from legal action or losing a contract. This theme was very common in the interviews: All union members and pilots mentioned this theme, as did the regulator and many industry bodies. This implies that this issue directly effects employees and hence these issues have been raised. Despite so many stakeholders being aware of this issue, little has been done to improve the situation.

Norway

Norway's legal system is in contrast based upon a "Civil Law" principles. Therefore, legislation is the predominant source of law, however not the sole one. The main difference between civil and common law traditions lies in the sources of law and the role of the courts. In civil law systems, emphasis is put on legislation as the primary source of law, whereas in common law systems, judges play a more active role by establishing legal precedents.

In comparison, Downie and Gosling (2019) found, Norway has stronger employee protections and laws. In Norway, employees shall stop work when they feel it is unsafe without the fear of punishment. Employers in Norway are much less likely to dismiss employees for apparently trivial reasons as the compensation from a dispute case is much higher and the employee would need to be offered back their job if the case is won. This puts employees in a much more powerful position, makes employers think twice before dismissal, and ensures employees are openly reporting any risks they see. This possibly explains why Lande (2015) found a lower amount of reporting in the UK compared to Norway. The UK situation regarding employment protection has the potential to worsen due to Brexit. The UK government were expected to review the existing employee laws and make amendments in January 2021 which BBC (2021) said had the potential to degrade job protection further. This review was cancelled but it shows the potential effects of Brexit and this issue can potentially arise again in the future. To correct this issue along with the lack of intervention by the government, the government should review the current law but with the aim to give more powers and protection to employees and enforce better working conditions.

10.4.4 Future Greening

In 2020, spending by O&G companies operating in the UK North Sea fell to the lowest levels since 2004, as they concentrated on preserving cash during the pandemic, while production from the more than half a century-old basin has re-entered "longer-term" decline. O&G companies collectively spent £3.4bn less last year than in 2019, a 23 % reduction (OGUK, 2021). This decline in spending can be seen in the following, when compared to 2019:

- Companies deferred field developments and maintenance to cope with the fallout of the pandemic, which triggered a sharp slump in prices in the first half of 2020.
- Drilling activity also fell to levels not seen since the birth of the British offshore oil and gas industry in the 1960s and 1970s.
- Production declined 5 % in 2020 to about 1.6m barrels of oil equivalent a day.

Despite recent rises in the oil price, OGUK expects the effects of the pandemic to persist for many years, forecasting a further 5–7 % decline in production for this year. The group, which represents offshore oil and gas operators and supply chain companies, warned that the industry remains in a "fragile state" and is re-entering a period of "longer-term production decline". Production had increased 20 % between 2015 and 2019, following nearly 15 years of falling output. UK North Sea production peaked in 1999-2000 at about 4.7m barrels per day. Despite the increased switch to newer technologies, nearly three quarters of the UK’s energy needs are still met by O&G, despite the growth of cleaner technologies. Last year domestic oil and gas production met 70 % of that demand, according to OGUK.

The UK government has set the world’s most ambitious climate change target into law to reduce emissions by 78 % by 2035 compared to 1990 levels. In line with the recommendation from the independent Climate Change Committee, the sixth Carbon Budget limits the volume of greenhouse gases emitted over a 5-year period from 2033 to 2037, taking the UK more than three-quarters of the way to reaching net zero by 2050. The Carbon Budget ensures Britain remains on track to end its contribution to climate change while remaining consistent with the Paris Agreement temperature goal to limit global warming to well below 2°C and pursue efforts towards 1.5°C. For the first time, this Carbon Budget will incorporate the UK's share of international aviation and shipping emissions – an important part of the government's decarbonisation efforts that will allow for these emissions to be accounted for consistently. The new target will become enshrined in law by the end of June 2021.

The UK government also released the North Sea Transition Deal in March 2021, which outlines its plan for how the UK's offshore O&G sector and the government will work together to deliver the skills, innovation and new infrastructure required to meet stretching greenhouse gas emissions reduction targets. The Deal aims to support and anchor the expert supply chain that has built up around O&G in the UK, to both safeguard and create new high-quality jobs. The Deal will transform the sector in preparation for a net zero future and catalyse growth throughout the UK economy. Specifically, this Deal includes:

- early reductions in offshore production emissions of 10 % by 2025; 25 % by 2027; and 50 % by 2030, against a 2018 baseline, to meet the sector's aim of creating a net zero basin by 2050. This will be supported by joint work to address the commercial and regulatory barriers to electrification of offshore platforms to realise these targets
- investment of up to £14–16 billion by 2030 in new energy technologies, with supported by business models to enable CCUS and hydrogen at scale
- a voluntary industry target of 50 % local UK content across the lifecycle for all related new energy technology projects by 2030, as well as in oil and gas decommissioning. This will be supported by the appointment of an industry supply chain champion who will support the coordination of opportunities with other sectors
- a 60 Mt reduction in greenhouse gas emissions, including 15Mt through the progressive decarbonisation of UKCS production over the period to 2030
- support for up to 40,000 direct and indirect supply chain jobs in decarbonising UKCS production and the CCUS and hydrogen sectors.

> *If you look at the Civil Aviation Authority, okay. If we have a department and a team that look after the oil and gas sector, why is there a separate department and a separate team, looking after the renewable sector? Don't understand that. It's the same helicopter, often the same helicopter operator, you know, doesn't matter whether it's flying to an oil field, or to renewables, it's still a landing site.*
>
> *The government are so focused on renewables, nothing else matters, and renewable energy have learned straightaway that if there's any resistance anywhere in the system, the magic words are "Do I need to speak to the Minister?" and all of a sudden, people go the minister, alright. Oh, well, a they're gonna get their way anyway, because the Minister's view is renewables, renewables, whatever it takes. And they trump everything. All right. And even within the oil industry. It's like dealing with two separate companies, they might all live in the same building. But, you know, they, the left hand doesn't know what the right hand is doing. And you know, the guy that's looking after renewables, his trump card is always the Minister, because you go to government or whatever they do. And that's - now we're seeing evidence of that in the CAA, within their within one department that's looking after the renewable sector. They're trumping everything that the other guys that have got 40 or 50 years of aviation experience in there, but somebody else comes along and says … "renewables".*

10.4.5 Background to bases in the UK

The UK has four bases of operation for offshore helicopters: Sumburgh, Blackpool, Norwich and Aberdeen with the latter by far the largest. The main operators are also based in Aberdeen. Given the scope of the operations in Aberdeen, the operators are under considerable time pressure whereas this is unlikely to be the case at the other three bases. Compared to Aberdeen, flight times are much shorter at Norwich and Blackpool, e.g. in 30 minutes from those two bases the helicopter reaches the oil rig. However, from Aberdeen the outward journey time tends to be two hours. When it comes to safety standards though, there is expected to be no relaxation anywhere in the UK bases.

10.5 Implications

The four national themes factors outlined above all have a major impact upon individual aspects relating to offshore helicopter safety in the UKCS. While it is not possible to impact the four national themes, the individual themes outlined below however provide promise for interventions to improve safety. These 11 factors are considered in turn below.

10.5.1 The 90-day termination clause

Typically helicopter operators aim to fulfil their contracts for O&G companies by leasing helicopters for the duration of the contract. There is however a 90-day termination clause associated with each such contract, and hence a risk exists that the operator may lose the contract whilst still having the financial obligation for the lease.

> *Game of the oil companies play with awarding a contract at rock bottom prices - company who can just about breakeven doing that. And then use that to move the contract within 90 days to somebody else who will do even cheaper.*

In order to minimise this risk, operators therefore provide low bids. The competitive nature of the market makes the situation worse as there is always another operator willing to work at a lower cost, as Downie and Gosling (2019) suggested operators are each-others' worst enemies because of this.

> *Sure, you you're only too aware that the 90-day cancellation. So, this is basically the abuse of that, in terms of it was only ever meant for drilling, probably drilling operations that suddenly go out there do do the well, maybe the they were going to do a number, but maybe the first well they drill they sort of go there's no, there really isn't any point. And so, there's no point of staying out here, we'll bring the rig back or it will go off hire. And therefore, we don't need the helicopter contract. So, I think the 90-day cancellation was more around drilling operations. But then more and more, particularly as things were getting a bit tight. You had duty, let's call of duty holders, the duty holders probably been a bit more aggressive in the use of the 90-day clause.*

> *And as the helicopter operators were saying- you know we've got to go into long term leases here and and our strategy is based on we secure the business and then that's it. And we can't then secure leases knowing that you might suddenly turn around and say, Well, this two year contract or three-year contract, we're actually going to cancel or give you 90 days' notice. So that was starting to put pressure on helicopter operators.*

Similarly, there is no financial incentive to invest in better technology and equipment, and this restricts how safe the operator is. This also directly effects employees as they would be aware of the financial constraints on the operator so would not want to raise their heads above the water too often as they may be dismissed. This problem may worsen with recent deals in the UK offshore industry worth of $2.5 billion bringing in smaller, more private profit orientated companies into the market (Thomas and Mathurin, 2021). It's worth emphasising that the O&G companies are not forcing anyone to work at a certain price, it is the competition that is driving down the prices.

> *Now, imagine signing a contract that involves say, four new helicopters. Yeah, 100 million dollars' worth. It's a five year seven-year contract, maybe with some options. And by the way, there's a clause in it that says maybe three months, four months' notice - It'll stop.*

The implications for this on O&G helicopter operations and safety are manifold. First of all, the reduction in investment may well impact investment in safety in the long term. While renewable energy sources, such as wind power, also require helicopter operations, these are not of the same requirement as offshore helicopter platforms.

> *If you look at the investment for renewables, with their limitations, this idea that renewables run forever, whereas, you know, wind farms have got, you know, certain operating limits, in terms of you know, in real bad weather, they can't necessarily run their turbines.*

The second point relates to the significance of helidecks. Interviewees mentioned many helidecks are currently beyond their design life. This naturally brings risks as certain safety features on the helideck may be no longer fit for use, especially as O&G companies are not investing to improve the condition. Similarly, after the decommissioning of an oil rig, there still needs to be made sure the lights on the rig are functioning so ships do not collide into them. However, O&G companies are reluctant to spend on rigs as they no longer have any use for it. These issues are explored further in the section on the Certification of Helidecks (ref.).

10.5.2 Role of the trade unions

The power of the Trades Union and their contribution to safety was deemed to be far greater in Norway than in the UK by the interviewees. Many interviewees believe that the unions play an extremely limited role within the UK, simply acting as an assurance for employees that it is safe to fly. Union interviewees felt that when they have previously raised concerns about safety, too often they have been ignored by O&G companies.

Interviewees also stressed having a powerful trade union gave employees the confidence to speak up and say no to anything they feel is wrong. The lack of such a collective trade union strength means that in the UK, individuals have to independently fight their battles a task made more difficult by weak legal employment protection in place:

> *They don't have that legislative protection - Which gives them the confidence to say, no.*

This means production coming to a halt, which several interviewees stressed was the only means by which to ensure O&G companies will act regarding safety, is unlikely so there is little chance of issues raised being quickly solved.

> *I was a safety rep and I tried to stop the flight - kind of went and complained and and you get to a point at which as a safety net with a contractor - You've got to decide whether or not you're going to refuse an instruction. And that's when you're stepping over the line. Because you're then being told that the operator, the duty holder, the company has assessed that risk and they have put in place all of these mitigations and is now in their opinion as the duty holder safe. If you refuse to take that instruction, you*

> *will then bring yourself into a disciplinary situation where you as a worker then refusing to undertake a reasonable instruction.*
>
> *And if we don't think it's wise or sensible, we can dig our feet in to a certain extent, but what we can't do is is turn around and say, well, we're not flying that, you know. We couldn't turn around and say to them, we're not flying today because we don't think ... your risk assessment is robust enough.*

This lack of involvement by the union was justified by the interviewees due to the limited powers of the trade unions, and one consequence of this is that union interviewees felt that they are only occasionally invited to meetings and discussions, but that too is solely on the O&G company's terms. Usually they are informed about measures to be taken after an O&G company have already made a decision. And when they are informed, interviewees felt this to be just a "box ticking" exercise to say they have been involved, rather than to genuinely involve them. There is a clear lack of collaboration and communication with unions, very much like Lande (2015) described in their paper.

> *I mean, we still have discussions we have discussions like with oil and gas UK, the oil and gas authority, we have discussions with various different contractor companies, and we some of the operators. In some ways, it seems to be like ticking a box. And other ways, it's very much on their terms a lot of times.*

The lack of power to unions also means unions need to earn respect from O&G companies, and interestingly interviewees stated that by successfully challenging O&G companies, they gained their respect. Once this happened, then communication and collaboration between O&G companies and trades unions improved.

> *I mean ironically probably the company's we've got the better relationships with - are the ones that we've had disputes with and we've had been in a dispute with that, and out of that has actually come a better relationship afterwards.*

Interviewees highlighted the marked contrast to Norway, where the trades unions are much more powerful and involved in safety decision making, a fact also acknowledged by Lande (2015) and Downie and Gosling (2019). Unions almost have the "legislative right" to sit in meetings and make sure they are happy with how the O&G company is working. Similarly, in Norway, unions are able to send out representatives to the rigs to ensure there are no safety risks.

It's worth noting that one reason why there is a difference in the involvement of the Trades Unions in Norway is that the accountable manager is ultimately responsible for safety of an operation. In case of legal proceedings, it is the manager who is held accountable in a court of law, never the trades Unions.

> *In Norway, you know, if you take the safety rep offshore in Norway, on an installation, that safety rep is empowered to stop operations, he can intervene and say to the installation operator, we want you to stop this operation.*

10.5.3 Discouragement of legal protections of employees

The current legislation and the legal system is such the employees in the offshore helicopter operations of the UKCS feel that it fails to sufficiently protect employees against operators and O&G companies, and operators against O&G companies:

> *But the biggest difficulty is the employment law itself, and the restrictions that actually puts there and what you've - what you can do, the I mean, for example, for redundancy selection, there's very little law regarding how the employer does that. If they just want to actually pick name - Generally, under the law, they can actually do it and call it a selection. So in some of these things, there's not a lot of laws so there's no actual chance for success.*

Currently, employment can be terminated for a variety of reasons, many of which the interviewees felt were often flimsy. Such dismissals can occur very unexpectedly and put the employees in a very difficult situation, with no safety net in terms of income.

> *If they followed process correct way, we might not agree with outcome - that they've done legally, everything they have to do, then it's hard to show that that case for unfair dismissal.*

After losing their job, employees can go to court for unfair dismissal but it is hard to prove this because, according to the employees, there is a lack of laws regarding how an employer can dismiss an employee. Downie and Gosling (2019) have mentioned this issue and highlighted it as a key reason for the poor safety record in the UK. Even if an individual successfully wins a case for unfair dismissal, the compensation they receive is paltry and with no recourse to getting their job back. Unsurprisingly, employees are reluctant to pursue this route:

> *And then you have you're getting into an employment tribunal. And this is another matter in this country that people often say, well, I'll take you to an employment tribunal - I'll get justice. You don't get this at an employment tribunal -Because there's no there's no facility to get your job back anymore. You don't get reinstatement order now with employment tribunal - You get some money in your pocket, if you win, why we have compensation. That's not justice.*

> *So in theory, it does because your full time employed, in actuality you're only protected by the UK statutory redundancy policies, which are not fit for purpose for people are not on minimum wage. But when you think we get relatively well paid for and when you're when your redundancy is based on 538 pounds a week for every year…. But there is not security because they could make you redundant at any time and you have nothing really to underpin in law.*

The implication for safety is that individuals may fail to report an event or take part in operations they may deem to be unsafe, for fear of dismissal. Of course, it is worth noting that this was not the aim of the legal system or legislation.

> *And they then started to tell me about the events they were having. And I'm saying, Why aren't you reporting these things? Well, you know, commercial, and you know, you don't want to be the one that put your head above all the time.*

> *I went back to the guy I said look the Health and Safety Executive would like to investigate with you - No, no, no, no, don't report. No, because they will know it was me. Because I questioned at the safety meeting. So, if the HSE investigate now - they will know it was me that reported it.*

Moreover, if the operator or O&G company was found to be operating in unsafe manner which led to an accident, the legal bar required to prove such a thing is very high. Similarly, in instances where the regulator has found regulations have not been followed, they are simply just given an improvement notice rather than any sanctions. These issues have been also mentioned by Downing and Gosling (2019), they also stated O&G companies use this to their advantage to save money.

An area which requires better legal protection for operators relates to sharing their data, specifically in relation to safety. Interviewees raised concerns that operators are not completely sharing data with one another due to fear that the shared data would be used against the operators in either law suits or to win contracts. Therefore, interviewees felt that the introduction of a law which allows for safe sharing of data between operators without any risk to the operator would enhance the safety of Offshore operations in the UKCS.

> *It could have been better (in the past) but I think right now and we talk regularly with all the intervals of the company's safety right now is not a thing we shy away from in the in the conversation. The only thing we don't talk about this commercial, either to different people, but it's also not appropriate in the forums we talk to mention commercial, but we do mention issues we ran into with air traffic control airspace types of helicopters.*

Again, there is a marked difference with Norway, where if an employee is dismissed unfairly, the compensation is far greater and the employee can get their job back. Furthermore, in Norway if an employee has been made redundant due to a sudden job shortage, the employer is obliged to pay the full salary during the notice period, after which the public unemployment fund covers the majority of the salary for the first year. In addition, agreements between employers and unions often include a re-employment clause should the market pick up again. This provides much more security for employees.

> *Whereas the Norwegian redundancy law that underpins their pilots and actually the Dutch redundancy law that underpins their pilots as well is significantly more robust and relative to the salaries that they own.*

> *You know, like Norway, I think with the oil and gas sector, if you're terminated as redundant, I think you remain on your I think 70 % of your salary for that for the first year. And you also have the right to go back to the job should activity levels pick up with that previous employer.*

10.5.4 The role of the regulator in offshore operations

The role of the regulator in the UKCS is a matter of great importance. In particular, the UK’s Civil Aviation Authority has considerable experience in rotary wing safety. This section therefore covers a number of relevant areas.

Culture of the CAA

Interviewees working outside of the CAA state the need to be aware of the organisational culture within the CAA, given their position of authority. Furthermore, there is a belief that within the CAA, a "silo" mentality exists.

> *I think the UK CAA has always had this authority sort of view … it's a government department it's going to be the authority.*

> *And this is just individuals in the CAA- just driving their own particular pet projects. And it seems that and I think that's part of the problem with the CAA, how- I get a sense that sometimes they work in silos.*

> *I do find sometimes the CAA is very steeped in sort of traditional, you know, it's a captain, there's a captain here's a captain, you know, Captain flying a jumbo jet, Captain flying helicopters, military, etc. And I think that breeds into an organisation as a little bit sort of that well, I wouldn't put - maybe it's*

> *hierarchal, etc. It's a bit stuffy a bit. And a bit sort of, you know, this is what we say, this is what you're going to do.*

Within such a culture, non-CAA interviewees stated that they thought that the CAA focussed primarily on the fixed-wing operations in contrast to helicopter operations:

> *And I don't see the CAA putting their resources in to that for commercial helicopter flights… They never saw the offshore oil and gas sector as the priority.*

Moreover, regulators seem to be unable to enforce regulation and place sanctions on anyone that fails to follow the rules. This is very different to the aviation industry, which is probably because the CAA prioritises the fixed-wing sector over offshore helicopters. Alternatively, they may not have the resources to enforce anything. Either way this creates a perception that the industry is neglected.

> *The regulatory bodies, whether it be the health and safety, the CAA, the position is very weak. Because they don't have in their view - they don't have the tools behind them to ….actually force change.*

> *Operator 1 and Operator 2 didn't train the pilots to use the system, which has been fitted in the aircraft, because they didn't have to.. it was not a regulatory requirement …because they were meeting the standard, they were already meeting the statutory requirement set by the CAA and by the EASA.*

> *So, I think and this, this is not to knock the regulator, but I - my sense is that the regulator over the last 20 years has played far less of an influential role than than they might otherwise have done.*

Several interviewees urged the UK CAA to focus on preventions measure rather than survivability. Moreover, many have expressed their dislike for the survivability equipment because of burden it causes on pilots.

> *We felt that the focus should have been more heavily on keeping the aircraft in the air and developing the new technologies and trying to make the aircraft safer.*

This lack of interest and involvement by the CAA has been seen in many other ways as well. An example is the reactive approach CAA have historically taken (e.g. the CAP 1145 had a primarily reactive focus).

> *After there's an incident, they have got to report it to the health and safety exec. Who will investigate it but and in my view, they don't do enough. I mean there's never been a prohibition notice actually put on any oil company. So, they'll give them maybe an improvement notice. And then if they don't do it within the time, they'll give them an extension to their improvement notice.*

> *And as I say - it was only as a consequence to criticism that was being levelled. And the failure to engage that the review came 2014/15 and CAP 1145.*

Such concerns were acknowledged by the CAA interviewees themselves, who expressed concerns about being a reactive regulator:

> *If we're going to be just that reactive regulator, then we'll lose the confidence of the workforce, and that culture will never never, ever change. And that will be to the detriment of, of society, generally.*

> *But I also think we are very what I would say is reactive. Typically, something tragic happens. Piper alpha, for example. Stepchange in safety was born out of Piper alpha.*

Performance-based oversight

The CAA previously had a more goal-based approach to regulation. In recent times, it has moved to more prescription-based regulation, though there is uncertainty within the CAA and the industry as to the meaning of this term and its application.

> *" a performance-based regulation system looks at the performance of an entity, a company/ organisation that has a number of approvals to it. So it might have a Part-145 for engineering, it might have a 147 to train the engineers, it may be an ATO to train the pilots, all of those different elements form what we call an entity. And then we have a single flight ops Inspector, who becomes the oversight manager for that entity… we have a meeting every cycle of the oversight cycle.*

Performance-based regulations are collaborative in nature and involve considerable interactions with the operators.

> *That can be one or two years, and then we sit down together. And then we pull all of the intelligence together that each individual has had with that entity. And we build this, this picture. Now, that's ultimately, the big meeting at the end of the year. But throughout the working year, you're also sharing with each other, the kind of intelligence that you're seeing along the way.*

Ultimately, it seems it leads to the same results as prior to the performance-based regulation and confidence in the operator’s ability to recognize its own non-compliance.

> *And the stuff that regularly shines through, like it did before performance-based regulation - is an operator's ability to recognise its own its own non-compliance for effective root cause in there and try and resolve it."*

The essence of performance-based audits conducted by the CAA is the compliance system as this is the traditional audit conducted by the CAA:

> *Because that's all we used to do - is truth is to employ engineers and pilots, we'd say, show us your records, let's have a look at your training records, let's have a look at your engineer records, let's look at an aircraft and tick the box around - does it have a fire extinguisher, does it have a first aid kit. So very much compliance and check checklist kind of mentality.*

Within the CAA this approach is considered favourably, as it provided the opportunity for access to the operator and to:

> *Start trying to smell the true nature of what this operator is about by assuming the compliance system is working correctly. And that's the assumption, then we can quite readily look at what the operator is doing about its own noncompliance, where the seat of the fire might be.and then go going to test that.*

Considerable effort is spent by the CAA in considering the system functions as part of its audit process. A consequence of this is that the CAA emphasizes:

> *The safety management system, process procedure, checklists, all that kind of stuff to make sure that that ongoing management of change within an AOC is fit for purpose.*

The CAA interviewees acknowledged that their move to performance-based oversight is based partly on resource constraints:

> *One of the tools that performance-based oversight gives us, is being able to understand where to put our resources. So it was partly driven on a kind of resource based idea as well. If you're a very complex organisation, with a very large oversight commitment from the CAA, we would we would first of all look to see that you're achieving the same kind of compliance standard that we would look for. And the minute we see that, then we can start applying our attention to the things, that may be very very high level risks.*

Non-CAA interviewees felt that the performance-based approach was more prescriptive approach in contrast to the goal setting approach, thereby curtailing innovation:

> *There's the danger that you might argue that if you make it sort of more goal setting, then you don't have someone telling you… it's up to you to decide the extent of the scope and whether you've got it got it right…. it gets you thinking about things that maybe the regulations could never have touched upon. Whereas if it's going to be prescriptive, if you say what, you can only fly for two hours, and that's it, and you must land etc, well, then that's what you do. But it doesn't encourage you to think outside of the box.*
>
> *I think that would be probably the difference from my perspective, in terms of if we have to work performance-based versus a bit more goal setting.*
>
> *You can do risk based auditing, or you can do risk based safety management, as long as you're doing all the traditional auditing stuff, as well. And that's the bit where modern companies like EasyJet or Ryanair, or other likes, would say, you're missing the point. We can't do both. We want to do the, the risk based bit because it's more flexible, and it gives us better capacity, but I don't know that they get much joy with that.*

Overall, non-CAA interviewees didn’t feel there was much practical difference between the UK CAA and those outside the UK. Rather the feeling was that the experience of the regulators mattered more.

> *I wouldn't put much of a difference between the UK CAA and the Norwegian CAA, the Dutch CAA. And it's difficult, I guess, because how do you bring more than risk based approach to oversight, when the people you employ are generally employed because of their experience and time in the industry in general?*

This the interviewees felt could be due to the personnel and experience of CAA personnel:

> *And so you know, that the grey haired men like me, and they would come in, and, they're not going to be off the scale with innovation. If you want to become a regulator, that says something about the personality involved, I would think, you know, you're not going to get the creative types that say, you know, I think my next challenge is to be a CAA inspector.*
>
> *Because I'll have the freedom to come up with some fantastic ideas and embrace new technology and just try something different. So I'm not entirely sure that that's what you're gonna get with a regulator, you're going to get somebody who knows the rules, understands how to apply them, and will ultimately say, yes, that's acceptable, or no, that's not acceptable.*

Regulatory independence

The vote in the UK in June 2016 relating to the country leaving the European Union (EU) eventually in 2020, has had and will continue to have profound impacts on the operational safety of the UKCS. Whilst a Member State of the EU, the rules outlined by the European Aviation Safety Agency (EASA) were followed by the UK CAA for aviation operations. Furthermore many of the UK CAA's staff were seconded to EASA at Koln, and thereby reducing the number of personnel based in the UK and indirectly the expertise present in the country.

When the UK government began negotiations with the European Union on its exit, the discussions were at the political level and hence the UK CAA was not a participant to this, rather it was the Department for Transport. With greater divergence from European regulations predicted, there was a fear in the industry about standardization being lost and inefficiencies creeping in due to duplication etc.

The interviewees highlighted that this was a problem, and it gave an impression that the aviation industry did not matter to the government. Following turbulent times, the UK CAA has since been greatly involved in the developing process. In particular, they have handled negotiations relating to bilateral agreements with the Netherlands, Denmark and Norway. Again the interviewees highlighted that the UK CAA has been very helpful in providing the information and support on these bilaterals.

> *Bilaterals ….which will help us with having the exchanges again on wet leases, dry leases, and the likes and hopefully licence recognition over because up until now, and I'm still flying on a EASA licence. I'm in the transition period. So I just did yesterday, my initial United Kingdom medical, because my EASA Medical was not recognised for that purpose. So I had to do an initial and this is not the CAA being difficult, but it's because of the way Brexit happened.*

The interviewees felt that the UK CAA would do things differently in the future, as they increased UK based staff and expertise. This is a potential positive given that this was noticeable and good for the future of the UKCS operations.

> *UK CAA now that is shaking off the chains of EASA and we don't need to kowtow to Cologne. We're back in business with the UK CAA of old. I think they'll probably be more akin to the Norwegian regulators. And they will do things a little bit more the British way.*

Again, the fear most expressed was standardization being an option from an efficiency viewpoint, with all companies that operated in Europe under EASA minimum regulatory requirements. What participants did not want was that the regulator in each country interpreted regulations to their "own national flavour" posing difficulties for an operator dealing with different legal entities to standardise their training, operating procedures and safety systems. Hence interoperability was preferred:

> *I hope that where we are now it will ease the interoperability. I've had interaction with the CAA because we will have a Norwegian crew fly into UK waters for crew transfers for Norwegian people to a Norwegian floating platform that will do a temporary work of drilling. But with all the COVID isolation and everything, it was better to fly them from Norway than from Aberdeen. Now because know what Norwegians have slightly different safety requirements than the UK, I went to the CAA and ask their permission, explained everything explained our risk assessment on it, how we were mitigating the differences in safety between Norway and the UK. And they gave approval for this. So they are cooperating the quarterly meeting that we have with the CAA and all the operators. So there is some good dialogue going on. Hopefully the bilateral agreements coming up between the UK and the different countries, we will mitigate most of the Brexit issues.*

That said, it’s worth noting that interviewees with experience of operations in other nations felt that while EASA regulations are common across Europe, interpretations of the regulations differ across countries. This they felt would increase.

Similarity with the Norwegian regulatory authority

As mentioned earlier, the collaborative nature of Norwegian operations is such that the Norwegian CAA has a much closer relationship to the operators and industry.

> *Norwegian CAA I think were far better at proper engagement with industry. They were a bit more like EASA - in the sense that they would engage in a genuinely collaborative way.*

Many believe Norway have a golden operations standard which is why they have much fewer accidents. They also believe the Norway CAA is more proactive which is why they tackled issues like non-standardised helidecks first. And finally, the Norway regulator is said to be much more collaborative with industry.

> *The Norwegians actually, I'm going to have to say this very quietly. In Norway, they have had that helidecks hacked for years. It's only the Brits that have got - we will land on anything.*
>
> *He said of the of the five accidents, which had occurred in the UK from February 2009 to August 2017, four of them would not have occurred - Had it been flying in Norway, had they applied what he termed the gold standard in terms of operating standards.*

Finally, one interviewee highlighted there was little difference between the UK and Norwegian CAA.

> *But I don't think that UK, CAA would stand out any not really any different from the Norwegian CAA….maybe if I was going to give them an edge I'd given 55 to 45 % to the UK because they've probably got demographics. …We see a lot of traditional people in the CAA in Norway.*

10.5.5 Helideck safety and its certification

As noted in CAP 1145, an additional issue at offshore installations is the fact that they are regarded as unlicensed operating sites. Helicopter operators must satisfy themselves that each helideck they operate to is ‘suitable for the purpose’, and they discharge their duty of care through an inspection programme undertaken on their behalf by the Helideck Certification Agency (HCA). HCA inspects helidecks and related facilities as being fit for purpose against the standards and best practice contained in UK Civil Aviation Publication CAP 437 (Standards for Offshore Helicopter Landing Areas).

The HCA was established by offshore helicopter operators to conduct independent inspections of helidecks on their behalf, and details of individual decks are published in a Helideck Limitations List (HLL). The HCA uses CAP 437 as their standard, although the provisions of CAP 437, including fire-fighting equipment, lighting and facilities (covering the suitability of the deck environment), are not mandated by any UK legislation. Hence it is important to recognise that the UK does not require helidecks to be licensed though a helicopter operator is required to ensure that a particular helideck is adequate for the type of helicopter and the operation concerned.

In contrast, in Norway legally-based standards are set on a national footing (BSL D 5-1) with, for example, a minimum helideck size equivalent to 1.25 times the greatest dimension of the helicopter.

> *I think the UK is leading the way. With a CAP 437 being used across the world, basically, in a lot of countries that want to look at the requirements for helidecks, circle lighting etc, EASA has adopted it officially, but different countries have their own different interpretation.*

The contrast with operations of helideck safety with Norway can be considered as a consequence of the different legal standards:

> *With Norway things are a bit more difficult because they have not adopted everything off CAP 437.*

To overcome any such issues requires special provision for helideck safety:

> *The wider passengers and the not flying to an overseas state six was easy because we issued a staff flying instruction in Norway saying for these emergency slides you have to fulfil the requirement of not flying above sea state six as defined by this and you shall sit your wider passengers in these seats. For other things we got permission from the CAA to go outside that.*

There is considerable collaboration between the HCA, the helicopter operators and the UK CAA when it comes to helideck certification in order to ensure that O&G companies maintain their helidecks safely:

> *We hold a technical committee of all the helicopter operators, the CAA and the HSE…and review our inspection reports and research that's going on and problems that arise….and review (relevant) standards. We do about three or four meetings a year …that's attended usually by chief pilot, flight ops manager, type of person, or a technical test pilot type person from the helicopter operator.*

When such a scheme was introduced in Norway, there was a noticeable difference between the two countries:

> *In Norway, they invited the oil companies a lot. We keep them away deliberately in the UK, whereas in Norway they've introduced them.*

The experience of the HCA in other countries of the world of including O&G clients to such committees is that it poses problems:

> *In other areas of the world where they're having the problems, 9 times out of 10, with the client customer on that committee, and his role there is to stop any progress because he knows he's gonna have to pay for it.*

The interviewees mentioned that many helidecks are currently beyond their design life. This naturally brings risks as certain safety features on the helideck may be no longer fit for use, especially as O&G companies are not investing to improve their condition.

> *So, right, the fact that the t platform or you know, is decommissioned, doesn't necessarily mean that it's out of service. Right. It just means that it's no longer producing oil or gas or whatever its function was.*

> *I would say 60 % of offshore platforms are over 40 years old now. Structurally, those platforms ...are beyond their sell by date, you just stretch in the elastic and get as much out of it, keep squeezing the lemon a bit more. All right, and try and extend the life a bit more.*

Similarly, after the decommissioning of an oil rig, there still needs to be made sure the lights on the rig are functioning so ships do not collide into them. However, O&G companies are reluctant to spend on rigs as they no longer have any use for it.

> *To give you an example, the Beatrice Charlie platform, was decommissioned in 2008... pretty much abandoned.... sits in the Maury Firth just off Wick. But there is a marine requirement to go out and check the navigation warning lights and everything like that, so ships don't bump into it. Periodically, the only way to get out there is fly out by a helicopter. So the helideck needs to remain certified. The problem was that the oil company won't spend any money on something that is technically derelict. So as it gets older for purpose.*

10.5.6 The co-ordination of safety bodies and its implication

A characteristic of the UK sector is the considerable number of stakeholders involved. This requires in turn considerable cooperation and management across these stakeholders in the various fora for the initiatives to progress, occupying much time and effort. In this respect, the UK differs markedly from Norway. Figure 10.5 shows the various committees involved.

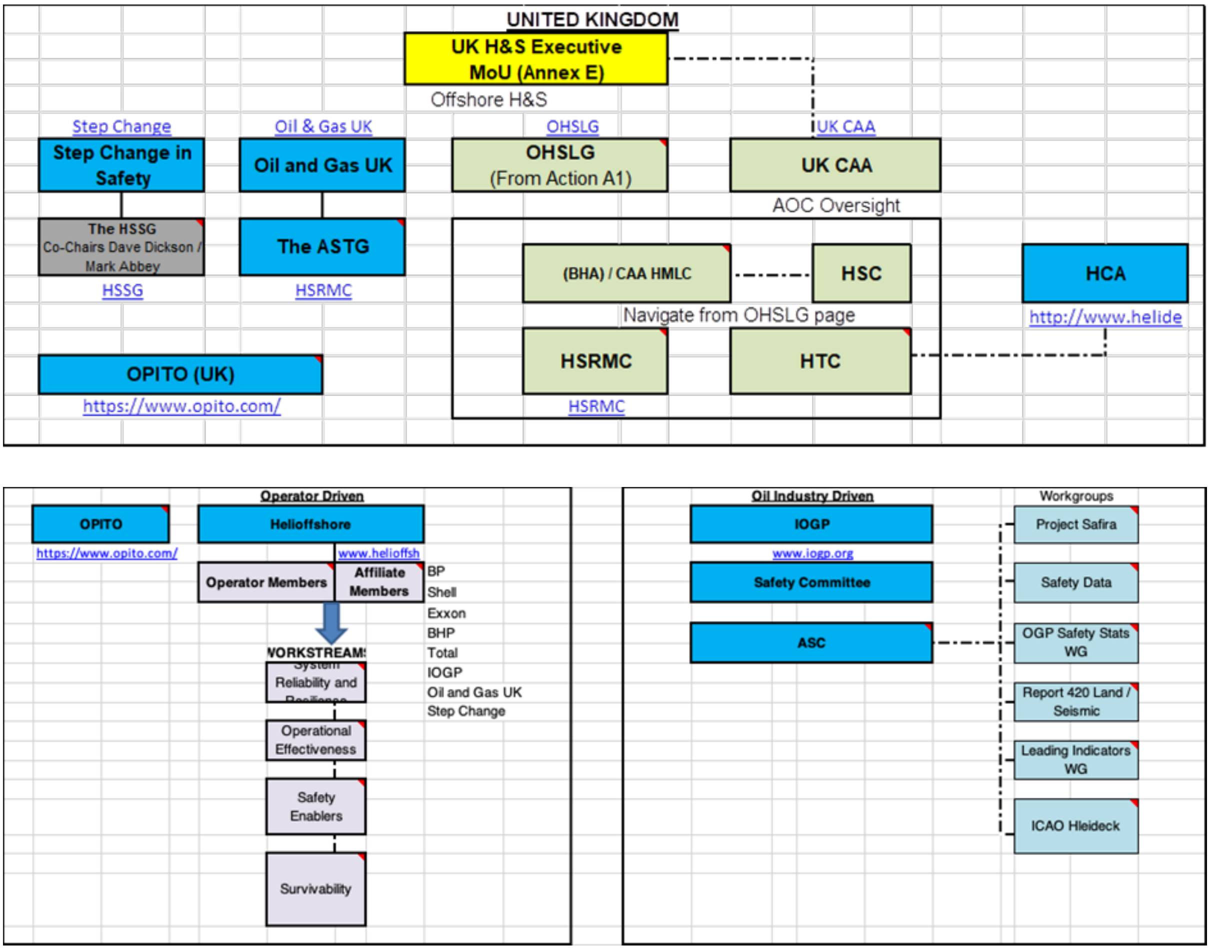


Figure 10.5: Committees involved in North Sea Helicopter Operations in the UKCS.

The interviewees raised a number of issues relating to the plethora and efficacy of these committees. The first issue raised is the sheer number of committees and people involved.

> *I think we have too many associations for very specific topics. I think it can potentially be a drain on the industry's horsepower, if you wish. I think we could be far more efficient in collaborating across some of these associations.*
>
> *There's a lot going on, and yet we don't always get - there's probably too much going on. Too many people involved in too many different things.*

Whilst acknowledging the importance of hearing a variety of viewpoints regarding the safety of offshore helicopter operations, certain for a needed greater focus with regards to their terms of reference, agenda etc to prevent them from being "talking shops", without any concrete action being undertaken.

> *I hear a lot of good stories on HUMS or pilot training, things like that. But you never quite get confident that things are actually being delivered. And that's probably because so many people are involved in this piece. So I do believe that we've we've got probably far too many groups and committees.*

One possible reason for the lack of delivery maybe due to the absence of any decision making powers of these committees. However, one interviewee highlighted that the issue lay in actually putting these in use.

> *The powers exist, putting them into use can sometimes be challenging. I think the regulator's ultimately make the calls on the regulations, but I think through our goal setting regime and our principals, I think we have a good opportunity to influence what is best for our industry.*

With a clear agenda, there is an opportunity of the committees being effective:

> *And as long as there is an outcome, it's good to talk. If you just have a meeting for meeting sake, and I've been in a few of those, then, you know, what's the point? If there's, there's no real agenda, but there are some really good meetings.*

One major advantage of such committees is that an open culture seems to exist, with participants unafraid to speak.

> *I would say people are definitely allowed to speak their mind. It's an open forum. It can be challenging at times, differing of opinions...But also, I think everybody attends those meetings, understand that it's for the greater good, and sometimes it's compromise to be had. So I'd say we are collaborative. And we are, I would say we are more engaged in solutions rather than the protecting our positions, if you like.*

When such fora do work well, a major plus is that matters of importance in safety are openly discussed for the general learning of everybody without any competitive aspect.

> *One of the meetings that runs every quarter in Aberdeen is ...basically a runway users group meeting. And it's split into two elements, there's the offshore helicopter group and it is ... all run by users, including the fixed-wing. And that allows the flight safety officers from the different companies to talk with air traffic about stuff like level busts, transformer coverage, radio coverage, anything that comes up between the operators and the air traffic. It's a really good open forum because everything gets discussed. And I must say, all of the companies, if they have something, everybody holds their hand up and say,*

> *"Hey, listen, this happened to us", or for the general learning of everybody, because it may be a commonplace to say that we don't compete on safety, but we don't amongst each other.*

Another possible danger lies in the fact that new entrants are reluctant to participate in such fora. Given their business model, there is a reluctance on their part to allocate time and personnel to such matters. Since they are increasingly growing in their operations in the North Sea, their lack of participation poses considerable problems for the future.

The interviewees highlighted that such a fora structure differed markedly from the collaborative structure of Norway, though this can be attributed to the difference in the two countries.

> *There's that collaborative, societal organisation, the regulator, the unions, the operators, the customers, they're all in the room discussing it. In the UK, it's a little more complicated because you have far, far more oil and gas companies. And you've got twice the number of operators. And you've got many more unions... , I don't think the oil and gas UK structure is as effective as the offshore safety group in Norway. . But it is more complicated. And I guess it is built on a different societal structure. So I'm not sure it could ever be as effective as as the offshore safety group in Norway. But an equally not entirely sure the offshore safety group in Norway, always get it right.*

10.5.7 Safety Audits

Safety auditing was mentioned in detail in CAP 1145 which noted that:

> *"The presence of greater numbers of customer organisations in the UK sector, …produces a notable audit and inspection commitment by the customer for the helicopter operators (one operator cites over 100 audits in one year). The CAA has previously noted the level of distraction that helicopter functional managers are subjected to by this activity, and recognises that the matter has been under discussion by the industry for some time…… In contrast, the Norwegian sector operates a 'pooled' audit scheme that tempers this commitment."*

The interviews revealed some scepticism as to what contributed to the amount of auditing noted in CAP 1145:

> *Because with what they told the CAA, … they had wrapped all the audits, internal and external and regulatory, they had and said - we're over audited. And that distorted the picture. Actually, it's a subtle thing. What you've got is a small number of oil - Long and invasive audits.*

Has there been a change in the culture of audits since the CAP 1145 report? The interviews suggested that there has indeed been a progressive change, though there remain certain impediments.

> *There has been to be fair, some improvement, we are seeing collaboration with a number of oil and gas companies now. But the audit burden is still significant.*

Interviewees expressed the belief that notably, the O&G majors will always conduct their own audits, given their desire to distinguish themselves from other operators and develop their own brand. Multiple audits conducted on helicopter operators, can take considerable resources:

> *The challenge that we face still is that each of the operating companies, oil and gas companies still have their own standards. And they feel they're not just auditing us to our operational requirements. They're also auditing us against our contractual obligations, as well. And each of those contracts are bespoke to each of the clients.*

> *in-house advisors, (who)…audit, audit and audit. It's like audit is the number one tool in the toolbox.*

Certain interviewees highlighted that the O&G companies use audits post-tender and contract award to revisit the terms of the contract:

> *You win the contract after blood, sweat and tears and bidding and then you start and suddenly, they come and give you an audit almost automatically….well, I suppose your readiness demonstrated all and suddenly they have 71 findings that they didn't have when they came before they gave you the contract, even though you are a current supplier. And last year it was okay, but this year it seems appalling. But of course this year you have a five year contract and they come and beat you up too often to put in things that didn't ask for in the contract.*

> *So everything looks like a problem solved by auditing….you don't get what you want in a contract so you audit it in by writing the findings afterwards.*

Certain interviewees believed that this could be due to the lack of management experience of aviation advisors in O&G companies:

> *Advisors who've never had any management experience, have never worked in safety or quality, but inside an oil, they are doing a safety and quality type of job. And many of them have never really had any contractual experience, in the sense that they understand how to write a contract for what you actually want. So often their ability to write requirements is poor as well.*

Change has occurred with the advent of the new entrants in the UKCS, which has led to "pooled" audits according to the interviewees, conducted by an external body. Such pooling also leads to reduced costs for these entrants:

> *And we've got a bunch of independent oil companies, they have a different philosophy - they're keener on having a good relationship, having a bit of a partnership, they want a stress free operation - they're quite comfortable with not auditing a lot.*

> *A lot of the smaller companies that are coming in …recognise that aviation isn't there isn't their bread and butter isn't their core business are comfortable to allow other third parties…, to come in and audit as a group audit…. It also cuts their costs.*

HeliOffshore in particular is attempting to put together a combined audit basis.

Interviewees felt that having multiple audits are not necessarily a bad thing, since it keeps companies "on their toes" and makes them realise the importance of continuous safety. For this to happen, the auditor must be competent and have the confidence of those being audited, rather than being seen as someone make recommendations for the sake of it.

> *It's always good to have an independent view of what you were doing. And especially as most of them (auditors) would go and look at all of the companies, and so you would get an unofficial view of how they were doing compared to the rest….especially if you just sat down and had an off the record chat.*
>
> *But again, a classic of a lot of auditors be they third party contractors, for in house auditors is a lot of them feel obliged to find things. Because if they don't find things, they can't justify coming back the following year. And in some cases, it also justifies like, one independent audit company actually won't close things until they go and visit and see it.*

What is apparent is that interviewees understood the legal rationale for audits, which is still significant, but would welcome any reduction.

> *We are also obviously heavily audited by the Civil Aviation Authority. And we also conducted a significant audit programme on ourselves – our internal audit programme. And it needs to be for the environment that we are operating in.*
>
> *I think if we could take one of those away, and we could simplify the, the client burden, that would be welcomed. I recognise and fully accept the requirements from the legislative standpoint and the CAA's requirement to audit and we work very closely with them, to see ways in which we can improve on that. And if you think about the move to performance-based auditing, that that's something that we think will be beneficial in the years to come. But yes, we are there are still significant audit burden on all the helicopter operators in the UK.*
>
> *In contrast, Norway has a very different process for safety audits, with an annual grand audit involving both the regulator, the clients and the helicopter operators involved for a focused period of time, which I believe could be beneficial here in the UK.*

10.5.8 Catering for O&G and renewables

As previously mentioned in this report, the UK government places a considerable emphasis on the use of renewable energy for the future of the UK's energy needs. In the UKCS, this emphasis can be seen in the number of wind farms, comprising of wind turbines in the North Sea, in close vicinity of traditional O&G infrastructure, which may lead to safety concerns and limit helicopter usage.

> *But if they got a ship there to build a wind farm, or if they got a fixed platform that they use as a hub, it does not matter to me, whether it's got oil on it, or whether it's got a wind farm on it, for flight safety purposes. Bringing those two worlds together will be the challenge. And we fly for both at the moment.*
>
> *When it comes to the proximity of a wind farm, next to an oil field - I'm just in the process of putting a restricted sector on the XXX platform. It's a gas field in the southern North Sea and the reason for that is the proximity of the wind farm now means that you can't do a particular approach to the platform in poor weather because the wind farm this turbine is so close. At the moment, the CAA are writing regulations saying initially that we agreed that there should be nine miles of separation between a wind farm and an oilfield … in some cases, that's been whittled away down to half a mile. Yeah. And you kind of look at that and going, how can we have this thumping great obstacle within half a mile of an oil and was an established oil platform?*

Wind turbines require maintenance and hence helicopters must be used to do this, though in a different manner from their use for traditional O&G infrastructure.

> *We already see a transition, we're doing a lot more wind farm building work including transport for renewable companies. There is a different need for the use of helicopters for renewable companies, then then oil and gas companies that they want to use the helicopter slightly differently.*

However, interviewees mentioned that there is a "culture clash" between those working in the renewable sector and those in the traditional O&G sector. The antagonistic approach may well lead to a decrement in safety if not carefully monitored.

> *The one interesting thing I see and which I think is a bit questionable - because they are renewables, they see oil and gas as the enemy that's the old that's the polluters and everything. But what they throw away with that as well is all the good practice over the years that oil and gas has built up on the use of helicopters on the safety of helicopters and they want to completely reinvent the wheel on that as well.*
>
> *It would be so much easier if Renewables UK said okay, we're not going to call it IOGP 690, we're going to call it renewable 690, but it's basically the same rather than reinventing the wheel. And it's good to have a look at stuff with fresh eyes. But it's also good to take the lessons from the past and why we do certain things. Because from a helicopter perspective, yes, it's different to flying the windmills.*

The helicopter operators noted in their interviews that working with the renewable sector on wind turbines added to their pilots' workload.

> *The renewables people require of my pilots to do is do an induction every so often for each of their different wind farms. Because all the personnel needs to do an induction. And these inductions have nothing to do whatsoever with flying is for the people who come from a boat onto the surface, the windmill, etc, And this is a burden on the pilots because they now have to do this extra work, which is not relevant to what they're doing. It's nothing to do with safety for them. But it is a requirement of the people who put wind farm in so we're now going to have a conversation with stakeholders. I say listen, is this really necessary? Because x y z, and this is what we could be doing better with this time that we now throw away?*

10.5.9 Helicopter training

Helicopter pilots, consisting teams of two, undertake routine flights to and from offshore installations, providing a commercial service to oil and gas operators. Generally, a pilot undertaking an offshore transport role will be provided with broad information the day prior to flight and meet with the other crew member on the day of the flight to begin in-depth planning processes. This will involve accessing multiple systems to gain an awareness of weather states, local air activities and other notices to airmen. Offshore transport pilots operate under flight time limitations, restricting the maximum number of flight hours that can be accrued in any single period of time, yet crews are still exposed to fatigue and the stresses associated with operating within a commercial environment which can have a detrimental impact upon non-technical skill utilisation. Recently, concerns have been raised in relation to human error in the industry, with an analysis revealing that a significant proportion of offshore transport operator's accidents have been caused by operational factors, including crew errors such as erroneous decision-making.

It is essential, therefore, that operators continue to enrich non-technical skills training, specific to the domain in which the offshore transport pilot works. The HeliNOTS (O) system is the result of a range of studies exploring in detail the non-technical skills utilised by pilots during offshore transport operations. It has been developed to provide a structured, empirical framework in which to address these skills. It provides a common language for pilots and Crew Resource Management (CRM) trainers to discuss and train non-technical skills and lays a foundation on which debriefing sessions may be structured. It is expected that such a nuanced system will be ideally placed to address the unique elements of the offshore transport pilot role and further enhance CRM training.

It is accepted that whilst technical knowledge is a core component of high-level performance, non-technical skills (NTS), encompassing interpersonal (e.g. communication) and cognitive (e.g. situation awareness) skills, are a necessity for safe and efficient practitioner outcomes (Flin, O'Connor, & Crichton, 2008). Within the aviation industry, NTS have been the focus of significant attention due to a series of fatal human-error related incidents in the 1970s.

Over the following decades distinct generations of CRM training has evolved in the industry, aimed at addressing non-technical skills and ultimately mitigating human error (Helmreich, Merritt, & Wilhelm, 1999).

CRM courses involve the modular, classroom-based training of NTS by certified CRM trainers. These programmes have been adopted globally as the training of knowledge and skills relating to human performance have become a mandated component of flight training by all major air operators worldwide (ICAO, 2010). In the UK, both fixed-wing and helicopter operators are subject to CRM training regulations from the Civil Aviation Authority (CAA) which stipulate that pilots should receive training and assessment on non-technical skills (see Flin, 2019). Indeed, it is outlined that a marker of effective training is that there is a degree of role- specificity in CRM courses (CAA, 2017).

Considering the significant presence of human error in helicopter accidents, it is essential to study initially the flaws within the current training.

Many interviewees stated the following issues relating to the training schedules, that are interrelated:

- They are too inflexible. There is a fixed plan to what things will be delivered and there is no room for deviation as a very limited amount of time is provided to training.
- There is a lack opportunity to reflect on recent flying, and the time upon any incidents in the company or learn from any accidents in the industry is very limited. These limited opportunities maybe the result of operators attempting to maximise their flying hours.
- Helicopter manufacturers have not always provided manuals to guide how to use the helicopters. Consequently, different operators are teaching different techniques, there is no standard approach and no one knows the best approach. Thus, interviewees urge manufacturers to start providing manuals known as FCOM, especially as it is already a legal requirement in the fixed-wing industry.

> *There's always pressure on hours from the company. From a commercial point of view, there's very little scope to revisit things within a training event. There's normally very little time to do anything off script, because there's so many things you're trying to get done within the allotted time frame. Because you're trying to satisfy the regulator's requirements to sign the LPC form off.*

Time pressure exists because training is having to be fit around the current flight schedules and the training facility is not necessarily close by. Moreover, time constraints also mean the pilot misses out on opportunities to clarify anything they are unsure of.

> *We contract our simulator time to a third party, though we provide our own instructors for it, which means that all of our simulators are remote from where we operate, which is not unique in aviation by*

> *any stretch of imagination, but it means that we're not necessarily masters that when we do our training, and we have to fit that in with flight schedules to get there, we have to fit that in with hotels, and this year COVID.*
>
> *But if for example, you say, you know, I would quite like to go and try and do some night approaches or something out of the night - We generally do the night stuff running into the winter, because we can go all summer and not night fly. But the - if for say the start of the summer season - you wanted to do some night flying practice, there would be very little scope to do that. So you couldn't go of night flying all winter. And if I just want to clarify a few points before we move on to the next thing -there would be no time to do that.*

When it came to non-technical skills, e.g. crew communication and teamwork, interviewees felt that CRM had contributed to a greatly improved situation, with little or no hierarchy in the cockpit, and improved communications.

Of note is that the interviewees suggested numerous improvements to the industry which have been listed in Table 10.4.

Table 10.3: Suggestions on improvements to training by the interviewees.

Area of improvement	Quotations
Interviewees recognise human error contributes to a large proportion of accidents, as did CAA (2014) mention in CAP 1145. Interviewees feel there is a need to focus more on human performance, fatigue issues, interactions between pilots and co-pilots and to understand how it can be ensured despite a very complicated cockpit, the pilot makes the correct decision. Reasons as to why humans make certain decisions is unknown. There have been many occasions, where despite there being clear signs of something being wrong, the pilot has reacted incorrectly and the co-pilot has failed to correct it. These issues have also been recognised by Kråkenes et al. (2017) in HSS-3b.	*"I think where they start to sort of struggle is where we're all struggling. So around human factors or human performance, and fatigue issues and things like that, and the complexity of trying to you know, and this is all around human performance, you know, a cockpit that's full of so many flippin dials, bells, whistles, alarms, etc. thrown at you - being able to sort of respond in the right way. And you only have to look at the Sumburgh incident as to why did that - why did the pilot do what he did in that regard? And what was the co-pilot doing in terms of ignoring your- or doing a sort of landing that was already in sort of pretty poor visibility?"* *"I can't explain as to why that happens- the Sumburgh incident they were talking about tools might have helped, it might have given the pilot - enough early warning that would have alerted him to try - hang on, I'm getting into a bit of a problem here….there were enough indicators - that I've read about that that still would have said why you - don't still understand why you made that that mistake. well got to a point where he had no option… it was only gonna only going to go one way and it crashed into the sea."* *"You know (the) massively over emphasised*

	statement that 80 % of accidents down to human error."
A training programme that should be flexible, recognising that problems faced by the industry change with time as the industry condition, pilot demographics and other factors vary. Therefore, interviewees believe each operator should create a dynamic training programme which suits the current situation.	*"And then you've got to work out from data, what is it that you're seeking pilots to deal with? So, you know, is CFIT a big issue for you? Well, yeah, okay, if it is, you better make sure that that's a key part of your training programme. Is loss of control a big issue for you? Well, if it is, you better make sure it's a key part of your programme. Our system failures have a certain nature and - Yes, let's put them in. And that's a slightly different dynamic to the current training paradigm, which is based on training framework from 50 years ago, quite literally."*
The interviewees indicated a lack of reflection opportunities. Thus, many suggested for there to be more frequent reflection opportunities (e.g. monthly) to ensure everyone learns from recent incidents and that these incidents do no occur again. And in general, even if no incidents have occurred, they suggested that the collected data can be used to improve the flying technique.	*"So the pilots etc. Maybe over a month, right - You, you when you approached that installation, you went like that, but that was slightly against the the correct way, why did you do it? And it's an opportunity for them to I don't know, yeah, maybe we'll learn from it. I'm sure there's lots of learning from the flight data monitoring."*
This quotation signifies how good training can potentially save a life. In this instance, the passenger did not use the life jacket correctly, the interviewee suggests a plausible reason behind this is because the passenger was not trained with such a type of life vest so was unfamiliar with it. This means it is essential to ensure when new equipment is rolled out, new training is provided. Moreover, the interviewee implies another plausible reason is because the information regarding the life jacket was only a small part of the safety brief. Hence when briefings provide information regarding life-saving equipment, a short demonstration should be given on how to use the equipment to refresh the training knowledge.	*"It's possible that she would have survived if she had had been confident in its use. To be fair, if she'd been confident in the use of the life jacket she had, she may have survived, because clearly, it was - eye to eye contact before the water rose above the head. So probably just enough time to have a good chance of deploying the life jacket. But apparently, everyone failed to understand that the life jacket was a hybrid re-breather with a small oxygen cylinder in - that was going to charge the charge the air pocket to give them a chance to breathe as long as they deployed it before the water came up. Even if their lungs were empty, the life jacket would have replaced that. Why didn't people understand that? Could it be that all the training in the pool was with a lap jacket with no cylinder? And maybe it was said only in a brief bit of the briefing? You know, and the briefing is only part of a day or so with sea survival and pool and HUET training. So, I suspect that many people did not appreciate that. Many people would have done the training with the earlier non-hybrid lap, potentially. And*

	therefore, there would have been some confusion."
Many interviewees stated several accidents in the UK occurred that could have been prevented if the pilots knew how to use the systems on board. This means upon introduction of new systems; the pilots are insufficiently trained such that they lack the confidence to use the new systems. Hence, when a new system is introduced, it should be ensured that the pilots are completely familiar with how to use the system before they are set to fly again. Some interviewees mention many accidents that occurred in the UK would simply not occur in Norway as the pilots know how to use the system on board.	*"He said that the aircraft that went under the sea in February 2009 wouldn't have done that, because the pilots would have been trained to use the systems which were in the aircraft - would have prevented it."* *"And he shared that the August 2013 event at Sumburgh wouldn't have happened because the pilots would have been trained to use again the system which was in the aircraft, which would have prevented the aircraft going in the sea."*

10.5.10 Air Traffic Services

It is worth noting that despite the drop in air traffic operations in general, NATS provision of air traffic services (ATS)[6] from Aberdeen Airport has hardly been affected, despite the COVID-19 situation which led to a major drop in fixed-wing air traffic. As for the offshore traffic itself, there is a peak which effectively begins at 06:30 am when helicopters fly out to the oil rigs and ends when they return at about 2 pm. The rest of the day is not very busy.

NATS believe they have an excellent internal safety culture, with a strong focus on reporting culture.

> *I've no issues at all with the safety culture within the company..... I'm very confident that we know about everything that happens, to the reporting culture that we have.*

In particular, with incident reporting of 'lower level' events, the aim of investigations based on the reporting, is to highlight areas of potential safety risk. Should anything of interest be identified, something that NATS feels the need to take to the operators to prevent this becoming a major occurrence, they will do so. What facilitates this is that there are open communications with both the operators and the regulator. An element of geographical proximity assists in such maintaining such good communications:

> *From an Aberdeen perspective we have regular quarterly meetings with the helicopter operators in particular. And in addition to all our internal safety activities, but we're in constant contact with the helicopter operators all the time. That's the advantage of them being based at Aberdeen, ... we all have very, very good lines of communication. We all know each other... just to send an email or pick up the phone. We don't hold back when it comes to safety.*

Relations with the regulator are also good and meetings with the local CAA inspector and the rest of the Northern Inspectorate team based near to Aberdeen in Sterling, ensures close cooperation.

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[6] ANS implies Flight Information and Alerting Service. Note that NATS do not provide air traffic control (ATC) to offshore traffic on the UKCS.

Given the commercial nature of the operations for the North Sea, NATS develop procedures in conjunction with the operators in order reduce the complexity of operations for controllers. Furthermore the organisation attempts to improve equipment provision for controllers with the intention of making the service safer and more efficient.

10.6 Summary

The various factors outlined in the above section do not act on the safety of offshore helicopter operations in isolation. Rather they have a compounding effect, and the following example will suffice to show this.

The government are at the very top of the stakeholder ladder (Figure 10.6), so can shape how the industry is run. The government limiting their intervention to build on the £360 billion tax revenue the industry has brought since 1970, signifies the reliance of the government on the O&G company and the large degree of freedom in the operations of O&G companies from government interference and regulations (Thomas, 2021). The nature of the O&G industry means that such freedoms may allow them to focus on short-term, cost-cutting measures and actions that may well have adverse effects on safety in the long term. This lack of intervention not only affects how O&G companies behave, but also makes employees vulnerable as they don't have the top stakeholder looking out for them and many safety features (e.g. safety representatives) become less effective. Downie and Gosling (2019) also added, the government may be reluctant to intervene as they expect for the major O&G companies to lead the path to renewable energy. To further ensure the O&G companies are kept happy, the government is providing a generous tax regime and relief for decommissioning (Thomas, 2021), this amplifies the issues mentioned earlier.

Figure 10.6: The stakeholder ladder.

Table 10.5 outlines the main features of the characteristics that affect helicopter operations in the UKCS.

Table 10.4: Main features of the characteristics that affect helicopter operations in the UKCS.

Characteristic	Main Features
Little Government Intervention in the Markets	- Major financial imperatives for the U.K. government in supporting the O&G sector, e.g. O&G companies have bought in £360 billion in tax revenue since 1970. - Financial focus of the government seen through the lack of requirements in issuing licenses as well. - Government wants O&G companies to remain in the UK and one of the 'most attractive tax regimes' in the World (a headline rate of 40 %, compared with the 70+% for Norway) and financial relief for the decommissioning of oil rigs - O&G companies have a large degree of freedom in their operations free from government interference and regulations, allowing them to adhere to and further develop their own "brand". - Freedom from government intervention allows O&G companies to focus on short-term, cost-cutting measures and actions with potential long term safety impacts.
Legal System	- As currently constituted, the legal system favours employers hence challenging employee

	dismissals are challenging. - Employers pay relatively small compensation in such a case and have no obligation re-employ the employee. - Employees are hesitant to raise concerns to prevent themselves being dismissed. - The competitive nature of the industry is such that there are more skilled people than jobs currently available. The recent pandemic is expected to eliminate 30,000 jobs in the industry which will further increase the competition for jobs. - Legal bar is set very high to prove that negligence or unsafe behaviour of an O&G company has caused an accident. i.e. must prove beyond reasonable doubt that the company has done something wrong. - Helicopter operators concerned about sharing data between themselves as it could put operators at risk from legal action or losing a contract.
Dynamic, competitive market	- UK government wishes to encourage competitive, dynamic markets in the UK explaining its reluctance to involve itself in the operations of O&G operations. - The UKCS has seen a major increase in new entrants since 2014 and currently the entrants comprise 30 % of O&G production. This number is expected to rise. - Aim to extract as much as possible from the current resources available, including decommissioned oil rigs. - Very lean operations, often owned by finance companies, focussed on costs in the UK sector only. - Pay operators for a service in a "Uber" like manner and may not invest in future safety needs, beyond the minimum required. - May not participate in various helicopter safety committees, viewing these as a drain on their resources.
Environment	- UK government policy moving towards Net Zero for emission by 2050 and enacted into legislation. - Government plan for the transition in the North Sea outlined in March 2021 highlights the steps and investment required to move away from O&G exploitation. - Increasing wind turbine energy in the North Sea, in the same regions as certain oil rigs. There are still requirements for helicopter operations for their maintenance, but at a much smaller scale and considerably less revenue for the operators. - Planned decommissioning of oil rigs, with a cost to the taxpayer of £18 billion. Still some requirements for helicopter operations on decommissioned rigs, but reduced.
Characteristic	- Major Features
Regulatory Competence	- After many years of downsizing staff numbers, transferring expertise to EASA in Koln, Brexit has brought the UK CAA to a situation where it must now hire competent staff and improve its expertise to take on its new role as the UK's regulator. - There are enough aviation professionals in the UK to be able to staff the CAA, though questions relating to pay and conditions need to be addressed. - Rapid developments in aviation mean there is a need for CAA staff to have the relevant knowledge and competence updated regularly. - There is always an issue as to whether the CAA regulates all aviation in a "fixed-wing" mode of thinking, or if it is sufficiently flexible to understanding the needs of rotary aircraft.
Regulatory independence	- After many years of delegating tasks, procedures etc to EASA, Brexit requires the UK CAA to take back these delegated duties. - UK CAA was not a participant to the discussions on future aviation regulatory requirements. - There are concerns that any move to regulatory independence will lead to a drop in standardisation, which in turn leads to inefficiencies in operations. - A series of bilateral agreements are now in discussion with neighbouring countries with regards to operations which will enable a reduction in duplication of processes. - One advantage of regulatory independence is to have the ability to understand offshore helicopter operations and develop regulations based upon this knowledge, rather than follow generic knowledge.
Safety Culture	- Operators in the UKCS have experience globally and have developed mature safety systems. - There has been a move towards "just culture" in the UKCS operations, with improved reporting,

	analysis etc. - Good communications has ensured pilots are supportive of such a culture. Impediments remain with HR departments showing reluctance; though by training HR personnel, this resistance is reducing. - There is a need to be aware that engineering maintenance departments do not report to the same extent as pilots. This can be down to a lack of awareness to report or other cultural factors. - There is a need to constantly work at maintaining the "just culture" approach and enabling trust.
Maintenance operations safety	- Reporting is strong for the pilot operations – this is due to the safety culture among pilots in global operators, as well as their training. - In the engineering maintenance sectors, the reporting is less developed. - This is partly due to the operations of the maintenance sector of helicopter operations, as the mindset is focused on solving the problems rather than on reporting. - Training and other aspects, e.g. reporting systems are under development to improve the nature of reporting in the maintenance sector.
Helicopter cockpits and their training requirements	- Helicopters used in the UKCS are as advanced as they can be. - Little involvement of union representatives in their design. - Advanced cockpits see increasing automation and there is a need to carefully assess this automation workload in the cockpit. - There is need to ensure appropriate training of human factors, in particular the non-technical skills, e.g. communication, situation awareness and leadership. - This should lead to improved awareness and - The level of regulatory requirement and checks of such training is a matter for discussion.
Market conditions	- Increasing competition between operators in the UKCS means that there is enormous pressure on their revenues. - Operators live under the threat of the 90-day contract termination rule which can mean a long-term contract, can be rapidly terminated given the competition. - This affects operators' ability to invest in future safety needs and training. - This also affects the working conditions and financial security of the pilots and other personnel, who can rapidly lose their employment or see their salary reduced. This leads to financial insecurity for the employees.
Safety Audits	- Multiple audits conducted on helicopter operators, which can take considerable resources - Recent efforts by new entrants on combining audits by having an external body conduct an audit. - Belief in the industry that some organisations, in particular the O&G majors will always conduct their own audits, given their desire to distinguish themselves from other operators and develop their own brand. - Helioffshore attempting to put together a combined audit basis. - Interviewees felt that having multiple audits can be good as it keeps companies "on their toes" and makes them realise the importance of continuous safety. - For this to happen, the auditor must be competent and have the confidence of those being audited, rather than being seen as someone make recommendations for the sake of it.
Role of trades unions	- The power of the Trades Union and their contribution to safety was deemed to be far greater in Norway than in the UK by the interviewees. - Unions play an extremely limited role within the UK, simply acting as an assurance for employees that it is safe to fly. Union interviewees felt that when they have previously raised concerns about safety, too often they have been ignored by O&G companies. - Lack of such a collective trade union strength means that in the UK, individuals have to independently fight their battles a task made more difficult by weak legal employment protection in place. - This lack of involvement by the union due to the limited powers of the trade unions, and one consequence of this is that union interviewees felt that they are only occasionally invited to meetings and discussions, but that too is solely on the O&G company’s terms. - Unions are typically informed about measures to be taken after an O&G company have already made a decision. And when they are informed, interviewees felt this to be just a "box ticking" exercise to say they have been involved, rather than to genuinely involve them. There is a clear

	lack of collaboration and communication with unions. - Lack of power to unions requires them to earn respect from O&G companies, and interviewees stated that by successfully challenging O&G companies, they gained their respect. Once this happened, then communication and collaboration between O&G companies and trades unions improved. - Marked contrast to Norway, where the trades unions are much more powerful and involved in safety decision making.
Stakeholders	- UKCS North Sea operations involves a considerable number of stakeholders. - This requires considerable cooperation and management across these stake holders in the various fora for the initiatives to progress, occupying much time and effort. - An advantage of such fora is that matters of importance in safety are openly discussed and share learning. - The interviewees though raised questions about the efficacy of these committees. - There is a need for greater focus with regards to their terms of reference, agenda etc for certain to prevent them from being "talking shops". Without a clear agenda, there is a danger of these becoming nothing more than that. - New entrants are reluctant to participate in such fora. Given their business model, there is a reluctance on their part to allocate time and personnel to such matters. Since they are increasingly growing in their operations in the North Sea, their lack of participation poses considerable problems for the future. - Helioffshore can play a major role in improving the nature of coordination.
Helideck Safety	- Helideck Certification Agency in the UK has a major role to play in certifying helicdecks – though unlike the CAA it is not a regulatory body. - Works closely with operators and the UK CAA to ensure the O&G companies maintain their helidecks safely. - Major issue for certification of decommissioned rigs.
Catering for renewables and traditional O&G	- Government focus on renewable energy means wind farms exist in close proximity to traditional O&G infrastructure. - Renewables often see O&G as old-fashioned and antagonistic. This can lead to a desire to do away with the experience of helicopter operation gained from O&G. - Helicopters needed for maintenance of wind-turbines, but used in a different manner to O&G facilities.
Air Traffic Control	- ATC for offshore operations conducted by NATS out of Aberdeen airport. - NATS operates on a commercial basis with its contract up for renewal after a certain period of time. - Attempts to focus considerably on customer needs in liaison with the helicopter operators and the UK CAA. - Major reductions in the complexity of the operations have been conducted in the UKCS North Sea operations, saving customers time and money.

Recommendations

Characteristic	Recommendations
Regulatory competence and independence	i) Recruitment of professionals with sufficient aviation background. Questions relating to their pay and conditions need to be addressed. ii) Development and delivery of a programme of relevant knowledge and competence in recent aviation advances to CAA staff on a regular basis. iii) A need for regular checks on standardisation to ensure that regulatory independence does not lead to a drop in standardisation and subsequent inefficiencies in operations.
Safety culture	i) Continue the move towards "just culture in both the UKCS and NCS. ii) Educate the HR departments of helicopter operators in the "just culture" approach. iii) Regularly monitor the safety climate, e.g. through questionnaires, to ensure that the

	"just culture" approach is maintained and trust is enabled.
Maintenance operations safety	i) Develop a training package for the engineering maintenance sectors, on the importance of the reporting; ii) Host workshops on reporting for maintenance personnel to explain the why and how of reporting, demonstrate the level of detail required etc.
Helicopter cockpits and their training requirements	i) Develop appropriate training of human factors, in particular the non-technical skills, e.g. communication, situation awareness and leadership. This could be based on the HeliNOTS scheme and expanded. ii) Pay particular attention to the increasing automation of advanced cockpits on helicopters and, in particular, develop a robust method for assessing this automation workload in the cockpit. iii) In coordination with the regulators, develop the regulatory requirements and checks for the training of pilots in advanced cockpits.
Market conditions	i) In the UKCS review the procedures in place for the 90-day contract termination rule which can mean a long term contract, can be rapidly terminated given the competition. ii) Using stakeholder fora ensure that the working conditions and financial security of the pilots and other personnel are carefully considered in the contractual agreements.
Safety audits	i) Continue efforts to coordinate safety audits, especially for new entrants, using registered and trusted external, independent bodies. ii) Engage further with HeliOffshore to provide the requirements for a combined audit. iii) In addition to a combined audit, ensure that a small number of other audits also occur in order to keep companies "on their toes". iv) Ensure that auditors understand that must be competent and have the confidence of those being audited, rather than being seen as someone make recommendations for the sake of it.
Role of trades unions	i) Ensure Trades Unions have a role to in the UK by ensuring their presence on stakeholder bodies. ii) Ensure that there are clear channels of communication between O&G companies and unions in the UK for safety purposes.
Stakeholders	i) Given that the UKCS North Sea operations involves a considerable number of stakeholders that requires considerable cooperation and management, ensure clear terms of reference, agenda etc in order to prevent them from being "talking shops". Without a clear agenda, there is a danger of these becoming nothing more than that. ii) Provide incentives for new entrants to participate in such fora. Given their business model, there is a reluctance on their part to allocate time and personnel to such matters. iii) Actively work with HeliOffshore in improving the nature of coordination.
Helideck safety	i) Ensure that the Helideck Certification Agency works closely with the regulators to ensure the safety of helidecks with regular inspections. ii) Pay particular attention to Major issue for certification of decommissioned rigs.
Air traffic control	i) Ensure that the ATC provider focuses on customer needs in liaison with the helicopter operators and the UK CAA. ii) Focus on major reductions in the complexity of the operations to save customers time and money.

– PART III –

11 Safety measures

This chapter describes and analyses 39 *safety measures* within eight areas of *improvement needs*, in addition to *assumptions* regarding continuations of important existing measures to ensure today's safety level is maintained. Based on the analysis, it is recommended to prioritise implementation of 18 safety measures. The chapter also includes methodology for identification and analysis of measures.

11.1 Identification and assessment of recommendations

The process of assessing and recommending measures is illustrated in Figure 11.1. First, a wide range of *possible* measures were identified from various sources, notably by invitation from industry stakeholders, accident/event reports, and from the different activities of the HSS-4 study. Second, the identified measures were prioritised roughly with respect to their relevance, risk reduction potential and practical considerations. This prioritisation was obtained through interviews and expert judgements. Third, the *suggested* measures were analysed with respect to cost and effect using the quantified HSS model. The outcome of the analysis was a smaller set of *recommended* measures.

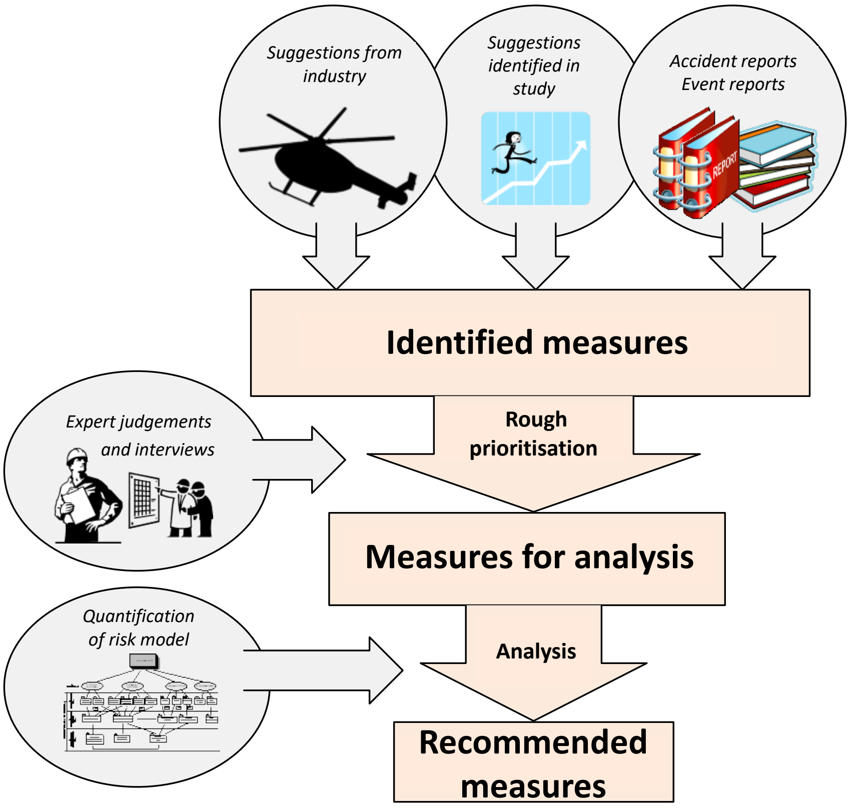

Figure 11.1: Assessment for recommendations.

Measures are safety measures neither implemented nor planned today, which are realistic to implement during the next five to ten years and expected to be effective for at least ten years. Some measures are rather to be considered as *mapping studies* to specify future safety measures. An *improvement need* is defined as an area of improvement, and each measure is classified into one of the improvement needs. Existing measures that are still highly recommended in order to maintain the current safety level, are defined as *prerequisites*.

In total, 150 measures and improvement needs were identified from sources such as:

- Invited suggestions from the industry
- Interviews and workshops with key persons and experts (see below) throughout the study
- HSS-3 and HSS-3b, but still not implemented
- Measures and recommendations in reports from the Norwegian Safety Investigation Authority and the UK Air Accidents Investigation Branch (AAIB)
- Minutes of meetings in The Committee for Helicopter Safety on the Norwegian Continental Shelf for the period 2010–2020
- Other written sources such as reports, presentations, and websites

After systemising the possible measures and improvement needs (e.g. removing duplicates), we were left with approximately 120 measures sorted on different improvement needs. In addition, some prerequisites and mapping studies (also analysed with respect to cost/benefit) were identified.

Each safety measure is formulated to start with a verb, and is to be clearly and self-explanatory defined.

The relevance of each of the 120 possible measures were assessed by experts according to the following criteria:

- Coarse risk reduction evaluation
- Coarse cost evaluation
- Possibility to implement the measure within reasonable time (five to ten years)
- Possibility to appoint responsible persons/groups/organizations for implementing (and financing) the measure

For some improvement needs, an internal prioritisation was done, particularly regarding needs with conflicting measures (e.g. "allocate helideck inspections to CAA-N " vs. "let a third party organization perform helideck inspections ").

The experts involved in the prioritisation were in the possession of both generic offshore helicopter safety competence and specific competence within and experience from maintenance, helicopter operation and air traffic service. Also, in the expert meetings some measures were merged, and additional measures were identified.

Based on the prioritisation, 39 *suggested* measures were analysed further.

11.2 Prerequisites – Continuation of existing measures

The following prerequisites (detailed below) are seen as essential to maintain today's safety level:

a) Continue compliance with ON-066 as a recognized norm
b) Maintain exemptions from the EU’s standardized regulation, e.g. ensure requirement for Norwegian AOC with all its elements intact
c) Maintain the existing competence on offshore operations within the air traffic service
d) Develop an infrastructure for air traffic service and emergency response in the Barents Sea
e) Revitalize The Committee for Helicopter Safety on the Norwegian Continental Shelf to become more than a forum for information exchange

a) Continue compliance with ON-066 as a recognized norm

ON-066 comprises important and required technical, operational, and organizational requirements in addition to the regulatory minimum requirements. The guideline is based on several decades of experience with helicopter operation on the Norwegian continental shelf (NCS). **It is recommended that the listed measures are to be implemented in future revisions of ON-066**. Implementation of ON-066 requirements is to be highlighted, and the guideline should serve as an appendix to contracts with all oil and gas companies. This will contribute to equal frameworks and harmonization of relevant supplementary requirements within the industry. ON-066 has historically contributed significantly to the high safety level on the Norwegian shelf, which is internationally acknowledged, but still has potential for improvement – e.g. to phrase existing requirements more specific and to include new requirements. The prerequisite is high quality and continued development of the guideline through constructive cooperation of involved parties.

b) Maintain exemptions from the EU's standardized regulation, e.g. ensuring requirement for Norwegian AOC with all its elements intact

BSL D 2-3, Regulation of helicopter offshore operations, includes specific Norwegian requirements, additional to the EU regulations. An important prerequisite for the industry is the continued application of unique Norwegian requirements. Helicopter operation on the NCS follows EASA and HOFO regulations to the degree possible. However, the possibility for national, supplementary requirements to the European regulations (as in BSL D 2-3) is a prerequisite to maintain safety in areas with special conditions (as for the Norwegian shelf) by e.g. required competence and experience from operations under these conditions.

c) Maintain the existing competence on offshore operations within the air traffic service

Knowledge of offshore helicopter operations and associated special conditions among air traffic control staff, is a prerequisite to maintain the safety contribution of air traffic control. Proximity to professional helicopter environment is an advantage for the cooperation between helicopter operators and air traffic control. If offshore air traffic service is to be moved from Stavanger Offshore, a set of pre-requisites need to be fulfilled[7]: "The biggest risk will be in the transition phase, and the transition must be carefully planned, such that training, and transfer of experience can be performed optimally. Further, special measures must be implemented to ensure the daily, ad-hoc contact among the actors."

d) Develop an infrastructure for air traffic service and emergency response in the Barents Sea

For increased activity in the Barents Sea, the infrastructure and emergency response infrastructure need to be developed. Installation of (satellite based) ADS-B, communication coverage (down to 1000 feet) – comparable to the rest of the shelf is a prerequisite to ensure safety for flights to/from facilities in the Barents Sea. In addition, improved infrastructure is required for temporary exploration activities – equivalent to established infrastructure for exploration in licenses supported from Kirkenes via Vardø. A prerequisite will be continued cooperation and agreements with Russia. Barents Sea Exploration Collaboration (BaSEC) has published two reports on Emergency preparedness for exploration activities in the Barents Sea[8], including recommendations for emergency response, to be considered as requirements for increased activity in the Barents Sea.

e) Revitalize The Committee for Helicopter Safety on the Norwegian Continental Shelf to become more than a forum for information exchange

Implementation of the new mandate for The Committee for Helicopter Safety on the Norwegian Continental Shelf (CHS) of November 2020 is a prerequisite for the committee becoming more than a forum for information exchange. CHS has a significant potential for safety dialogue and safety work. ***It is***

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[7] See SINTEF report STF38 A04421 (2004). (In Norwegian).

[8] Report – SSEPA Barents Sea (23 R – South East) (2016), Report – SSEPA Barents Sea South West (2016).

recommended that CHS takes the main responsibility for follow-up of the recommended measures in HSS-4. Working groups initiated by CHS to work with recommended measures must be ensured financial resources and time frames. It is expected that CHS will work to avoid company-specific safety requirements, which may represent a challenge (as pointed out earlier in HSS-3).

11.3 Improvement needs

The improvement needs covered by the 39 safety measures are detailed below and are seen to be the most important improvement opportunities for the industry.

Improve the reliability of helicopters and associated systems
Based on the technology development within helicopters and associated systems, there is a need to implement systems to improve the reliability. Older helicopters should be replaced, and new systems should be implemented, to improve safety. It is a prerequisite that the technology that is implemented is proven in use. New technology also opens the potential for new systems such as Helicopter Terrain Avoidance Warning systems (HTAWS), continuous data transfer, modernized procedures and charging capabilities for tablet computers. This may require some contribution from customers. With the introduction of new helicopters and systems, it is also important that training programs for pilots are updated accordingly (i.e. improvement recommendation on pilot competence).

Improve maintenance
Based on interviews, workshops and other project activities of HSS-4, increased focus on maintenance and continuous airworthiness has been identified as an improvement area. The most important areas identified are improved and more precise requirements (see also improvement on safety compliance) and improved training for technicians.

Increase pilot competence
Based on technology transfer, experience from incidents, and discussions with pilots, a need to increase pilots' basic competence and training has been identified. It is recommended to update the simulator training programs, as well as strengthen the Crew Resource Management (CRM).

Reduce the probability of landing on wrong helideck
Based on several incidents on landing on wrong helideck, both on the Norwegian and British shelf, the need to reduce the probability of landing on wrong helidecks has been identified. Even if such wrong landings often have limited severity, they increase unnecessary helicopter movement and have an underlying risk if a facility is unprepared (e.g. with ongoing crane operation concurrent with helicopter landing). Improved markings, improved lighting and use of AIS are measures that could reduce the probability of wrong landings. However, the basis for avoiding wrong landings is pilot alertness and adherence to procedures.

Reduce risk for personnel outside the helicopter
Based on incidents, measures from previous HSS studies and input from the industry, several measures have been identified to reduce the risk for personnel on the helideck. For pilots on helideck outside the helicopter, continuous communication with the second pilot and the HLO is recommended. For passengers and helideck personnel, improved procedure for handling baggage is recommended.

Improve safety compliance
Based on varying interpretations of requirements and guidelines, in combination with the CAA-N’s limited capacity for surveillance and monitoring of requirements, the need to align and clarify requirements (within

the regulations and ON-066) has been identified, as well as contracts (penalties and turnaround time). Increased capacity and competence within the CAA-N is required for more active surveillance and dialogue with helicopter operators and maintenance organizations, in addition to increased international cooperation. Follow-up of helideck operators is also relevant, and it should become simpler for helideck operators and pilots to report improvement suggestions to helideck owners/oil and gas customers.

Monitor safety and learn from incidents

Based on the Norwegian State Safety Program[9] of 2017, a need to focus on monitoring and follow-up of safety and SMS has been identified. There is a potential to utilize information from reported incidents and occurrences in "Altinn". Other sources of information for learning from incidents and non-conformities, are HUMS and FDM. Also, indicators, cause analysis and learnings from incidents are relevant to consider – both within the helicopter operators and the authorities. Further, new risks such as jamming, UAVs, and risk impact from wind farms should be included in risk assessments and potentially regulations.

Map perceived risk

Based on limited studies of perceived risk, the need for a thorough mapping of perceived risk in the entire industry, including technicians, pilots, and passengers, has been identified. In addition, there is potential in improved feedback to passengers following non-conformities and incidents.

11.4 Description of safety measures

In the following, the 39 measures are described with respect to:

- What the measure implies
- Which prerequisites are needed to implement the measure – for measures having important prerequisites
- What is the background for the measure

The safety measures are classified according to their corresponding improvement needs.

Each measure has been classified further as either reducing expected frequency (F), reducing consequences (C), both reducing frequency and consequences (F+C), or reducing perceived risk (P).

11.4.1 Measures to improve reliability of helicopters and associated systems

T1: Update passenger transport helicopters to new models (F)

The measure implies an upgrade of the entire helicopter fleet with new and more automated technology, new systems, new procedures, improved HMI, etc.

The prerequisites are that the new technologies of the helicopters (incl. gearbox) are proven-in-use.

Various models can be relevant depending on the requirements for range, passenger capacity, etc.:

- *Airbus H175* is available, but with limited operational experience. For the time being it lacks a anti-icing system and has a relatively limited range and passenger capacity.

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[9] State Safety Program Norway: https://luftfartstilsynet.no/en/for-organizations/state-safety-program-norway/

- *Bell 525* is expected to become available in 2022 and requires more operational experience before the technology can be considered proven in use. The aircraft features a fly-by-wire system and improved seating comfort for pilots, apart from reduced vibration and noise levels. On the downside, Bell 525 also has a relatively limited range and passenger capacity.
- *Leonardo AW189* is available, but has limited range, passenger capacity and baggage space. The helicopter is an upgraded version of the AW139, which is an advantaged as that technology to a large degree is proven in use.
- *Sikorsky S-92A+ (upgraded S-92) and S-92B (new aircraft with corresponding upgrade/capabilities as the S-92A+)*, are to become available in 2023–2025. These models are expected to reduce operating costs due to longer life cycles and extended interval of gearbox removal compared to current S-92 models. In general, Sikorsky's helicopters have long range and good capacity, but are costly and burn more fuel compared to other helicopter types. In addition, there is a concern that increased weight of the new models could lead to increased loads with increasing wear/maintenance as a result.

Background:
Since HSS-3 there have been several accidents due to gearbox failure. Most of these involved Super Puma helicopters which are no longer in use on the Norwegian sector, but S-92 helicopters have also experienced gearbox issues. Therefore, the manufacturers have been working with development of helicopters with improved, more reliable gearboxes and warning systems. Newer models can for example continue flight for several minutes (depending on model) without lubrication oil supply from the main system. Checklists have been revised and now give the pilot more limited and specific information rather than detailed information. Particularly in critical situations, they hold fewer check points on (emergency) check lists compared to e.g. today's S-92 aircraft.

Other developments are improved avionics and electronics, improved auto pilot systems (and fly-by-wire), more integrated procedures and improved safety systems (ACAS II, HTAWS, etc.). The new autopilot and fly-by-wire systems represent a significant step forward compared to older aircraft and involves best available technology and associated procedures – that shall function in all phases of flight. The autopilot must be reliable to be trusted in all modes and be operational at all speeds, heights, and phases of the flight that the helicopter is certified for. The autopilot should include functions such as automatic leveling during PBN approach and automatic take-over at ACAS II under manual flight. In addition, software must be easy to update, and hardware must accept updates without problems.

An improved automation and a good HMI will in other words be able to assist the pilot in a challenging situation, such as poor visibility, darkness, emergencies or just everyday operations, with a better safety margin. When the operators seek to upgrade the current automation to "next" generation it will lead to an overall increase of flight safety.

S-92 has some technological limitations, particularly associated with the autopilot. Some incidents could probably have been avoided with a more modern autopilot. Upgrading of S-92 autopilot systems is considered as too demanding and costly (estimated to roughly 10 mill NOK per helicopter), as these helicopters are approaching the end of their life cycle and Sikorsky will not support life extensions of the aircraft. With today's activity, only a few years remain until it is required to replace the first S 92 passenger transport helicopters.

T2: Upgrade the older SAR- and shuttle helicopters (F+C)
The measure implies to phase out older SAR and shuttle helicopters (Super Puma AS332L/L1) and replace them with new, proven technology. These older helicopters include one shuttle helicopter (Valhall), two active offshore SAR helicopters (Oseberg and Heidrun) and back-up SAR helicopters. The upgrade would

include both the helicopter itself, as well as associated systems and equipment (autopilot, modern navigation assistance, moving map, satellite and mobile telephone, lights, FLIR/video, NVIS/NVG, radio, wireless communication, cockpit design, etc.).

Background: Application of the most recent helicopter technology has a significant higher safety level compared to older technology, mainly due to increased redundancy, improved absorption impact, and better fire protection. It also could improve the SAR capabilities and potentially reduce the consequences (save lives) when needed in emergencies, such as helicopter ditchings.

T3: Ensure availability of information in the electronic flight bag (EFB) (F)

The measure implies to ensure reliable access to electronic flight bag (EFB) by providing sufficient electric current to the pilot's tablets throughout the flight. The measure also implies to assess SIM cards for the tablets – or other solutions – to provide updated information on weather conditions etc. directly from the facility or heliport en route (see T4). In addition, one or more of the following alternatives are recommended to ensure availability of the EFB:

- Integrate charging port in the cockpit for in-flight charging. (Today’s practice with minimum 67 % charge before flight is recommended to continue). Fixed holders for EFB, in conjunction with charge ports, should be integrated.
- Avoid use of old tablets (e.g. tablets older than 2 years), and introduce a replacement interval for the tablets. Opting for the fastest processor type should be standard when new tablets are purchased.
- Continue the practice of dedicated tablets to the pilots, rather than to have tablets following the helicopter.
- Establish selected check lists (e.g. emergency check lists) not integrated in the helicopters HMI as laminated A4 pages wherever these are seen as simpler than representation on tablets.

Background: Pilots are fully dependent on the tablet, as the tablet is their EFB and there is limited paper documentation in the cockpit. All procedures, manuals and helideck information are available only from the tablet. Even with two tablets (one per pilot) in cockpit and the practice of minimum 67 % charged tablet at beginning of flight, there is a risk that tablet batteries discharges during flight. Some apps (e.g. chart apps) requires an extensive battery capacity. Also, the tablets de-charge faster the older they get. Situations where pilots need to focus on saving battery charge and limit use of EFB during flight should be avoided. External battery banks are not recommended due to the risk of fire. For continuous updating of information, SIM cards (such as SAR pilots are using) or similar integrated communication solutions are needed.

T4: Ensure continuous and updated information en route (F)

The measure implies to implement an information platform in cockpit – with high-speed network and ability for continuously updated information on weather conditions, wave conditions, helideck movement, lightning activity, route information, and other relevant information during flight and well in advance of landing. In addition, helideck reports can become available live.

The prerequisites are preparations of relevant information for continuous information update. E.g. updated weather forecasts at all destinations onshore and offshore, as there have been challenges especially for movable facilities, and for the airports at Florø and Vardø.

Background: Live information will reduce the need for communication en route and prior to landing. Improved weather forecast will also reduce the number of unnecessary flights in bad weather conditions where 1–2 hour delay rather is preferred. The RNNP report published in 2021 also recommends helicopter operators and customers to investigate the potential for continuous data communication during flight.

T5: Make rig data electronically available (F)

The measure implies that necessary, rig specific information is made available for pilots and automatically updated in the EFB. Integrated map and AIS should also be considered.

The prerequisites are that relevant systems support continuous updating of changes (e.g. updated rig locations), besides reporting and correction of errors.

Background: Pilots should get available and updated information from rigs, in particular information on local conditions. Several events reported to CAA-N during the latest decade were related to outdated Jeppesen/HeliApp information, particularly on location, wind limitations and turbulence. An electronic rig data system also must be updated and maintained. It should also be noted that number of apps in the EFB should be reduced by integrating comparable information into the same application.

T6: Modernise procedures (F+C)

The measure implies modernisation of procedures, utilizing the technology offered by modern autopilots. Examples of procedures are automated approach procedures with Satellite Based Augmentation Systems (SBAS), Standard Instrument Departure (SID), and contingency procedures (helicopter specific procedures for engine loss).

Background:

- SBAS technology is developing fast, and SBAS approaches open up possibilities for e.g. lower minima and increased safety during operations in demanding weather conditions. (Inherent in new helicopter types, however, the ambition should be fully automated approaches to helidecks).
- SID is often developed for fixed-wing operation but should be adapted for helicopters. In particular related to a need to reduce the high requirements for climb rate/angle.
- Contingency procedures include relatively complex maneuvering and should be simplified. Helicopter operators have initiated their own procedures (e.g. for Alta and Kirkenes), but further development of procedures requires customer support. The benefit for the customers is to improve regularity and avoid restrictions on the number of passengers under certain conditions (for example in icing conditions today’s procedures require a reduction of 4–5 passengers per flight).

T7: Ensure the infrastructure of a navigation system redundant to GPS (F+C)

The measure implies to maintain the conventional navigation system (including VHF coverage and NDB stations*). This also implies formalized requirements for associated simulator training (see T16). Alternative solutions, such as Inertial Navigation System (INS)** should also be considered.

> *By non-directional beacon (NDB) stations we mean the long range NDB stations/radio masts that have been part of the enroute navigational infrastructure, and not the small, local stations at each facility. The measure requires these NDB stations and an adequate radio coverage on the Norwegian shelf to remain. Today, there is inadequate radio coverage in the Haltenbanken area at Aasta Hansteen, such that NDB stations may be installed, possibly in conjunctions with ADS-B. Radio coverage is also vulnerable with loss of lines and there is a need for redundant VHF lines to Statfjord CTA.
>
> **INS can be considered to at least support sufficient precision of navigation for return to land during a limited period at good height over open seas.

Background: GPS jamming can become an increasing threat – for example due to attempts to avoid systems of road tax (pay-as-you-go) by use of GPS or when other states perform military training within the Norwegian air space. (GPS jamming is experienced yearly at Vardø, and other locations have experienced GPS jamming as well). If GPS becomes unavailable, both surveillance and navigation support are lost. Today, there are no redundant systems to GPS.

T8: Ensure sufficient coverage of ADS-B and VHF in areas on the Norwegian shelf with regular traffic (F+C)
The measure implies ensuring sufficient coverage for ADS-B and VHF on the Norwegian shelf wherever there is regular traffic to fixed installations – and that customers facilitate such radio coverage.

The prerequisite is the possibility to install radio equipment on fixed installations. Facilitating the installation of radio equipment should be part of the infrastructure of each installation by assuring space in the facility architecture and installation during the project stage for the installation.

Background: Today there is inadequate coverage for radio and especially ADS-B at 20-40nm from Aasta Hansten (see above) – the most critical area for surveillance and communication on the Norwegian shelf apart from the Barents Sea. (For rescue services one is dependent on GPS and satellite telephone).

11.4.2 Measures to improve maintenance

T9: Ensure maintenance and modifications are performed under Norwegian regulatory oversight (F)
The measure implies that maintenance and design/modification are performed in Norway and with proximity to the operations, by Part-145 organizations approved by the Norwegian authority. This can be assured by contractual agreements between customers and helicopter operators (practiced to some extent today) or by regulatory requirements. This measure also holds for subcontracting of Continued Airworthiness Organization (CAMO).

A prerequisite is that the CAA-N follows up such requirements.

Background: The Norwegian offshore helicopter industry has been highly concerned about moving abroad the control of airworthiness. This measure will ensure that maintenance competence in Norway is further developed, in addition to education and training of Norwegian skilled workers and technicians. There is a special need for skilled avionics and sheet-metal workers. To ensure continuity and competence of personnel, education/training and employment of new personnel is preferred rather than to hire personnel.

T10: Improve availability of spare parts (F)
The measure implies improvement of availability of spare parts both from manufacturers and by cooperation with other operators. The operators should both put more pressure on the manufacturers and optimize the spare part stock with respect to prioritizing important part considering the tied capital of the spare parts. Oil companies should also consider if Pay By Hour/Power By Hour (PBH)* should be included in contracts to ensure delivery of spare parts. Further, operators should cooperate with other operators in their dialogue with the manufacturers.

> *PBH is a contractual agreement between vendor and operator/maintenance organization where the operator/maintenance organization pays an agreed price per flying hour on a continual basis, and the vendor at all times keeps a certain amount of spare parts available for the operator/maintenance organization with an agreed delivery warranty.

Background: Access to spare parts is necessary to avoid cannibalism (i.e. taking/borrowing parts from other aircraft). Improved availability of spare parts was also recommended in HSS-3 but was considered closed in HSS-3b due to an improved situation and ongoing processes with manufacturers. However, it was pointed out in HSS-3b that the situation should be monitored. Today, access to spare parts is experienced as worse than ten years ago and cannibalism is practiced extensively. In some cases, the same part could be circulating among aircrafts three to four times, until a new spare part became available. This leads to more and unnecessary maintenance transactions, increased cost, downtime, workload, and stress, and can contribute to increased frequency of maintenance errors. Also, lack of spare parts can challenge the tradition of not delaying replacement of worn parts.

T11: Standardise requirements for "independent inspection" (F)

The measure implies a standardized safety requirement for independent inspection after completed maintenance actions on critical components – as well as standardized education and training. The requirement must apply across operators/maintenance organizations. There is a need to specify which inspections/parts that need what extent of independent inspection and by whom (which category personnel and associated standardized requirement for training). The requirement needs to be specified by technical competent personnel.

Background: Today independent inspections vary (e.g. via video link vs. pilot being physically present vs. technician being physically present). Standardisation and more specific requirements should consider that certain inspections still can be executed via video link to a technician, and that independent inspections of critical parts could be executed by a person physically present, viewing, touching and sensing the part. The person could in some cases be a pilot or a hoist operator, with required training, whereas in specific cases a technician could be required.

T12: Improve training in use of computerized maintenance system for technical personnel (F)

The measure implies specific training for technicians in the use of the maintenance systems, electronic maintenance manuals, and associated information systems.

Background: Technicians spend an increasing amount of time in front of the computer, documenting and following up maintenance. At the same time, they point out lack of training and competence in operation of the maintenance system. This has led to several documentations of the same maintenance tasks, which is time-consuming. The measure would reduce the risk of maintenance error and spurious records and that maintenance procedures are not followed.

T13: Improve training for technical personnel (F)

The measure implies more and better training for technicians – particularly "continuation training". The following improvements are pointed out:

- Training for tasks involved in daily maintenance.
- Increased use of simulator (e.g. Flight Safety’s maintenance simulator at Sola).
- Specification of requirements for execution and content of training, including which technicians are to complete which training.

Training requirements (amount, content, and for which groups) should be precisely defined in the regulation and guidelines. In general, ON-066 should become more specific on maintenance requirements and requirements for technicians. Training should consist of both theory and practice (classroom training and simulator-based training).

Background: Today, the requirements in the regulations and ON-066 are unclear regarding training content, including simulator training, which again lead to varying training practices.

T14: Improve specification of requirements for maintenance personnel (F)

The measure implies to formalise precise definitions of maintenance levels and requirements for maintenance personnel.

Background: Today's definitions of line maintenance and base maintenance are somewhat unclear, both with regards to content and which technicians (B1/B2/C) are required for which types of maintenance tasks. Then, the operator/maintenance organization must assess what type of maintenance to be executed by which type of personnel, equipment, and facilities.

11.4.3 Measures to increase pilot competence

T15: Maintain the pilots' basic competence (F)
The measure implies to maintain the pilots' required basic competencies. The content of (simulator) training should be adapted to include basic competencies of pilots (see T16). Evidence based training (EBT) should be developed and based on the pilots need, reported incidents, statistics and FDM data – especially for use in the simulator.

The prerequisite for the measure is cooperation of helicopter companies and pilot trade unions to define tools and guidelines for selection of captains and first officers. The selection should be based on a good balance of relevant experience and capabilities such as skill set, compliance with rules and procedures, independent thinking, cooperation, handling of unexpected situations, understanding of technology, etc. Limited turnover of pilots within a helicopter company is an advantage for maintaining base competence, continuity, experience transfer and pilot development.

Background: Several incidents throughout the past years, both nationally and internationally, have been related to human errors and/or lack of CRM (see below). Combined with more advanced technology, improved autopilots and increased complexity, there is a need to maintain the pilots’ competence and CRM. With new autopilots and fly-by-wire the helicopter will be able to take control in an increasing amount of (dangerous) situations (e.g. in approaching obstacles). Increased complexity can also introduce new risks (cf. Emergency landing on Yme 2013). Basic competence and Upset Prevention and Recovery Training (UPRT) is necessary to maintain crew skills and will become more important with increased automation.

T16: Adjust content of simulator training (F)
The measure implies to adjust the existing programs for simulator training to become more efficient, i.e. to include more relevant safety training within the already dedicated hours for training. The program should be meaningful for pilots, cover basic skills, be evidence-based, and include situations such as:

- Basic instrument flight
- Handling of digitalization, modern technology, and complexity
- Approaches to ships in the vicinity
- Immediate landing in critical situations
- Avoid collision with obstacles, including manual override of autopilot during dark with object in front of helicopter
- Use of emergency check lists
- Conventional approach without the use of GPS, i.e. by cross checking of magnetic compass/radar/sun
- Upset prevention and recovery training, e.g. discontinue automatic approach after loss of signal*
- Realistic use of ACAS II*
- Emergency situations and reinforcement of CRM

*This implies upgrading simulators for realistic training, as already required in ON-066, sec. 5.1.3, that simulators should reflect helicopters regarding cockpit lay-out and instrumentation.

Background: Simulator training and corresponding program must be continually developed and adapted to technological changes, and interaction between pilots and instruments (CRM). CRM is an essential skill in both normal operations and emergency situations, especially those emergency situations not included in the emergency check lists. Weak CRM has been identified as a cause for almost one third of fatal accidents worldwide. Examples of incidents experienced in Norway and Canada that good CRM should have revealed, are confusion in the cockpit about the situation and the responsibility for tasks, as well as breach of procedures at take-off from helideck in darkness.

11.4.4 Measures to reduce the probability of landing on wrong helideck

T17: Harmonise requirements for helideck lighting with British requirements (F)
The measure implies to harmonize Norwegian and British requirements for design and use of lighting on helidecks – for both ordinary lights (landing circle and 'H') and status lights (red/green light showing if helideck is cleared/not cleared). This is a particular need for unmanned facilities.

Background: CAP 437 on helidecks lighting sets requirements for a lighted circle and 'H' marking, improving visibility and showing orientation for helidecks on the British sector. Pilots having flown on both British and Norwegian shelf state that the visibility on British decks is better compared to Norwegian decks, especially the lighted circle and 'H'. In Norway it is a requirement to have status light (red/green), based on helideck movement, but there are no requirements for lighting of the circle. Illumination like British requirements is expected to reduce the risk during landing on helidecks in darkness and in demanding weather and light conditions. The effect of status lights should be evaluated against the risk of setting wrong status (due to technical or human causes). CAA-N has not yet adapted the CAP 437 (and ICAO Annex 14 vol II) lighting standard, partly due to uncertainty about the system reliability / mechanical robustness.

T18: Improve rig name marking (F)
The measure implies that the rig name marking has good visibility and is centrally placed on the rig (e.g. on derrick), in addition to the name on the helideck.
Background: Rig name markings should be standardized. The helideck is normally the last thing visible to the pilots before landing, such that a more centrally placed name panel would contribute to reduce the frequency of wrong landings.

T19: Assess the need, feasibility, and risk of implementing AIS for passenger transport helicopters (F)
The measure implies to make a risk assessment of implementation of the display of Automated Identification System (AIS) in passenger transport helicopters.

Background: All larger vessels and facilities on the Norwegian shelf are obliged to carry AIS transmitters. AIS receivers in helicopters can simplify identification of ships and reduce the risk of collision with nearby vessels during approach to helidecks. In addition, AIS can reduce the risk of landing on a wrong helideck. If an emergency landing should arise, AIS can be used to identify relevant facilities in the planning of the emergency landing. However, an associated risk factor is the pilots' reduced focus during the approach due to the strong reliance on the AIS – even if AIS is not functioning correctly or larger vessels do not carry AIS. Due to varied opinions on the effect of AIS, and possible introduction of additional risks, it is recommended to perform risk assessment of an AIS implementation to evaluate if AIS should be implemented or not.

11.4.5 Measures to reduce the risk for personnel outside the helicopter

T20: Introduce requirement for communication for pilots on helidecks (F)
The measure implies to establish requirements for pilots on helidecks outside the helicopter, to carry radio equipment for communication with the other pilot and the HLO.

Background: Today, pilots moving outside the helicopter or checking fuel do not have any communication possibilities. A simple radio, connected to a headset, would enable to communicate when required.

T21: Improve handling of baggage on helideck (F)

The measure implies to improve the baggage handling on the helideck by e.g.:

- Include instructions for handling baggage trolleys on helidecks in the Offshore Norge helideck manual
- Ensure correct baggage mass calculations
- Increase the weight limit per bag to decrease the allowed number of bags from two to one per person
- Update and standardize procedures for picking up baggage, e.g. each passenger picks up the first bags, regardless of ownership, and carries the bags to the heli-lounge for final distribution.

Background: There is a potential to reduce the risk to personnel (fall on ladders, stumbling over baggage, etc.) on the helideck and to the helicopter (by e.g. loose/flying baggage). Many incidents have been reported to the CAA-N involving incorrect calculation of baggage mass, which can lead to overload of the helicopter and/or incorrect fuel calculations.

11.4.6 Measures to improve safety compliance

T22: Implement completely ON-066 (F+C)

The measure implies that oil and gas companies by means of their contracts take responsibility for implementing the complete set of requirements in ON-066. The requirements not implemented today are mainly:

- Completely automated approach to land bases
- ACAS II in all helicopters
- To connect all helicopters to a network during flight (ref. T4)
- Use of most recent helicopter technology, and to upgrade older helicopter (ref. T2)

Background: To ensure the safety improvement ambition of ON-066, all the requirements in the guideline should be fulfilled. However, today, the guideline’s requirement for automated approach and live Internet are not met. Also, not every helicopter is equipped with ACAS II (formally required from January 1, 2022). In addition, some older helicopters are still in use.

T23: Align on turnaround time and penalties (F)

The measure implies an alignment among helicopter operators and customers on reasonable turnaround times and penalty regimes (penalty payments for delays). The oil and gas companies must ensure that penalty regimes do not threaten safety and safety culture. Experiences with penalty regimes and turnaround times is also recommended to be included in a study of perceived risk (ref. T38).

Background: Penalty was introduced to compensate for the customers cost from delays, and for the operator to follow the time schedule as far as possible. This may conflict with safe operation, especially when unexpected (delaying) situations occurring during and between flights. The operators, and particularly the operation centers, now experience the penalty regimes as increasingly stricter and more stressing. Turnaround times onshore is also experienced as a stress factor by some pilots and has led to sick leave. Another factor is that engines on the S-92 are not recommended to be re-started less than 20–45 minutes after shut-down, also affecting the turnaround time. Turnaround time must be sufficiently long to allow for the required activities with adequate quality and without compromising safety. This means that turnaround times must be sufficient also upon extra landings and other unforeseen events (delays due to maintenance, weather, traffic, etc.). Technicians must always be given the required time to complete necessary inspections and/or maintenance. Turnaround times should also be adapted in line with the technology development. The penalty regime can be replaced by e.g. measurement of punctuality over time (e.g. based on monthly statistics or indicators) rather than for each flight. The helicopter operators and customers should agree on the balance between regularity, safety, and work environment.

T24: Increase the frequency and quality of helideck inspections (F)

The measure implies to increase frequency and improve quality of helideck inspection. The helideck inspections should mainly be performed by the CAA-N.

A prerequisite is that the CAA-N gets sufficient resources and competence to perform the helideck inspections (ref. T27). In addition, helicopter operators and customers must maintain their competence on helidecks and associated operations. A possible delegation to an independent helideck inspection organization must comply with Norwegian regulations and should not weaken the helideck competence within helicopter operators and customers.

Background: Today, the interval between helideck inspections on a given facility is often several years. The CAA-N establishes yearly a list for the PSA of prioritised helideck inspections, but helideck is only one of many responsibilities of the PSA such that the number of helideck inspections is limited. Even if customers and/or helicopter operators have continual inspections, there is a need for increased supervision by an organization independent of the helicopter companies and the oil and gas companies. RNNP also points out the challenges associated having three different supervisory authorities. The RNNP recommendation is that the PSA, the CAA-N and the Norwegian Maritime Directorate should cooperate closer on challenges that involve more than one of these bodies.

T25: Implement completely the helicopter operators' SMS (F)

The measure implies to implement the complete Safety Management Systems (SMS) within the helicopter operators, with a focus on overall risk management and safety monitoring.

A prerequisite for the measure is follow-up from the authority (CAA-N), as well as improved understanding of regulations (ref. T27).

Background: Even if helicopter operators have robust quality systems, there is a need to develop their SMS functions for risk monitoring and safety performance. Especially relevant is the need to associate "Event Risk Classification" of individual events and safety monitoring (safety assurance) with identified safety indicators and targets. The measure is expected to increase safety focus on airworthiness, and to increase the focus on a systematic SMS rather than on individual event analyses.

T26: Improve follow-up of helideck operators’ SMS (F)

The measure implies that oil and gas companies – either through the Aviation Specialist Network or individually – follow up safety of helideck operations. Recommended improvements are:

- Introduce English helideck phraseology.
- Improve procedures for fueling (procedures, testing, inspection).
- Ensure understanding and use of weather services and associated equipment.
- Increase sharing of experience among helideck personnel.

A prerequisite is that helicopter operators record non-conformities and possible areas of improvement (ref. T35) for continual improvement.

Background: Both reported incidents and suggestions through HSS-3, HSS-3b and HSS-4 have identified the need for improved quality of the helideck services, especially with respect to fueling and communication. Communication between pilots and helideck personnel/HLO is mainly in Norwegian, while the communication with ATC is in English. Several pilots are non-Norwegian and need to understand the HLO. In order to communicate better and avoid misunderstandings, HLO/helideck personnel should be familiar with standard English phraseology, like e.g. "abort, abort" if a landing has to be aborted due to retracted landing gear, gas on platform, interfering crane operations, etc. Many of the reported helideck events have been related to the helideck personnel's misunderstanding of the rules for when a helicopter can land after the thresholds for helideck movement for landing have been exceeded. Also, a number of events are reported regarding incorrect amount of fuel, and therefore the need for improved competence and procedures for fueling has been identified. From a specific event, it was also proposed to standardize the use of measuring units to avoid overfilling (return mass from the installation was in this case reported in pounds instead of kilograms). Another fueling event involved a loose wire almost causing personnel injury.

Helideck personnel shall report to the CAA-N in accordance with BSL A 1-3 § 2. However, individuals may find it challenging to report in NF-2007 and find it difficult to know who to report to in various situations (helicopter operator, own organization, or CAA-N). Then important information can be lost.

RNNPs incident indicator 3 also shows that lack of/insufficient information from helideck, equipment failure, and non-compliance with procedures are involved in the majority of the reported helideck incidents – in particular for movable installations. RNNP points out the importance of prioritizing weather data and more detailed data. The experience is that there is little value in being referred to weather reports for installations 30 nautical miles away from the actual platform. RNNP recommends that the oil and gas companies responsible for movable rigs ensure that helidecks have been inspected by an approved party, that personnel have received adequate training, and that the helideck manual is being followed.

T27: Strengthen the capacity and required competencies in the CAA-N (F)

The measure implies to strengthen both capacity and the competence within the CAA-N. Improved conditions and increased flexibility for employees may need to be considered.

Background: There is a special need for sufficient competence and resources in the offshore helicopter field within the CAA-N to maintain the safety level of offshore helicopter transport. In CAA-N it is relevant to increase the understanding of regulations and particularly SMS (see T26 and T28), to improve internal cooperation, to strengthen the technical department, to strengthen knowledge within the legal department regarding regulatory changes, and to improve follow-up and coaching of their employees (e.g. after training). The regulations include expectations about what to address in audits, but limited information on how to perform audits and which questions to ask at audits. Increased competence and standardization of inspectors is therefore needed.

T28: Improve dialogue on risk reduction and safety improvements between the CAA-N and the helicopter operators (F)

The measure implies to implement a holistic dialogue on risk reduction and safety improvements between the CAA-N and helicopter operators – for systematic and continual monitoring and analysis of safety performance within the industry.

Background: Despite the fact that airworthiness regulation now has included a formal SMS-requirement, the focus of SMS has been mainly on compliance with SMS requirements (along with other requirements) rather than to question if SMS works according to the intention. The connection between the industry's safety performance, and dialogue on risk reduction and safety improvement, is stated in the Norwegian State Safety Program (SSP), section 2. The CAA-N has developed a new method for risk profiling of organizations, in which SMS components and underlying functions represent half of the risk profile. The implementation, however, has been challenging, especially in the professional environments (e.g. technical and heliport/airport) with strong compliance traditions. Contact meetings with the operators also need to be part of an improved supervision process – a potential arena for safety dialogue beyond the traditional dialogue with focus on regulatory issues.

T29: Increase cooperation between national and international authorities (F)

The measure implies for the CAA-N to seek increased cooperation with international authorities – especially within offshore helicopter operations.

A prerequisite is increased competence and resources at the CAA-N (ref. T27).

Background: After Covid 19 increased meeting activity in international fora, such as Helicopter Expert Group, is to be expected, and Norwegian participation is important. By increased participation by the CAA-N, Norway will have better chances to promote national needs, as well as to be prepared for possible upcoming changes. Active cooperation between Norway and the UK is also highly important as the UK is now outside EASA and since it is mainly Norway and the UK that have been engaged in developing the regulatory framework for offshore helicopter operations.

T30: Establish regulations framework for offshore UAV activity and wind farms (F)

The measure implies to establish regulations framework for offshore drone traffic and wind farms, such that the interface between offshore and land is maintained.

Background: The use of drones offshore is continually increasing, and activities are planned to increase development of wind farms. In comparison, the CAA-UK established CAP 764 "Policy and Guidelines on Wind Turbines" in 2006 (latest update in 2016).

11.4.7 Monitor safety and increase learning from incidents

T31: Improve HUMS (F)

The measure implies to implement live HUMS, to develop automatic analyses, and to adapt analysis results for pilots in the cockpit. Within HUMS analyses there is also a need for improved trend and in-depth analyses (ref. T1) which can be considered as a safety barrier in addition to reliable helicopters and systems.

Background: See chapter 3.2.1. A reliable HUMS system offers the possibility to identify faults and stop flight before an incipient failure can develop further. Live HUMS, comparable to fixed-wing, connected to the base via the Internet or satellite could give significant safety effects. Potential faults could be detected in flight such that the helicopter could return to base or perform other safety actions to avoid dangerous situations or accidents. (There are many examples of helicopters that should have returned when they did not). Live HUMS can to a large degree be implemented by introduction of SIM cards and improved mobile coverage, but preferably by satellite-based ADS-B, combined with high-speed Internet. (ref. T4). One challenge is that some aspects of such use of HUMS most likely will need to be part of certification of the aircraft/systems, and consequential actions to be conducted in flight or on ground, must be published in the approved documentation.

T32: Specify inhouse FDM requirements (F)

The measure implies to specify how FDM is to be incorporated in the helicopter operators' flight safety work by more detailed descriptions, e.g. guidelines for parameters to be monitored and associated thresholds for specific operations/activities. Especially the operational limits for each operation should be addressed. The descriptions should also include how to utilize FDM to identify potential weaknesses of individual operators' procedures and manuals.

A prerequisite is a cooperation on FDM among helicopter operators (in line with the recommendations of CAP 1145).

Background: Each company has its own way of utilizing and following up FDM. Standardisation could be challenging due to cultural differences and national regulations. Anchoring of FDM procedures by the CAA-N or EASA with regulations on how FDM-data are to be used for operators and crews would increase the acceptance of FDM and increase its effect.

T33: Develop relevant indicators and analyses for offshore helicopter transport (F)

The measure implies to develop safety information and indicators for continuous follow-up of safety. The measure also implies to establish good presentation of incidents and statistics from the CAA-N and the operators, including more qualitative analyses of incidents. Relevant indicators are based both on experienced incidents (lagging indicators) precursors of accidents (leading indicators). Existing data and analyses should also be coordinated by the CAA-N and in cooperation with the PSA/RNNP regarding classification of incidents (cf. varying data sets and differing categories/definitions).

A prerequisite is and improved basis for to monitor safety and risk influencing conditions, to further identify relevant measures. For the development of indicators, we especially refer to:

- HSS-3, sect. 9, where a set of reactive and pro-active safety indicators, as well as criteria for choice of indicators.
- CAP 1145, recommending standardization of safety indicators with the industry, amongst other based on FDM.
- ON-066, attachment 1 listing a set of KPIs.
- Heli-Offshore's work for establishment and use of indicators
- Avinor ANS safety indicators
- The CAA-N and Norway's flight safety program*
- RNNP**

Background: With indicators, organizations and authorities can identify risk mitigating measures before accidents happen, in addition to measures identified from accident investigations and follow-up after incidents. Indicators can be utilized by different stakeholders. While the authorities depend on a limited set of indicators for e.g. yearly monitoring of safety levels, helicopter operators need continual monitoring as part of their safety management. An obvious alternative is a holistic follow-up of safety in the industry (ref. T34), for example based on the HSS model and its accident categories and risk influencing factors. An alternative could be to distinguish between the different ICAO categories or other parameters (e.g. based on NF-2007 reporting of accidents and incidents in civil aviation).

Despite reporting directive 376/2014 being in effect for several years, the CAA-N still does not receive updates on incidents after investigation or ERC (risk classification) from the helicopter operators. Technical incidents in flight remain unresolved in the national database, including lack of risk classification or "closeness to accident". This measure would therefore contribute to e.g. identification of problem areas and causal relationships as a basis for improvement.

*Authorities are obliged to set targets and monitor the development within different areas of aviation such as offshore helicopters. The CAA-N published the first edition of the Norwegian flight safety program in 2017, with the following principles for development of systematic and continual measurement methods for safety performance:

- Flight safety associated development trends shall be identified and a risk-based approach shall be used to prioritise areas where concern and need is highest.
- Flight safety results of Norwegian aviation is to be monitored continually and by national high level flight safety indicators as well as service providers indicators for flight safety results.
- The aviation industry shall be involved in discussions about flight safety related issues and work continually to improve flight safety.
- Flight safety information shall be collected, analysed, and exchanged by and among all relevant organizations and service providers.

Safety indicators shall be included in service providers' SMS and shall reflect the service provider's activity and complexity, potentially to result in different sets of safety indicators among service providers. To monitor and analyse safety indicators will provide information of whether the safety performance is acceptable.

- If the SMS works as intended.
- If the effect of initiatives is as expected.
- For authorities to enable risk-based auditing.
- To contribute to a holistic and aligned view of flight safety enabling proactive flight safety work.

** RNNP includes five indicators related to offshore helicopter transport, based on incidents reported by helicopter operators:

Incident indicator 1: Number of incidents with little or medium remaining safety margin. Registration and classification of incidents is being practiced differently by the helicopter operators. The indicator is therefore based on an expert group's independent evaluation of remaining barriers to an accident (0,1 or >=2).

Incident indicator 2: Number of events with a safety impact, based on event categories (technical, operational, helideck, ATM, bird strike and others) or phase (parked, take-off, landing and in-flight).

Incident indicator 3: Number of helideck incidents with a safety impact, distributed on spurious position of rig, spurious/lacking information, equipment failure, turbulence-heave/roll, obstacles, persons in dangerous zone, non-compliance with procedures, and other.

Incident indicator 4: Number of ATM events with a safety impact. This includes close encounters, loss of communication, miscommunication, unintended, significant deviation from flight speed, planned track or height, non-authorised intrusion of air space, tarmac intrusion, and clearances that could not be met.

Activity indicator 1: Number of flight hours and passenger flight hours per year.

T34: Establish a tool for monitoring safety and risk influencing factors (F)

The measure implies to establish a tool for safety monitoring (safety trend) based on a set of defined indicators and potentially, surveys/in-depth studies, with an associated management framework, i.e. procedures and defined responsibilities for data collection, processing, and analysis. The data should be compiled and analyzed yearly, and results published yearly as information for involved stakeholders.

Figure 11.2 shows an example of a structure for a web-based solution for publication of indicators (and possibly reporting of input data). Indicators for which data have been collected could be presented by status and trend. Indicators could also be sorted by categories, e.g. accident categories and risk influencing factors, in addition to perceived risk. It is also recommended to establish one or more aggregate indicators (total indicators), Such indicators should include results from qualitative investigations (e.g. based on surveys and/or interviews). Such investigations can be published at a frequency of e.g. bi-yearly. Data reporting should be possible to perform in the same web solution, and the reported data need to be quality assured prior to aggregation and publication (See also appendix D)

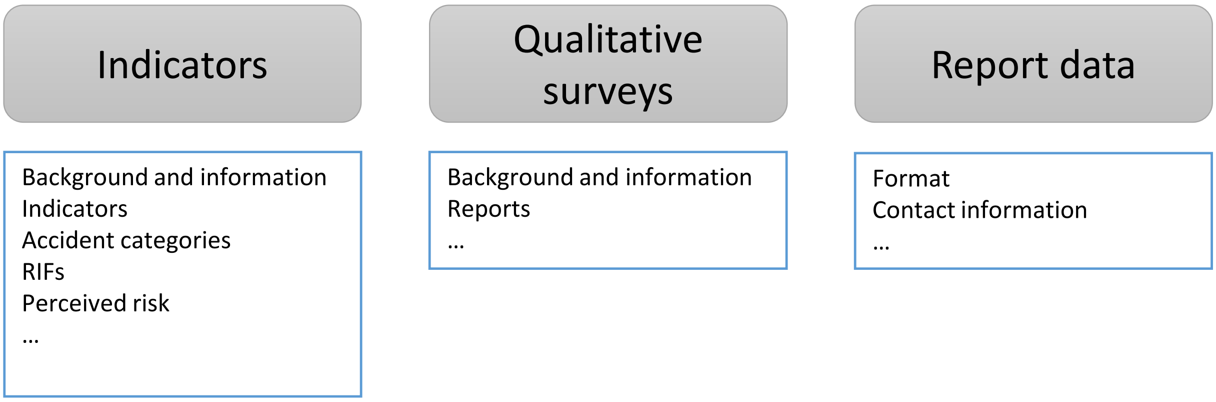

Figure 11.2: Suggested screen menu for indicators.

A prerequisite is that a set of indicators has been established that as far as possible reflects the risk of offshore helicopter operations, at the same time as data for the indicators can be collected relatively easily (i.e. that requires limited effort from helicopter operators, Avinor ANS, customers, and trade unions.

Background: Recurrent status mappings create a knowledge base for identification of challenges and prioritization of measures. In addition, such mappings contribute to increased attention and discussion on safety and need for potential measures.

In the petroleum industry, RNNP has been monitoring safety trends and challenges within the petroleum industry for 20 years. This has been a success factor for the high safety level within the oil and gas industry in Norway. RNNP combines risk targets for both objective and perceived risk, through structure of incident data from the involved companies and interviews/surveys amongst employees. Incident data are reported for defined situations of hazard and accident (DSHA) associated with major accident risk. Questionnaire surveys and qualitative studies are used to map work environment, safety climate and perceived risk. Incident data is reported yearly, while questionnaires are performed bi-yearly. RNNP has performed questionnaires for a number of years and this initiative has therefore been well incorporated in the RNNP work. To achieve success of corresponding studies for offshore helicopters data gathering should not being too demanding in terms and time and effort. A relatively short selection of concrete questions is to be preferred.

The CAA-N should be in the lead of the collection of data/indicators and the execution of questionnaire surveys for offshore helicopter transport.

T35: Improve reporting system for feedback from pilots to helideck/heliport (F)

The measure implies to improve the reporting system for helicopter operators and pilots to improve their feedback to helideck and heliport personnel/organizations. Based on reported incidents, potential improvements, standardization, guidelines, etc. can be assessed. The helicopter operators should collaborate in the reporting system development (cf. T36).

Background: Many incidents reported to the CAA-N during 2010–2019 include improvement proposals from pilots for the helideck/heliport (e.g. bad radio coverage, failure in fueling, spurious weight calculations, spurious passenger lists, obstacles on/at the heliport, lack of compliance with or knowledge of 20 minute rule for red helideck by helideck personnel, spurious reporting of cloud height, etc.). During HSS-4 workshops, challenges have also been identified related to the amount and/or quality of communication during the final phase of flight (0–20 min before landing on the helideck). If such situations cannot be resolved directly with the facility or the involved personnel, this must be reported to avoid similar repeating situations. The reporting system is presently too complicated and should be simplified. The same applies for reporting from helideck/heliport to pilots (cf. T26).

T36: Increase collaboration among helicopter operators (F)

The measure implies to increase the cooperation among helicopter operators, especially in areas as spare parts (cf. TR10), competence and training (cf. T15 and T16), statistics and incidents (cf. T34 and T35), and reliability data sharing to reduce technical failures. To ensure good solutions, the customers should potentially cover associated costs for collection of data and analyses.

Background: Reliability data and learning from incidents are relevant across operators, especially in an industry with relatively few accidents and serious incidents. If knowledge about and equipment or event/incident is relevant for other operators, this information should be shared as quickly as possible. A framework for open dialogue on safety related subjects should exist at management level, as well as for pilots, technicians etc.

T37: Implement requirement for video recording of cockpit (F+C)

The measure implies to introduce a requirement for video recording of cockpit solely for use by the Norwegian Safety Investigation Authority (NSIA) to investigate causes and contribute to learning. The video recordings should be integrated with the cockpit voice and flight data recorder.

A prerequisite is that recordings can only be used by the NSIA for required investigations and that data cannot be misused. Cockpit video recording is a controversial topic.

Background: Video recordings would be highly valuable sources of information for accident investigations. They are partly implemented for onshore helicopter operations.

11.4.8 Measures on perceived risk

T38: Mapping perceived risk (P)

The measure implies a study to map perceived risk in the entire offshore helicopter industry. The study should include (not be limited to) passengers, pilots, technicians, operation center, and management. Relevant subjects to address are the penalty regime and turnaround time, as well as influence from the company's financial situation on pilots and technicians.

T39: Improve communication to passengers after incidents/occurrences (P)

The measure implies that passengers are given more detailed information after incidents. To ensure that pilots are not unduly burdened, it may be beneficial if Offshore Norge or the O&G companies are responsible for the extensive communication to passengers in the aftermath of incidents, as recommended in ON-066 for major incidents.

Background: Feedback to passengers after incidents is presently being given by helicopter operators and their pilots – a task that comes in addition to ordinary pilot activities such as planning for the next flight, or it may happen to interfere with the rest time between working days.

11.5 Analysing measures

The measures described above are analysed with respect to effect and cost based on expert judgement and by using the quantified HSS risk model. Table 11.1 summarizes the results of the analysis.

The *effect* of a measure is related to a set of RIFs and accident categories and their corresponding risk contribution. The relevant RIFs and accident categories for each measure are listed in Table 11.1. The frequency and consequence contributions from the respective RIFs and accident categories are summarized from the quantitative risk model. In addition, each measure's effect on frequency (F) and consequence (C) *within* the relevant RIFs and accident categories are considered as either low (L), medium (M), or high (H) according to the following intervals (and representative values):

Effect	F effect	C effect
Low (L)	0–10 % (10 %)	0–5 % (5 %)
Medium (M)	10–40 % (30 %)	5–25 % (15 %)
High (H)	> 40 % (60 %)	> 25 % (30 %)

The risk reduction of the measure is then quantified by combining the contributions from the risk model for the relevant RIFs and accident categories with the effect (L/M/H). In the calculations, the representative values are used.

The *cost* associated with a safety measure is also assessed in three categories:

Cost	Cost estimte [MNOK]
Low (L)	0–10
Medium (M)	10–100
High (H)	> 100

The cost categories include contributions from both investment costs and operating costs (during a period of about ten years). Differentiation of investment costs and operating costs has not been performed due to great uncertainties in the cost estimates. The cost category for each measure is considered mainly relative to other measures.

In addition to effect and cost, the implementation time and industry need are aspects that are considered in the prioritisation.

The *implementation time* is the time from the measure is planned to be implemented until it reaches full effect. For each measure, one of the following categories are selected:

Implementation time	
Low (L)	0–2 years
Medium (M)	2–5 years
High (H)	> 5 years

The *industry need* is not solely related to the safety effect of the measure. The need may be due to repeated incidents of low severity, specific demands from (parts of) the industry, potential for operational improvements, or due to many years with the same need. Accommodating a high industry need may entail the relocation of resources to e.g. safety work and thereby implicitly improve safety. For industry need the following categories are defined:

Industry need	
Low (L)	Need for a single organization / Recent industry need.
Medium (M)	Need for a large part of the industry, for example helicopter maintenance or helicopter operation.
High (H)	Need for the entire industry / Need has existed for at least 10 years / Measure prioritised by experts.

Table 11.1: Summary of analyzed safety measures.

Measure		RIF		Accident category	Effect c)		Reduction d)			Cost e)	Relative effect/cost f)	Impl. time g)	Indus nee
		F a)	C b)		F	C	F	C	R				
	Improve reliability of helicopters and associated systems												
T1	Update passenger transport helicopters to new models	1.1–1.4	-	all	M	-	11 %	0 %	11 %	H	2 %	> 5 years	H
T2	Upgrade the older SAR- and shuttle helicopters	1.1– 1.3	1.10	all	L	H	4 %	3 %	7 %	H	1 %	2–5 years	H
T3	Ensure availability of information in the electronic flight bag (EFB)	1.3–1.4	-	all	M	-	2 %	0 %	2 %	L	4 %	< 2 years	M
T4	Ensure continuous and updated information en route	1.4, 1.11	-	all	M	-	3 %	0 %	3 %	M	1 %	2–5 years	H
T5	Make rig data electronically available	1.4	-	1	M	-	0 %	0 %	0 %	L	0 %	2–5 years	M
T6	Modernise procedures	1.1, 1.4	-	all	L	-	0 %	0 %	0 %	M	0 %	> 5 years	M
T7	Ensure the infrastructure of a navigation system to redundant GPS	1.4, 1.8	-	1, 2	M	-	1 %	0 %	1 %	L	2 %	2–5 years	H
T8	Ensure sufficient coverage of ADS-B and VHF in areas on the Norwegian shelf with regular traffic	1.8	-	all	M	-	1 %	0 %	1 %	L	2 %	> 5 years	H
	Improve maintenance												
T9	Ensure maintenance and modifications are performed under Norwegian regulatory inspection	1.2	-	all	L	-	3 %	0 %	3 %	L	6 %	< 2 years	H
T10	Improve availability of spare parts	1.2	-	all	M	-	8 %	0 %	8 %	M	3 %	> 5 years	H
T11	Standardise requirements for "independent inspection"	1.2	-	all	L	-	3 %	0 %	3 %	L	6 %	< 2 years	M
T12	Improve training in use of computerized maintenance system for technical personnel	1.2	-	all	L	-	3 %	0 %	3 %	L	6 %	2–5 years	L
T13	Improved training for technical personnel	1.2	-	all	M	-	8 %	0 %	8 %	M	3 %	2–5 years	H
T14	Improve specification of requirements for maintenance personnel	1.2	-	all	L	-	3 %	0 %	3 %	L	6 %	< 2 years	L
	Increase pilot competence												

Measure		RIF		Accident category	Effect c)		Reduction d)			Cost e)	Relative effect/cost f)	Impl. time g)	Indus nee
		F a)	C b)		F	C	F	C	R				
T15	Maintain the pilots' basic competence	1.3, 1.5	1.5	all	H	M	7 %	2 %	9 %	M	4 %	2–5 years	M
T16	Adjust content of simulator training	1.5	-	all	H	-	3 %	0 %	3 %	H	1 %	2–5 years	H
	Reduce the probability of landing on wrong helideck												
T17	Harmonise requirements for helideck lighting with British requirements	1.7	-	1, 6, 7	L	-	1 %	0 %	1 %	M	1 %	> 5 years	M
T18	Improve rig name marking	1.7	-	1, 6, 7	L	-	1 %	0 %	1 %	L	3 %	2–5 years	M
T19	Assess the need, feasibility, and risk of implementing AIS for passenger transport helicopters	1.4, 1.7, 1.10	-	1, 7	-	-	1 %	0 %	1 %	-	1 %	< 2 years	L
	Reduce the risk for personnel outside the helicopter												
T20	Introduce requirement for communication for pilots on helidecks	1.5, 1.7	-	6	L	-	0 %	0 %	0 %	L	0 %	< 2 years	H
T21	Improve handling of baggage on helideck	1.6, 1.7	-	6	L	-	0 %	0 %	0 %	L	0 %	< 2 years	L
	Improve safety compliance												
T22	Implement completely ON-066	1.1–1.9	-	1	M	-	12 %	0 %	12 %	H	3 %	2–5 years	H
T23	Align on turnaround time and penalties	1.2, 1.3	-	all	L	-	3 %	0 %	3 %	L	7 %	< 2 years	H
T24	Increase the frequency and quality of helideck inspections	1.7	1.8	1, 6	L	L	1 %	0 %	1 %	M	0 %	2–5 years	M
T25	Implement completely the helicopter operators' SMS	1.3–1.5	1.5, 1.6, 1.7	all	L	L	1 %	2 %	3 %	M	1 %	2–5 years	L
T26	Improve follow-up of helideck operators' SMS	1.7	1.8	1, 6	L	L	1 %	0 %	1 %	L	2 %	< 2 years	L
T27	Strengthen the capacity and required competencies in the CAA-N	1.1–1.10	1.1–1.10	all	L	L	9 %	4 %	14 %	M	6 %	2–5 years	H
T28	Improve dialogue on risk reduction and safety improvements between the CAA-N and the helicopter operators	1.3–1.5	1.5–1.7	all	L	L	1 %	2 %	3 %	M	1 %	2–5 years	L
T29	Increase cooperation between national and international authorities	1.1–1.3	-	all	L	-	4 %	0 %	4 %	M	2 %	2–5 years	M
T30	Establish regulations framework for offshore UAV activity and wind farms	1.8, 1.10	-	1, 3	L	-	0 %	0 %	0 %	L	0 %	2–5 years	L

Measure		RIF		Accident category	Effect c)		Reduction d)			Cost e)	Relative effect/cost f)	Impl. time g)	Indus nee
		F a)	C b)		F	C	F	C	R				
	Monitor safety and increase learning from incidents												
T31	Improve HUMS	1.1, 1.2	-	2, 4, 5	M	-	3 %	0 %	3 %	M	1 %	2–5 years	M
T32	Specify "inhouse" FDM requirements	1.4, 1.5	-	all	L	-	1 %	0 %	1 %	H	0 %	2–5 years	L
T33	Develop relevant indicators and analyses for offshore helicopter transport	all	-	all	L	-	10 %	0 %	10 %	M	4 %	2–5 years	H
T34	Establish a tool for monitoring of safety and risk influencing factors	all	-	all	L	-	10 %	0 %	10 %	M	4 %	> 5 years	M
T35	Improve reporting system for feedback from pilots to helideck/heliport	1.7, 1.9	-	1, 6, 7	M	-	4 %	0 %	4 %	L	10 %	< 2 years	H
T36	Increase collaboration among helicopter operators	1.2, 1.5	-	all	L	-	3 %	0 %	3 %	L	7 %	2–5 years	L
T37	Implement requirement for video recording of cockpit	1.3, 1.5, 1.6	-	all	L	-	1 %	0 %	1 %	L	1 %	2–5 years	L
	Perceived risk												
T38	Mapping of perceived risk	-	-	-	-	-	0 %	0 %	0 %	L	0 %	< 2 years	H
T39	Improve communication to passengers after incidents/occurrences	-	-	-	-	-	0 %	0 %	0 %	L	0 %	< 2 years	L

a) RIF-number in the influence diagram for frequency. See Figure 2.2.

b) RIF-number in the influence diagram for consequence. See Figure 2.3.

c) Estimated percentage reduction of the frequency contribution to risk (F), consequence contribution to risk (C) and total risk (R) for the measure to assume effect.

d) Estimated effect for frequency, consequence and risk reduction for the relevant RIF and accident categories when the measure has been fully implemented.

e) Estimated cost.

f) Relative estimated effect/cost compared to the remaining measures. (The sum of all relative estimated effect/cost is 100 %)

g) Estimated implementation time (number of years starting 2021/2022) before the measure is assumed to take full effect.

h) Industry needs based on recurring experienced occurrences, needs for (parts of) the industry, potentials for operational improvement, or measures that have had broad and long-lasting support without being implemented.

11.6 Recommended safety measures

The recommended safety measures are those measures with the highest total score in the analysis based on the safety effect and cost-effectiveness. In addition, implementation time and industry need have been considered. Recommended measures and the substantiation for the recommendations are given in Table 11.2. The table contains a total of 17 frequency reducing measures and one measure for perceived risk. Four of the frequency reducing measures have also been classified as consequence reducing.

Table 11.2: Recommended safety measures and their substantiation.

Safety measure	Substantiation
Improve reliability of helicopters and associated systems	
T1: Update passenger transport helicopters to new models	The analysis shows that this measure gives a relatively significant reduction in risk (frequency reduction), combined with the industry's need for continual improvement of reliability of the helicopters and safety in general with e.g. improved autopilot and HMI. Even if the measure is costly (estimated price for a helicopter is 20 to 40 million dollars, depending on type) somewhat reduced operations and maintenance costs can be expected and reduced environmental emissions (due to less fuel consumption). A combination of existing S-92 and one or more newer models would also reduce the present vulnerability to operating only one helicopter type for commuter traffic. Long implementation horizon is required to ensure proven technology and adaptation to Norwegian conditions (weather, wave, distances, infrastructure, etc.)
T2: Upgrade the older SAR- and shuttle helicopters	The analysis shows that this measure gives a relatively significant reduction in risk (frequency and consequence reduction), combined with the industry's need for upgrading of older aircraft to latest technology. This coincides with the requirements in ON-066. Implementation time would not have to be long, as the technology is available, and only few helicopters are affected.
T3: Ensure availability of information in the electronic flight bag (EFB)	The analysis shows that this measure is cost-efficient and has been identified as a significant need among pilots. The measure could also be implemented within a relatively short time frame.
T4: Ensure continuous and updated information en route	The analysis shows that this measure gives some risk reduction and is in demand by large groups in the industry.
T7: Ensure the infrastructure of a navigation system redundant to GPS	The analysis shows that this measure is cost-efficient and is identified as a major need – especially by Avinor ANS. It should be possible to implement the measure within a short time frame.
Improve maintenance	
T9: Ensure maintenance and modifications are performed under Norwegian regulatory oversight	The analysis shows that this measure is cost-effective since maintenance and continued airworthiness contribute to 26 % of the accident frequency, according to the risk model. The measure has further been prioritised due to the industry's need to maintain and develop maintenance competence in Norway, and ensure compliance with (Norwegian) rules and regulations.
T13: Improved training for technical personnel	The analysis shows that this measure is cost-effective, especially due to its significant effect on risk reduction. The measure has also been identified as urgent by maintenance personnel.

T10: Improve availability of spare parts	The analysis shows that this measure is cost-effective, especially due to its significant effect on risk reduction. The measure has also been identified as urgent by maintenance personnel, but also by the industry as a whole. The measure has been recommended for many years, without satisfactory response/implementation. .
T11: Standardise requirements for "independent inspection"	The analysis shows that this measure is cost-effective with a short implementation time. It addresses a long-time recommendation to improve and standardize varying practices.
Increase pilot competence	
T15: Maintain the pilots' basic competence	The analysis shows that this measure is cost-effective, due to its relatively significant risk reduction. The measure has been, combined with the need for more specific training and CRM, been high-lighted as a industry need, due to increased complexity and experienced incidents.
T16: Adjust content of simulator training	The analysis shows that this measure gives a significant reduction in the frequency of accidents and reflects a need especially among pilots, but also a broad need of the industry. The requirement is part of the continual improvement of pilots' competence.
Reduce the risk for personnel outside the helicopter	
T20: Introduce requirement for communication for pilots on helidecks	The measure has been identified as a requirement among pilots since HSS-3. The measure is associated with a relatively low cost and is easy to implement. Since the risk reduction is low, the measure has not been considered cost-effective. The measure should still be given priority, considering the low cost combined with a potential to avoid hazardous situations for pilots on the helideck.
Improved safety compliance	
T22: Implement completely ON-066	The analysis shows that this measure is expected to be cost-effective, due to its relatively significant frequency/risk reduction. The measure also reflects a need from the industry and has been highlighted since HSS-3. Once full compliance with ON-066 has been achieved, there is a need for further improvements/ development of the guideline to ensure continual improvement of safety.
T27: Strengthen the capacity and required competencies in the CAA-N	The analysis shows that this measure is cost-effective, due to its relatively significant risk reduction. The measure also reflects a broad industry need, as pointed out by many industry actors over a long period of time.
T23: Align on turnaround time and penalties	The analysis shows that this measure is cost-effective and has been identified as a need by helicopter operators since HSS-3. The measure should be able to be implemented relatively quickly.
Monitor safety and increase learning from incidents	
T33: Develop relevant indicators and analyses for offshore helicopter transport	The analysis shows that this measure is cost-efficient due to relatively significant risk reduction. The measure has also been identified as a need by the industry for a period of time.
T35: Improve reporting system for feedback from pilots to helideck/heliport	The analysis shows that this measure is cost-efficient. There is a need for an improved reporting system between helicopter operators and helideck/heliport. This will have an impact on both safety and regularity.
Perceived risk	
T39: Mapping of perceived risk	The measure is not expected to increase safety as such, but could contribute to reducing the perceived risk. The measure has been requested and identified as an industry demand. Compared to other measures the cost would also be quite small.

Reduce the probability of landing on wrong helideck	
No recommended measures	*None of the measures within this improvement need are analysed to be sufficiently cost-effective and/or a significant industry need compared to the other recommended measures. Nevertheless, measures should be considered to reduce the probability of landing on wrong helideck.*

It is worth emphasizing that although the table above highlights the 18 *recommended* safety measures, the entire list of 39 *suggested* safety measures described in this chapter should be given attention in the safety work ahead. Still, the recommended measures should perhaps be prioritised first.

11.7 Implementation and follow-up of safety measures

The recommended safety measures should be implemented and followed up in a structured manner. The measures should be coordinated and followed up by CHS and be documented in a standardized way. Each measure should have a dedicated responsible. Also, it is important to identify prerequisites and closing criteria for implementation of each measure.

Measure responsible
Each measure should have an assigned 'responsible', which could be an organization, a working group, or an individual with the responsibility to follow-up the implementation of the measure.

Designing, implementing and closing measures
All measures should be executed under a common framework for designing, implementing, and closing of measures.:

- *Designing* includes information about which conditions that need to be in place, how the measure is to be adjusted, as well as criteria for closure.
- *Implementing* includes a plan for and the execution itself of the measure, actions, time schedule, assignment of responsibilities, allocation of resources, etc.
- *Closure* includes information about activity and result based closure criteria and how these can be met, evaluation of the implementation, as well as an assessment of the effect with possible additional measures to be considered.

Documentation
Documentation of each measure should as a minimum include the following:

- *Purpose*: A description of the purpose of the measure and how it is to be achieved.
- *Clarifications and prerequisites*: Information about which clarifications that need to be done, which prerequisites that need to be in place before the measure can be implemented, and other conditions to considered before the measure can be implemented.
- *Closing criteria*: an overview of the criteria to be fulfilled to close the measure. Two types of closing criteria can be identified: Activity-based or result based-criteria. Application of activity-based criteria implies that a measure can be closed after a certain pre-defined activities have been completed. Application of result-based closing criteria implies that a measure can be closed after certain results have been achieved.
- *Cost.*
- *Measure responsible.*
- *Time schedule.*

Follow-up of measures

It is recommended to establish a tool for follow-up of the measures from HSS-4, primarily for the CHS/CAA-N, but also with the possibility for other stakeholders to monitor the status of the implementation work. Se appendix D for a specification of such tool.

12 Main conclusions

The main conclusions of the study are presented in this chapter. The conclusions are structured around the various themes of the study, as follows:

1. Accident statistics
2. Main development features
3. Potential threats to helicopter safety
4. Maintenance of helicopters
5. Crew Resource Management
6. Comparing helicopter operations in the British and Norwegian sectors
7. Recommended safety measures
8. Recommendations for continued work

12.1 Accident statistics

- For the period 2010–2019 there have been two helicopter accidents on the NCS of which one was fatal with 13 fatalities (Turøy 2016). This gives a rate of **1,9** fatalities per million-person flight hours.
- For the extended period 1999–2019 there have been three accidents (one fatal, 13 fatalities). This gives a rate of **0,9** fatalities per million-person flight hours.
- The fatality rate on the NCS over the last decade (2010–2019) is higher than the UKCS. However, over the last two decades (1999–2019) the NCS fatality rate is far lower that of the UK.
- For the British sector in the period 1999–2019 there have been 15 accidents of which 4 were fatal with a total of 38 fatalities. This gives a rate of **3,4** fatalities per million-person flight hours.
- The British sector has seen a remarkable decrease in the number of accidents and fatalities over the last decade (2010–2019) compared to the previous decade (1999–2009).
- Offshore helicopter traffic numbers on the NCS peaked in 2014 and then dropped significantly in the years after. From 2017, traffic volume is slowly increasing again.

12.2 Main development features

- Diminishing petroleum resources and a strengthened focus on green energies make the future of the traditional petroleum industry uncertain. A downturn in the business may result in increased pressure on safety through downsizing and an overly strong focus on economy, both within the oil companies and the helicopter operators. Even though there is not a one-to-one relation between economics and the level of safety, the fear is that safety margins may erode over time due to decreased redundancy, loss of competence, longer maintenance intervals, etc.
- Along with the expected decline in petroleum production, offshore wind is growing in volume. This may give rise to new helicopter activity, but also introduce potential new threats to flight safety. In the longer term, the decommissioning of offshore installations may also become a driver for activity.
- The Turøy accident in 2016 created a new situation where a large part of the operating fleet (H225) was no longer available for passenger transport or SAR. The NCS today relies almost exclusively on the S-92A, which has a solid operational history, but the technology is ageing. Newer and smaller helicopter types seem to be slowly introduced, which will contribute to the robustness of the transport solution on the NCS.
- Increased petroleum activity in the Barents Sea is introducing new and potentially bigger challenges for offshore transport by helicopter due to long flying distances and a harsh environment.

12.3 Potential threats to helicopter safety

The most important potential threats to helicopter safety in the coming years are to a large extent the same as those identified in the HSS-3 (and HSS-3b) study:

- Lack of the possibility to maintain established Norwegian additional requirements for offshore flights, or that it will not be possible to introduce new requirements adapted to the conditions on the NCS.
- Exemption from offshore special requirements and deviation from recommended guidelines.
- Lack of competence and resources regarding offshore helicopters in the Civil Aviation Authority – Norway (CAA-N).
- An overly strong focus on economy by the different actors on the NCS.

12.4 Maintenance of helicopters

The study activity on maintenance of helicopters highlighted the following important focus areas:

- Facilitate and ensure a **just culture approach** rooted throughout the entire maintenance organization. Experiences from fixed-wing have shown that this can be challenging due to liberalization and increased market competition.
- The importance of **clear responsibility and reporting routines** within maintenance organizations and helicopter companies should not be underestimated. New ways of organizing, e.g. subcontracting and organizational fragmentation renders this particularly relevant.
- **Adequate access to resources**, operational as well as managerial, including technical expertise and competence. Changed (and increasingly tougher) competitive conditions and requirements for efficiency per se in the industry mean that local technical competence should not be underestimated. In this context, independent inspections are also relevant to discuss.
- **Tripartite cooperation** is an important contributor to safety through safeguarding dialogue and exchange of opinions, as well as facilitating trust among the various industry stakeholders.

12.5 Crew Resource Management

The study activity on Crew Resource Management (CRM) highlighted the following important focus areas:

- **Communicative practices:** Even more focus on how CRM through training of communicative practices facilitates the handling of complex situations, particularly where checklists/SOPs are inadequate.
- **Handling incapacitation:** Specific focus on developing CRM training methods and tools to further ensure that pilots develop strategies to recognize situations involving own as well as each other's varying degrees of incapacitation.
- **Train critical task trajectories:** Train explicitly on the task trajectory and coordination involved when executing critical flight tasks during time-critical events.
- **Sufficiency of current CRM regulations:** Assess whether the current CRM regulations are sufficient to meet the need for flexible and thorough CRM training, as well as the need to ensure baseline CRM skills and identification of standard best practices.

12.6 Comparing helicopter operations in the British and Norwegian sectors

The study activity comparing helicopter operations in the UK and NO sector highlighted the following:

- On a macroscopic level, four "cultural themes" have been identified as fundamentally different between the sectors: a) government involvement; b) market; c) legislation; d) "greening". These themes represent lasting structures that are difficult to change.
- The cultural themes set the basis for understanding specific differences between the two sectors. A range of such differences have been identified and discussed in the report.
- Some persistent hearsays and claims about differences in cockpit behavior have been scrutinized and found groundless. Pilots in both sectors today largely share the same experiences and attitudes.
- It is recommended to establish new meeting arenas for helicopter safety personnel in the NO and UK, with the purpose of information exchange, mutual understanding and relation building.
- The report presents a range of lower-level recommendations for improving safety in helicopter operations, mainly focused on the UK sector.

12.7 Recommended safety measures

The HSS-4 study confirms that many of the recommendations from HSS-3/3b are still relevant today. This shows that effort and focus over time is needed to be able to implement improvements.

Several of the recommendations in the HSS-4 study builds on important prerequisites about the continuation of the current regime and practice. For instance, it is presumed that implemented and planned measures from HSS-3/3b (and earlier) are not halted or reversed. Some of the HSS-3/3b recommendations have been implemented in the ON-066 guideline, but full implementation will need to take some time. As such, the most important **prerequisites** are identified to be:

a) Continue compliance with ON-066 as a recognized norm
b) Maintain exemptions from the EU standardized regulation, e.g. ensure requirement for Norwegian AOC with all its elements intact
c) Maintain existing competence on offshore operations within the air traffic service
d) Develop an infrastructure for air traffic service and emergency response in the Barents Sea
e) Revitalize The Committee for Helicopter Safety on the NCS to become more than a forum for information exchange

A total of 39 *suggested* safety measures are described in this report. The shorter list of 18 *recommended* safety measures below is based on a combination of a) potential risk reduction; b) relatively low cost; c) short implementation time; d) an identified need in the industry. The list is not in prioritised order.

T1: Update passenger transport helicopters to new models
T2: Upgrade the older SAR- and shuttle helicopters
T3: Ensure availability of information in the electronic flight bag (EFB)
T4: Ensure continuous and updated information en route
T7: Ensure the infrastructure of a navigation system redundant to GPS
T9: Ensure maintenance and modifications are performed under Norwegian regulatory oversight
T10: Improve availability of spare parts
T11: Standardise requirements for "independent inspection"
T13: Improved training for technical personnel
T15: Maintain the pilots' basic competence

T16: Adjust content of simulator training
T20: Introduce requirement for communication for pilots on helidecks
T22: Implement completely ON-066
T23: Align on turnaround time and penalties
T27: Strengthen the capacity and required competencies in the CAA-N
T33: Develop relevant indicators and analyses for offshore helicopter transport
T35: Improve reporting system for feedback from pilots to helideck/heliport
T39: Mapping of perceived risk

The recommended safety measures should be addressed in a structured way by the relevant stakeholders in the industry. The follow-up of measures should be documented and coordinated by e.g. the Committee for Helicopter Safety on the NCS. Each measure should have an assigned responsible for its implementation; this could be an organisation, a task group or an individual. It is particularly important that the measures are *completely* implemented before being "closed". This means that specific closing criteria must be defined for each measure.

12.8 Recommendations for continued work

The study has identified the following main areas for further work:

- The current practice of conducting regular safety studies of the helicopter activity on the NCS should be maintained. Such safety studies have proven to be effective means to establish a common understanding and cooperation on the implementation of safety measures.
- A review should be conducted of safety recommendations made in previous safety studies (HSS and UK), as well as accident investigation reports. The review should give the status of implementation, assessment of continued relevance, and investigation into the mechanisms that stops or slows down the implementation.
- Helicopter safety in the far north has not received much attention and should be studied especially. Increasing petroleum activities in the Barents Sea represents new challenges related to helicopter transport under other conditions than further south on the NCS.
- It should be examined to what extent recent accidents and incidents – especially the Turøy accident – affect the perception of risk in helicopter transport. The RNNP project features a simple indicator on perceived helicopter risk that is updated biennially, but this is not sufficient. HSS-3 discussed perceived risk in depth as per 2010 but having an updated picture of the situation today would be valuable.
- The possible consequences of subcontracting CAMO to a third party (outside the AOC) should be investigated in a separate study.

As part of the study, a memo has been produced (appendix E) suggesting a specification for a web solution for following up the status of safety measures. This solution will be for everybody but should be administered by the CAA-N or the Committee for Helicopter Safety on the NCS. In addition to tracking the measures, it will be possible to also include indicators and status for other safety work (cf. measure T33). The aggregated status of implementation may in itself also constitute an indicator.

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APPENDICES

A Resilience in practice

A.1 Background

The purpose of the study is to propose and implement a method that can be adopted by the industry to uncover sources of resilience in order to further support them and identify when they might be impacted by transformations of the system (e.g changes in processes, introduction of technology, new legislation).

The intended audience are safety managers or people responsible for analysis and improvement of helicopter operations, and other researcher of other transport domains as inspiration.

A.1.1 Resilience Engineering why and what

In complement to other safety approaches, for instance based on understanding risks and contributors to accidents, Resilience Engineering is concerned with uncovering what produces safety. More specifically, understanding the *resilience* of a system means identifying how actors of this system, at various levels, manage to adapt and maintain its performance (including its safety) in the face of varying and potentially surprising conditions experienced in daily operations or during exceptional circumstances. Identifying what creates or contributes to resilience allows organizations to further enhance the corresponding organizational conditions, technological support, behaviours and processes.

The context of the study, the Norwegian helicopter transportation industry, is that of a highly reliable industry (positive safety records in a regularly challenging environment). The assumption is therefore that there are aspects of the industry and processes in place that constitute sources of resilience. The investigation of resilience provides an additional perspective to understand safety and how it is produced. It aims to identify good practices and produce recommendations, as well as potential insights for parallel efforts (such as identifying topics of interest for the UK–NO comparison).

A.1.2 Objectives, scope and content of the study

This chapter describes a short investigation of resilience in helicopter operations in the Norwegian oil and gas industry. The findings are based essentially on the preparation for and the conduction of workshop with a group of participants representative of the actors of helicopter operations.

The study presented in this document had two main objectives:

1. Develop and test a simple resilience-oriented approach that can be used by organizations responsible for or involved in helicopter operations offshore.
2. Improve the understanding of resilient performance in helicopter operations in Norway and identify recommendations to contribute to safety improvements. Such recommendations would be based especially on the investigation of decision making and information sharing processes in operations, as well as on uncovering resilient practices and strategies.

To address both objectives, and in line with a perspective on resilience, the study's main focus was on everyday operations, including an exploration of how future changes in the sector might affect them. The study also aimed to include a variety of stakeholders participating in helicopters operations (transport organizations, oil companies, regulators, operators, managers).

The study was designed around two workshops, one essentially focused on operations, the other one taking a broader organizational view. These two perspectives were seen as complementary in order to identify and discuss in a larger sense the notion of resilience in helicopter operations in the Norwegian oil and gas industry. We were not able to organise the second workshop, to a large extent due to the COVID-19 situation and associated travel restrictions, which hindered our capacity to conduct a meaningful event. This report is therefore limited to the results and insights from the first event (including of the preparatory activities). We nonetheless offer some directions for additional work based on the planning that had occurred for a second event.

A.1.3 List of terms

An explanation of terms used in this chapter is found below.

Table A.1: List of terms.

Term	Explanation
Adaptive capacity	The ability or potential to adjust activities, resources, tactics, and strategies in the face of different kinds of events, variations, demands, and uncertainty to regulate processes relative to targets and constraints. This is an extension of an old definition for skill and expertise — the ability to adapt behaviour in changing circumstances to pursue goals. (Woods and Hollnagel, 2006; Weick and Sutcliffe, 2001)
Complex Adaptive Systems	In the resilience literature, work systems are characterized as complex adaptive systems. In this context, they are socio-technical systems (see definition below) composed of many interrelated technical and human components capable of some form of adjustment or adaptation in order to accomplish tasks in a variety of conditions.
Emergence	How a system's properties and behaviour arise from the relationships and interactions across parts, and not from the individual parts in isolation or properties of components.
Functional resonance	The variability of individual functions may combine in an unexpected way. This is the result of functional couplings in the system. Any part of the system variability can be a "signal" and the "noise" is determined by the variability of the functions in the system. Thus, the variability of a number of functions may resonate, i.e. reinforce each other and thereby cause the variability of one function to exceed normal limits.
Instantiation	In the FRAM modelling this term is used to describe a set of couplings among functions for specific time intervals (Herrera et al., 2010)
Intractable	A system which cannot be described in every detail and where the functioning and therefore is not completely understood. Intractable systems are only partly predictable.
Model	It is a representation of something else, of phenomenon or event such an accident or of a system such as an organization (Reason et al., 2006). • Retrospective model is the basis for explaining or understanding something • Prospective model is the basis for predicting something, including measurements of present states as an indicator of possible future states.
Performance variability	It relates to the ways in which individual and collective performances are adjusted to match current demands and resources, in order to ensure that things go right.

Term	Explanation
Resilience	The operational definition applied in the study is "*the intrinsic ability of a system to adjust its functioning prior to, during, or following changes, so that it can sustain required operations under both expected and unexpected conditions*" (adapted from Hollnagel)
Resilience Engineering	The scientific discipline that focuses on developing the principles and practices that are necessary to enable systems/organization to function in a resilient manner (Hollnagel, 2014)
Resonance	It is proposed as a principle that explains how disproportionate large consequences can arise from seemingly small variations in performance and conditions.
Safety	*"Aviation safety is a dynamic concept, since new safety hazards and risks are continuously emerging and need to be mitigated. Safety systems to date have focused largely on individual safety performance and local control, with minimal regard for the wider context of the total aviation system. This has led to growing recognition of the complexity of the aviation system and the different organizations that all play a part in aviation safety. There are numerous examples of accidents and incidents showing that the interfaces between organizations have contributed to negative outcomes. Safety risk management is a key component of safety management, and includes hazard identification, safety risk assessment and safety risk mitigation."* (ICAO, SMM 4th Edition available also as ebook 2018[10])
Safety-I	The condition where the number of adverse outcomes (accidents/ incidents/near misses) is as low as possible. Safety-I is achieved by preventing that things do not go wrong or minimising consequences (Hollnagel, 2014)
Safety-II	The condition where the number of successful outcomes (when nothing goes wrong) is as high as possible. Safety-II is achieved by trying to make sure that things go right (Hollnagel, 2014)
Safety Management System	A Safety Management System (SMS) is a systematic approach to manage safety, including the necessary organizational structures, accountabilities, policies and procedures (ICAO). ICAO through various Annexes to the Chicago Convention has incorporated requirements for service providers in various domains of aviation to have an SMS.
Socio-technical system	The term refers to a technical system where people who operate and maintain the system to a great extent influence the effectiveness of the system. The efficiency of the technology is therefore largely dependent on the people who operate and maintain it, and there is a complex interaction between people and technology (HSE, 2002).

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[10] https://www.icao.int/safety/safetymanagement/pages/guidancematerial.aspx

A.2 Resilience Engineering methods

A variety of methods have been proposed over the years in the field of Resilience Engineering. Among the basic principles are:

- Recognizing the difference between how operations are defined (e.g in procedures) vs. how they are conducted in real conditions.
- Understanding the work by elicitating knowledge from experts representing different perspectives: different actors of the system, different levels of management.

Methods of resilience engineering might involve a detailed investigation of work conditions and operations based on extensive data collection (documents, interviews, simulations, observations, etc.) and analyses. In the work described in this document, the ambition is

A.2.1 Functional Resonance Analysis Method

The starting point for a description and analysis of an operational scenario is the Functional Resonance Analysis Method (For a more comprehensive description of the method theory and its application, see Hollnagel, 2012, 2018[11]). FRAM is based on four basic principles: 1) the equivalence of successes and failures; 2) approximate adjustments; 3) emergent outcomes and 4) functional resonance (i.e. the potential effects of the propagation of variability across a system).

The purpose within HSS-4 case is to understand actual performance when nothing goes wrong. According to this method, the description and analysis takes place via the following steps:

Step 1. Identification and description of important system functions and characterise each function using six aspects. Together these functions represent the FRAM model

Step 2. Characterisation of variability of the functions in the FRAM model in one or more instantiations of the model.

Step 3. Determine the possibility of functional resonance based on dependencies or couplings among functions (potential and actual)

Step 4. Develop recommendations on how to monitor and manage the variability,Proposition of indicators to monitor performance variability.

A.2.2 Resilience Management Guidelines

Resilience Management Guidelines were developed by European project DARWIN, led by SINTEF, between 2015 and 2018 (DARWIN, 2018). The main purpose of these guidelines is to support critical infrastructure organizations to understand and enhance their resilience in the face of adverse events and potential crises. The guidelines were developed based on an extensive review of the literature. To ensure their operational relevance and applicability, the development of the guidelines involved operational partners and collaborators, especially from two initial sectors, air traffic management and healthcare.

The guidelines propose interventions around 13 topics belonging to 6 higher-level themes. The topics, addressed through Capability Cards, capture information structured in different sections to provide background, context and background to the interventions. The document ends with a comprehensive list of

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[11] http://functionalresonance.com/onewebmedia/Manual%20ds%201.docx.pdf

resilience-related terms used throughout the guidelines. The themes and topics of the guideline is presented in Table A.2.

Table A.2: DARWIN Resilience Management Guidelines (DRMG) themes and topics.

DRMG Themes	DRMG Topics
1. Supporting coordination and synchronisation of distributed operations*	• Promoting common ground for cross-organizational collaboration in crisis management* • Establishing networks for promoting inter-organizational collaboration in the management of crises* • Sharing information about roles and responsibilities among organizations involved in the management of the crisis*
2. Managing adaptive capacity*	• Enhancing the capacity to adapt to both expected and unexpected events* • Establishing conditions for adapting plans and procedures during crises and other events that challenge normal plans and procedures* • Managing available resources effectively to handle changing demands*
3. Assessing resilience**	• Assessing community resilience to understand and develop its capacity to manage crises • Identifying sources of resilience: learning from what goes well** • Noticing Brittleness**
4. Developing and revising procedures and checklists*	• Systematic management of policies involving policy-makers and operational personnel for dealing with emergencies and disruptions
5. Involving the public in Resilience Management	• Communication strategies for interacting with the public • Increasing the public's involvement in resilience management
6. Managing system failures*	• Supporting development and maintenance of alternative working methods*

** used in study; * relevant in helicopter operations' resilience

In the context of this study, the theme that provided the main inspiration is "Assessing resilience", indicated with a double star. While one of the corresponding topics is focused on community resilience and is less relevant in the context of helicopter operations, the two other Concept Cards propose interventions and guiding questions that were used during the study. In particular, the card "Identifying sources of resilience" describes a workshop-based method that was developed in a previous project in the context of the air traffic management sector (but is not specific to this sector). This method follows the same approach as described here, based on investigating first the sources of variability in operations, then how people in various roles share information and make decision (potentially supported by technology) in order to effectively adapt to this variability.

Other relevant themes for helicopter operations are indicated with a single star. The guidelines for facilitators provide guiding questions used to support the groups' discussions. These questions are in a large part inspired by the "triggering questions" proposed in Concept Cards of the first three themes of the DRMG.

The DARWIN Resilience Management Guidelines are available publicly and can be downloaded from the project's website[12].

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[12] https://h2020darwin.eu/wp-content/uploads/2018/08/DRMG_Book.pdf

A.3 Study design

The study is based on the conduction of two complementary workshops about resilience in the Norwegian helicopter transportation industry, with the participation of stakeholders relevant for each event.

The first workshop (Workshop 1) focuses on the short timeframe, i.e. on sources of resilience at play during operations. Workshop 1 is interested in the role of the various actors and organizations involved. It aims to build on similar studies in HSS-3, updating and complementing the results of this previous study (see Herrera *et al.*, 2010). In particular, a functional model of flight operations developed during HSS-3 using the FRAM methodology (Hollnagel, 2012) served as a basis in the current study.

The second workshop focuses on the longer timeframe, i.e. on longer change processes organizations in the industry are involved in.

The general approach to investigating the resilience of helicopter operations relies on some basic principles:

- The investigation should not focus only on unusual events and conditions, but rather aim at understanding everyday work performance. Unusual situations can be interesting to stress particular challenges.
- The main objective is to understand the variability a system of interest is confronted with on a regular basis, or sometimes in unusual ways, and how actors at various levels manage to adjust their operations to prevent unwanted events to occur or to recover from them.
- Considering the larger helicopter transportation system

Prior to the conduction of the workshops, knowledge-building activities aimed to create a basis for the study and help facilitators conduct the discussions. These activities included: a review of past documents such as previous HSS reports; a brief review of literature on resilience-related methodologies; interviews with stakeholders (planned or opportunistic). Those different activities helped updating knowledge about helicopter operations and define the methodological approach to collect data during the workshop (e.g functional modelling based on FRAM, using of triggering questions from the DRMG).

A.4 Conduction of the first workshop (October 2019, Sola)

A.4.1 Focus and structure

The workshop conducted is a one-day event, which central sessions are group discussions facilitated by researchers and followed by round-table discussions to share findings across groups. Rather than covering a full flight, the decision was made to focus on one of the most sensitive phases, i.e. landing on a helideck. However, to understand the various dimensions of the landing phase, especially when related to information sharing and decision-making, it is necessary to investigate: (1) how this phase is planned, (2) what factors are taken into consideration during the planning, and (3) how the plan is potentially updated as the aircraft approaches the platform.

Prior to the workshop, other choices were made to focus the event and facilitate discussions:

- Use of a simple case in order to make discussions more concrete
- Split the participants in two groups, “Preparation” and “Landing”, with a respective focus on planning and execution of landing.
- Use of the FRAM model built during HSS-3 in order to investigate particular aspects of these two phases and update the model.

Figure A.1 shows the different phases of helicopter operations and highlights what the two groups were asked to focus on. Note that the boundaries between phases do not aim to be strict boundaries, it is sometimes useful or necessary to refer to later or earlier phases in order to better explain an issue related to a particular phase of interest.

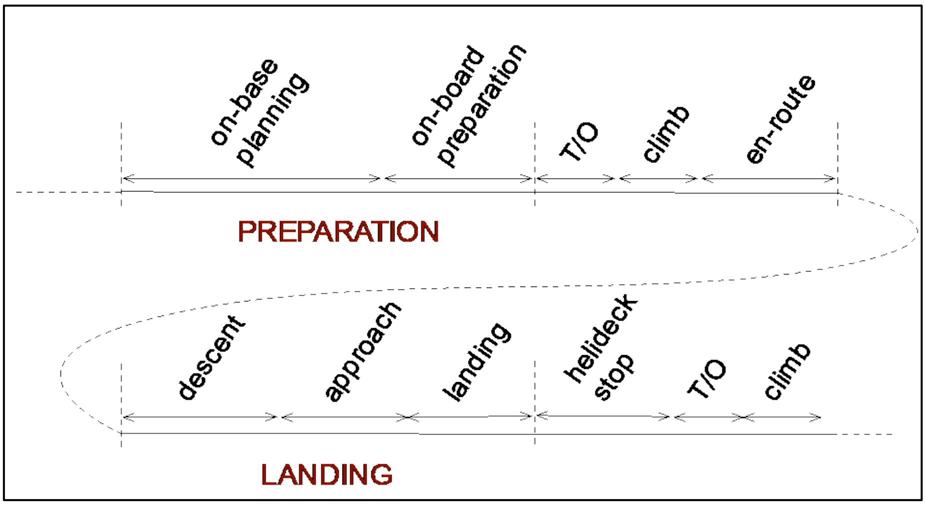

Figure A.1: Phases of helicopter operations to focus group discussions.

A.4.2 Preparatory activities

To help structure and make the scope of the workshop manageable, the study team developed a simple but representative fictional case about helicopter operations. A draft case was first developed based on the team's prior knowledge, informed by HSS-3 as well as by review of publicly available resources of helicopter operations (e.g companies' websites, press articles). A semi-structured interview with a highly experienced pilot was conducted with two main objectives: (1) updating the team's knowledge of operations, including in light of potential changes in the sector; (2) sharing and revising the draft cases based on expert feedback.

Based on this preliminary work, the workshop agenda was built. Participants were identified in collaboration with various organizations, and an invitation package was sent.

Finally, shortly before the workshop was held, the opportunity was seized to organise a short site visit in one of the transportation companies. Although they did not serve to modify the case, insights from informal discussions with a few managers helped identifying discussion points to focus on during the workshop.

A.4.3 Case: landing a helicopter

The following case was used during the workshop. It does not represent major or unusual challenges, but a rather normal situation with typical information exchanges, decision points and challenges (e.g presence of cranes on the helideck). The point of the case is to propose talking points to be discussed in detail and potentially challenged during the groups' exchanges from the different expert perspectives (e.g helicopter vs. helideck).

On Monday 16 September, a Sikorsky S-92 from CHC Heli is scheduled to transport 15 passengers around mid-day to Sleipner Alpha, a fixed platform about an hour away from Stavanger/Sola.

PREPARATION
11:00 – The pilots initiate the flight planning. They receive information from the helideck, weather is expected to be good. They also receive information about availability of fuel and navigation systems on Sleipner. Based on this information, they decide CP will be the pilot flying (PF) and PI the pilot monitoring (PM), and plan for an instrument approach. PI and CP have significant experience flying together, flight planning is effective.
12:00 – After passengers board, the helicopter takes off on time. The first part of the flight is uneventful.
…
LANDING
12:50 – At approach fixed point, pilot initiates the landing approach, descending to 1000ft and conducting pre-landing preparation…. In preparation for landing, the Helideck crew checks the deck for loose objects.
12:55 – PM establishes visual contact with the rig "visual look ahead", PF confirms. PF decides …landing angle based on low wind conditions and presence of cranes on the helideck. In the meantime, PM reads instruments and monitors potential alarms (caution lights). …
12:58 – PF performs landing. PM monitors visually, calls "over the deck" and "over the circle"
13:00 – Helicopter is landed.

A.4.4 Participants

Table A.3 lists the profiles of people who participated in Workshop 1, as well as which group ("Preparation" or "Landing") they were assigned to. The main take-away from this table is that participants were invited, then assigned to groups in order to ensure a variety of perspectives about helicopter operations. Such variety includes different organizations with different responsibilities in operations and different roles within these companies (operational and managerial perspectives). Although the purpose is not to be exhaustive, it is key to gather a systemic view of operations in order to investigate resilience.

Table A.3: Participants to Workshop 1: profiles and group assignment.

Company	Role in helicopter transportation	Assigned group
CHC	Pilot	Preparation
CHC	Safety	Landing
CHC	Technical	Preparation
Industri Energi	Passengers	Preparation
NSIA	Pilot	Landing
NSIA	Analysis	Preparation
Bristow	Pilot	Landing
Bristow	Technical	Preparation
CAA-N	Regulator	Landing
Equinor	HLO	Preparation

Aker BP	HLO	Landing
JRCC	SAR	Landing

A.4.5 Workshop format

After some initial introductions about the study and resilience concepts, the heart of the workshop consists of group discussions around the proposed case and facilitated by the investigators. These discussions are organised in two phases:

1. In the first phase, the main objective, starting from the "normal conditions" described in the case, is to identify potential sources of variability in operations. Variability can occur based on external factors (e.g weather conditions), but also in the operations themselves (e.g a piece of information used for flight planning is available later than usual).
2. In the second phase, the main objective is to review these sources of variability and identify how the system, i.e. the different actors from the different organizations, adapts to them.

In each phase, each group ("Preparation" or "Landing") discussed separately first before all participants reconvened for a common session to share the main insights from the parallel sessions. As mentioned before, the landing phase itself cannot be completely disconnected from its planning; the common sessions therefore created opportunities to highlight these links.

The discussions were supported by the elements of the case (e.g sequence of actions described, expected exchanges of information) and by a base functional model of helicopter operations (developed in HSS-3 and slightly revised for the purposes of the workshop). Prints of this model were shared with participants, and large prints were displayed on tables to take notes directly on the graphs (appendix x shows the graph for the "Preparation" phase, annotated during the workshop).

In addition to the annotations on the graphs, hand notes were taken by the facilitators throughout the workshop.

A.5 Results from Workshop 1

A.5.1 Expectations

Table A.4 presents the participants' and facilitators expectations that were captured at the beginning of the workshop.

Table A.4: Workshop expectations.

Participants	- Learn and contribute to move the industry forward - Wish to be better together - Learn and contribute to a good HSS-4 - Learn more about aviation safety and contribute to enhanced helicopter safety and operations - Contribute from Authority perspective - Learn something about resilience perspective on helicopter operations - Curious on how to analyse from the perspective of resilience

Facilitators	- Learn and contribute to improve safety - Learn a lot about helicopter operations and the various roles and organizations involved

As can be seen from this table, expectations were quite ambitious in the face of the workshop's compact format and limited scope. Interestingly, participants' expectations denote both a pragmatic desire to support safety in the industry and an intellectual interest about the concept of resilience and how it can be used to further support safety. The extent to which these expectations were met will be discussed in the next section.

A.5.2 Insights about resilience in helicopter operations

The focus groups' discussions highlighted a number of aspects and practices that contribute to operations' safety and resilience. The insights presented below relate to how information is exchanged, what critical decisions are made, and how both these aspects are influenced by organizational elements. A lot of aspects described below relate to the preparation or planning of flights and other similar processes outside of flight itself, which create the conditions for safe operations – resilience is seen in our study as a capacity of the system under investigation, not an outcome.

Information exchanges

Effective exchanges of and access to information across the system involved in helicopter operations are key elements supporting planning and flight decisions. The critical point we would like to emphasise here is that exchanges of information involve all actors, requiring a wholistic view of operations. Here are a few examples:

- Minimum Equipment Lists describing the functionality of aircraft equipment are provided by maintenance technicians and are a key piece of information in flight planning (or the decision to fly in the first place, based on an assessment of aircraft airworthiness). These roles were not captured in the previous model of operations (from HSS-3) and their participation in providing information such as MELs needs to be better investigated.
- The Electronic Flight Bag and associated tools represent a successful introduction of technology in operations. It provides new opportunities prior and during flight to access information and support planning and in-flight decisions.
- Helideck personnel represent a key resource of information for the aircraft crew. Their familiarity with helicopter operations makes them more able to identify and share the information that matters to the crew.

Decisions

Among the many decisions that occur during preparation and flight, specific topics were discussed in greater detail. Two are presented below:

- The assessment of aircraft airworthiness is a key aspect of planning. Interestingly, this notion is in part dependent on the conditions. For instance, radar is critical is low visibility conditions, but does not affect airworthiness if there is good visibility. Regulations (e.g from the FAA) are clear regarding the fact that the responsibility of declaring an aircraft airworthy lies with the pilot in command. This assessment is nonetheless done collaboratively, as the MEL produced by maintenance technician is a central support for decision.
- Fuelling decisions also vary across situations, because they depend on many factors such as the length of flight, number of legs in the rotation, expected weather conditions and opportunities to refuel along the route (e.g on some platforms). The choice of a quantity of fuel represents a trade-off between different safety and production goals, embarking more fuel allowing for longer flights, more capacity

to find alternatives in case of unexcepted constraints, but also higher weight and fuel consumption. While economic views focus on optimization around fuelling decisions, resilience concerns promote the use of margins.

Organizational practices and culture
Once basic elements of information exchange and decision making are highlighted, we can look at how organizational practices across the system affect these processes. Insights below are based on the group discussions, therefore reflect our understanding of the Norwegian context.

Among practices that seem to support resilience, we can distinguish formal and informal practices, depending. Formal practices include the collocation of technicians and pilot in transport companies. Such organization greatly facilitates exchanges of information: each role has a better understanding of the other role’s information needs. As a result, key decisions such as related to aircraft airworthiness are more efficient and assessments more accurate.

Participants provided various examples of informal practices, practices they have heard about or experienced directly but do not exist everywhere (i.e. implemented locally) or are not captured in procedures. In one company, pilots seized opportunities provided by the Electronic Flight Bag to start preparing for flights the day before. Such practice was described as allowing them on the day of the flight to have more time margins for preparation and move faster and easier to the identification of alternative plans when needed, thereby supporting resilience of operations. In another example, a transportation company was confronted with personnel with lower experience on a helideck not operated by a Norwegian company. The helicopter company organised training of this personnel, helping them to build higher familiarity with helicopter operations. Knowledge acquired could then be useful in subsequent operations, including conducted by other helicopter companies. Finally, pilots discussed how procedures were improved in the company: experimentations with practice are implemented locally before being turned into a procedure, i.e. a formal updating of rules. Such practice, in line with DRMG theme 4 in Table A.2, is seen as a healthy practice to regularly question and potentially improve ways of operating.

Overall, the helicopter operation in the Norwegian oil and gas industry have a very positive safety record. There are therefore elements in which other industries can find inspiration. A couple elements of the organizational culture in the Norwegian sector are noteworthy. As highlighted in the example of informal practice, there appears to be a highly collaborative culture among the industry, including between competitors. Such situation supports exchanges of information and problem solving. Moreover, it appeared from the discussion that clear emphasis was regularly given to safety (in spite of economic pressures). This culture was reflected in discussions around decisions involving trade-offs, such as related to aircraft worthiness, fueling or fitness for flight, in which a conservative approach (e.g margins, sacrifice flight in case of doubt) in promoted by organizations.

A.6 Discussion

A.6.1 Effectiveness of the approach proposed

Feedback collected from the workshop participants indicated an overall satisfaction and interest in the resilience approach. Organisers felt it participated to improving their knowledge of helicopter operations and provided insights for future events. When compared to the stated workshop expectations (see Table A.4), we can see the following outcomes.

Participants: learning about resilience concepts and methods

The workshop was an opportunity to discuss operations across organizations and roles, in a wholistic manner – such opportunity is not so frequent. Discussions highlighted for all participants the tight relationships between actors in providing safety and resilience. We argue that such events promote, at a relatively low cost, the adoption of a systemic perspective on operations, rather than a siloed view split between areas of responsibility. The conversation about resilience familiarized participants with typical notions around the concept of resilience, such as variability, adaptation, trade-offs, interdependencies, thereby promoting a view of safety grounded in real, sometimes surprising, conditions of operations (as opposed to conditions as expected).

Relative to methods, the FRAM model was useful to provide a basis from which to build in the workshop and participants developed some familiarity with this functional modelling format. However, it cannot be considered a training and participants would not be expected to be able to implement FRAM on their own after the workshop. Moreover, the development of a model with FRAM can be a challenging and resource-intensive process (see for instance Patriarca and Bergström, 2017). As a result, this method is not suitable to a single and relatively short workshop. Rather, such functional model should be considered a work in progress and a guide for investigation, capturing what is known at a given time and updating (revising, complementing) iteratively. The DARWIN Resilience Management Guidelines appeared a useful source of inspiration for the structuring and conduction of such event, through a set of directly relevant Concept Cards and guiding questions. They aim to be self-sufficient, i.e. not to require the intervention of an outside expert, but this was not confirmed by the HSS-4 workshop.

Organisers: learning about helicopter operations

The workshop (preparatory activities and group discussions) was an opportunity to update the previously developed functional model of helicopter operations. It led in particular to a more complete capture of information sources and exchanges. The discussions also highlighted that the maintenance technicians' participation in preparation and flight also needed to be better captured, i.e. corresponded to a significant gap in the model.

For the purposes of this study, the organization of the workshop in two phases (focused on variability, then adaptation) was a simplified version of the method proposed in the DARWIN Resilience Management Guidelines for understanding sources of resilience. The format was simplified in particular due to time constraints but should ideally be followed up by a third phase investigating what supports or hinders adaptation. While elements were captured in the discussions and reported here, this latter phase is important to investigate more systematically what enables resilience in organizations, from technological support to organizational practices.

All: participating in improving safety and resilience of operations

The results represent insights about what supports resilience in helicopter operations. Based on such short group discussions, the validity of these insights and their implications for organizations should be investigated further. As an example, it was identified that pilots enjoy, through the electronic bag, receiving information the day before the flight. This allows them to start preparing in the evening and be more effective in the preparation phase the day of the flight (this preparation becoming an update of the plan to account for new information). Such organization was seen as participating in flight safety / resilience, by allowing the preparation on the day of flights to focus on what matters the most that day. While this practice was, at the moment of the workshop, an informal practice, organizations might benefit from implementing it in a more systematic way. Such implementation has consequences at the organizational level: it supposes the capacity for all pilots to access electronic resources and, in order to be implemented, it might require that organizations validate the use of resources to support preparation the day before the flight (the evening preparation becomes part of the normal working day).

A.7 Recommendations

A.7.1 Potential directions for enhancing helicopter operations' resilience

The following questions emerged for the workshop results. They can be investigated within the Norwegian industry itself, or might represent topics interesting to investigate further to compare helicopter safety in Norway to practices in other countries or industries:

- **Clarity of procedures** (esp. maintenance procedures): How prescriptive are they? Are they actually clearer and simpler in Norway than elsewhere? What is the impact on job performance (e.g quality of maintenance)?
- **Helideck lighting**: pilots in Norway seem to appreciate the circled H lighting implemented in UK regulations. Is that affecting landing performance and safety? Why is it not implemented in Norway?
- **Cooperation across industry**: Norwegian organizations emphasize the cooperative climate across the industry, including between competitors and between operators (e.g transportation companies) and authorities (e.g CAA). Is it the same elsewhere? If not, what are the barriers? What are the conditions that make it possible in Norway?
- **Organizational culture**: Transport organizations in Norway seem to prioritise safety in cases such as pilot feeling unfit for flying and potential delays or cancellations generated (management supports pilots in staying home if they have a doubt). How are situations managed in collaboration with the customers in such events? What is the impact of potential penalties on safety-related decisions? Are there differences between Norway and other countries?

A.7.2 Proposition for further work: Second workshop

As part of a full approach to the investigation of the resilience of helicopter operations, a second workshop complementary to Workshop 1 was initially planned in 2020. Unfortunately, its organization was hindered by the traveling and meeting restrictions during the COVID-19 pandemics.

Workshop 2 aimed to cover longer term issues and focus on the organizational management of change. In particular, topics identified and shared already with Workshop 1 participants (see invitation package) were:

- Organizational responses to significant events and weak signals, i.e. how the industry has reacted in the light of events, technological, economical or organizational changes
- Organizational expectations on changes (e.g. new technologies and legacy systems), especially how the industry is anticipating how such changes might transform operations

Table A.5: Overview of proposition for Workshop 2.

Topic / focus	How organizations in the helicopter transportation respond to changes. Three types of change are considered: (1) safety events (accidents, incidents, weak signals); (2) technological changes; (3) changes in the commercial framework. Organizational aspects include good practices, strategies and recommendations.
Industry participants	• Starting point is the list from Workshop 1 • In addition, ensure the participation of the following perspectives: Safety manager, Technical manager, Regulator, Heli 1 (maintenance) - union representative, Avinor ANS

Methods	RAG, DARWIN guidelines, 16.06.01 resilience assessment method The methods present a lot of overlap. They provide a set of questions that support a discussion on resilience-related topics, potentially organised around the resilient capabilities/potentials of anticipation, monitoring, response and learning.
Format	• full day (09:00 – 15:00) • morning: Intro / Objectives; Group 1: safety event 1 (accident, incident, weak signal); Group 2: safety event 2 (natural / weather event); Synthesis across groups • afternoon: Group 1: technological change; Group 2: business change; Synthesis across groups; Closure / thoughts
Sources of inspiration, real world events	• Safety events o 2016 Turøy accident1 -> grounding of H225 Super Puma o 2019 Canadian incident2 -> involved S92, what would happen if grounding of this aircraft? Dependence on a single type of aircraft o Inland helicopter transportation: 2019 Alta accident3 -> how does offshore transportation look at these events? o Other aviation: Boeing Max • Weather events: o Icelandic volcano eruption, o climate change / changes in weather patterns. • Technological change o Introduction of Electronic Flight Bag – how was it introduced (who pushed for it)? How is it integrated in operations (all stakeholders)? o Trends, envisioned higher automation • Business change o Economic crunches o Fluctuation in contracts o Impact on Norwegian branch of larger company / group

A.8 References

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B Development and quantification of the HSS model

The HSS model developed in the HSS-4 study is a further development of HSS-3 model. This appendix describes the development and quantification of the HSS-4 mode. The quantification is performed based on experienced accidents and events, and in combination with expert judgements.

The accident categories are updated compared to HSS-3 to comply with ICAO's categories, to simplify the risk estimation, to align with classification of reported accidents and events, and to restrict to accidents (rather than event descriptions or in some cases, RIF contributions). Some of the RIFs in the model have been restructured in the influence diagrams compared to HSS-3. Otherwise, there are limited updates of the RIFs.

B.1 Accident categories

The HSS-4 model has adopted the ICAO categories (ICAO, 2011) that is common for accident and event reporting both national and international. Some of the ICAO categories are adopted (either directly or extended) as separate accident categories in HSS-4, while others instead are considered as RIFs, and some only are considered as events (not accidents). Also note that several ICAO categories are not relevant for offshore personnel transport on the Norwegian Continental Shelf. Table B.1 includes the ICAO categories and how they are interpreted in the HSS-4 model with respect to accidents and RIFs.

The accident categories can also be split into sub-categories depending on where or in what phase of the flight the accident appears, which will influence the consequence and the emergency preparedness. Accident categories and sub-categories together with their corresponding ICAO categories are listed in the table.

Table B.1: Accident categories with sub-categories and corresponding ICAO categories.

		Sub-category	**ICAO category** (cf. Table B.2)
A1	**Accident during take-off or landing at helideck/heliport**	a) Helideck b) Heliport	ARC CTOL
A2	**Controlled emergency landing / Landing on uncleared helideck** due to e.g. technical failure in helicopter or deviation from flight plan	a) Sea b) Terrain c) (Non-cleared) landing site	LOC-I*
A3	**Uncontrolled landing or collision with terrain or sea due to loss of control** due to e.g. technical failure in helicopter or pilot error	a) Sea b) Terrain	
A4	**Mid-air collision with another aircraft**	a) Manned aircraft b) Unmanned aircraft	(MAC)**
A5	**Controlled flight into terrain, sea or building** without any technical failure occurring	a) Sea b) Terrain c) Building, etc.	CFIT
A6	**Fire, smoke, explosion or toxic gas** caused by e.g. lightning strike, dangerous goods, or technical malfunction	a) Cruise b) Helideck c) Heliport	F-NI

A7	**Accident involving danger to persons located outside the helicopter**	a) Helideck b) Heliport c) Cruise	(RAMP)*** (LOC-G)
A8	**Ground collision** with aircraft, vehicle, or other at aerodrome	a) Heliport b) Helideck	GCOL (LOC-G)

* "LOC-I is an extreme manifestation of a deviation from intended flightpath. Loss of control may cover only some of the cases which an unintended deviation occurred. It is therefore suggested to change the category to deviation from intended flightpath (DEV). A further division of the category into controlled landing and uncontrolled landing is here suggested." (SKYbrary, 2019)

** The categories MAC and RAMP are used widely to report *events* and not only accidents. MAC reported events include near-collisions, ACAS alarms as well as loss of separation. Such events are also categorised as ATM or NAV.

*** RAMP includes ground handling events. Besides LOC-G there are no ICAO category representing accident category 7 above.

Table B.2: HSS-4-adaption of the ICAO categories (ICAO, 2011).

ICAO description		**Detailed description (ICAO)**	**HSS-4 approach**
Airborne			
AMAN	Abrupt manoeuvre	The intentional abrupt manoeuvring of the aircraft by the flight crew.	Considered as RIF contribution.
MAC	Airprox/ACAS alert/Loss of separation/Near mid-air collisions/**mid-air collisions**	Airprox, ACAS alerts, loss of separation as well as near collisions or collisions between aircraft in flight.	Mid-air collision adapted as separate accident category. The others as incidents or occurrences.
CFIT	**Controlled flight into/toward terrain**	Inflight collision or near collision with terrain, water, or obstacle without indication of loss of control.	Adapted as separate accident category.
FUEL	Fuel related	One or more powerplants experienced reduced or no power output due to fuel exhaustion, fuel starvation/mismanagement, fuel contamination/wrong fuel, or carburetor and/or induction icing.	Considered as RIF contribution.
GTOW	Glider towing related events	Premature release, inadvertent release or non-release during towing, entangling with towing, cable, loss of control, or impact into towing aircraft / winch.	NA for offshore pax transport.
LOC-I	**Loss of control – Inflight**	Loss of aircraft control while inflight or deviation from intended flightpath inflight.	Adapted as separate accident categories. Divided into an uncontrolled landing (crash) and a controlled landing situation (emergency landing).
LOLI	Loss of lifting conditions en route	Landing en-route due to loss of lifting conditions.	NA for offshore pax transport.
LALT	Low altitude operations	Collision or near collision with obstacles/objects/terrain while	NA for offshore pax transport.

ICAO description		Detailed description (ICAO)	HSS-4 approach
		intentionally operating near the surface (excludes take-off or landing phases).	
UIMC	Unintended flight in IMC	Unintended flight in Instrument Meteorological Conditions (IMC).	NA for offshore pax transport.
Aircraft			
F-NI	**Fire/smoke (non-impact)**	Fire or smoke in or on the aircraft, in flight or on the ground, which is not the result of impact.	Adapted as separate accident category.
SCF-NP	System/component failure or malfunction (non-powerplants)	Failure or malfunction of an aircraft system or component - other than the powerplant.	Considered as RIF contributions.
SCF-PP	System/component failure or malfunction (powerplants)	Failure or malfunction of an aircraft system or component - related to the powerplant.	Considered as RIF contributions.
Ground operations			
EVAC	Evacuation	Occurrence where either; (a) person(s) are injured during an evacuation; (b) an unnecessary evacuation was performed; (c) evacuation equipment failed to perform as required; or (d) the evacuation contributed to the severity of the occurrence.	NA with respect to accident frequency.
F-POST	Fire/smoke (post-impact)	Fire/smoke resulting from impact.	NA with respect to accident frequency.
GCOL	**Ground collision**	Collision while taxiing to or from a runway in use.	Adapted *together with CTOL* as a separate accident category. Collision is then extended to TDP, and not only ground.
RAMP	**Ground handling**	Occurrences during (or as a result of) ground handling operations.	Adapted as separate accident category for occurrences *during* ground handling. Considered as RIF contribution for occurrences *as a result of* ground handling.
LOC-G	Loss of control – Ground	Loss of aircraft control while the aircraft is on the ground.	Considered as RIF contributions.
RE	Runway excursion	A veer off or overrun off the runway surface.	NA with respect to helicopter.
RI	Runway incursion – Vehicle, aircraft or person	Any occurrence at an aerodrome involving the incorrect presence of an aircraft, vehicle or person on the protected area of a surface designated for the landing and take-off of aircraft.	Considered as an occurrence, and not an accident. The consequence of the occurrence may lead to other categories of accidents (e.g. GCOL).

ICAO description		**Detailed description (ICAO)**	**HSS-4 approach**
Miscellaneous			
NAV	Navigation error	Occurrences involving the incorrect navigation of aircraft on the ground or in the air.	Considered as RIF contributions. The consequence of the occurrence may lead to other categories of accidents (e.g. MAC or LOC).
BIRD	Bird	Occurrences involving collisions / near collisions with birds.	Considered as an occurrence with limited accident potential (ref. RNNP[13]). In case of accident possibility, relevant RIF contribution is RIF F1.11.
WILD	Collision wildlife	Collision with, risk of collision, or evasive action taken by an aircraft to avoid wildlife on a runway or on a helipad/helideck in use.	Considered as RIF contributions. The consequence of the occurrence may lead to other categories of accidents (e.g. GCOL).
CABIN	Cabin safety events	Miscellaneous occurrences in the passenger cabin of transport category aircraft.	Considered as RIF contribution with respect to emergency equipment. Otherwise covered by F-NI.
EXTL	External load related occurrences	Occurrences during or as a result of external load or external cargo operations.	NA with respect to pax transport.
MED	Medical	Medical – occurrences involving illness of persons on board the aircraft.	Not considered as an accident (neither as a RIF).
OTHR	Other	Any occurrence not covered under another category.	Not included as a separate accident category as it is assumed that all accidents can be classified into one of the defined accident categories. Considered as RIFs (all RIFs may be relevant).
SEC	Security related	Criminal/security acts which result in accidents or incidents.	Considered as RIF contributions (either RIF F1.12 or as weaknesses or barriers against threats within other RIFs.)
UNK	Unknown or undetermined	Insufficient information exists to categorize the occurrence.	Not included as it is assumed that all accidents can be classified into one of the defined accident categories.

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[13] Birdstrike is no longer considered as critical, as the helicopters in operation today are robust to withstand a birdstrike – even during high speeds (Petroleumstilsynet, 2019)

Non-aircraft related			
ADRM	Aerodrome	Occurrences involving aerodrome design, service, or functionality issues.	Considered as RIF contribution.
ATM	ATM/CNS	Occurrences involving Air traffic management (ATM) or communications, navigation, or surveillance (CNS) service issues.	Considered as RIF contribution.
Takeoff and Landing			
ARC	**Abnormal runway contact**	Any landing or take-off involving abnormal runway or landing surface contact.	Extended to include *abnormal take-off* and adapted as a separate accident category.
CTOL	**Collision with obstacle(s) during take-off and landing**	Collision with obstacle(s), during take-off or landing whilst airborne.	Adapted *together with ARC* as a separate accident category.
USOS	Undershoot/Overshoot	A touchdown off the runway surface.	NA with respect to helicopter.
Weather			
ICE	Icing	Accumulation of snow, ice, freezing rain, or frost on aircraft surfaces that adversely affects aircraft control or performance.	Considered as RIF contribution.
TURB	Turbulence encounter	In-flight turbulence encounter.	Considered as RIF contribution.
WSTRW	Wind shear or thunderstorm	Flight into windshear or thunderstorm.	Considered as RIF contribution.

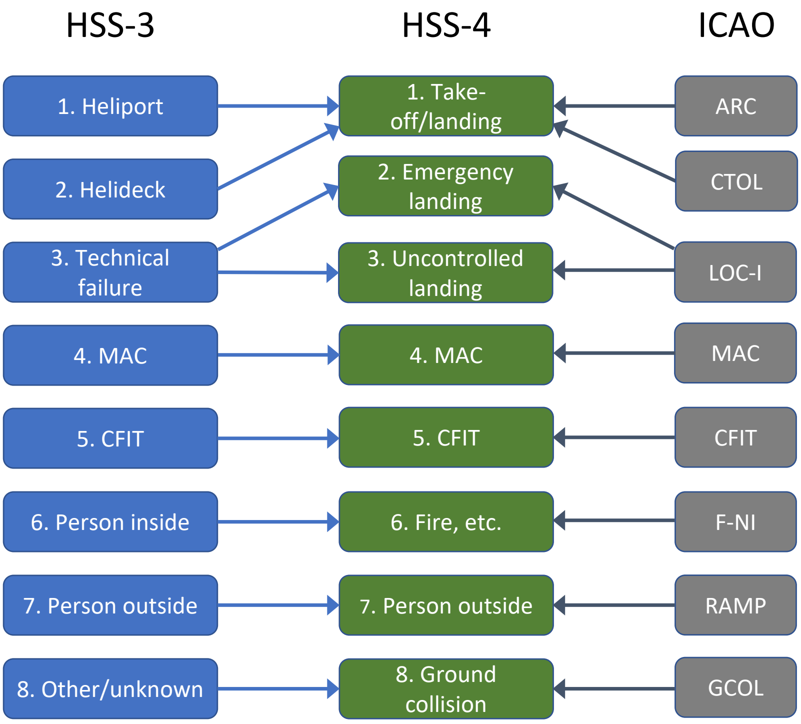
Due to few experienced accidents and the need for expert judgements in the risk estimation, a limited number of mutually accident categories should be defined. The accident categories must be clearly defined and cover all possible types of accidents without being overlapping.

Compared to HSS-3, the updates of the accident categories in HSS-4 are as follows (illustrated in Figure B.1):

- **Sub-categories** describing where the accident appeared (relevant for the consequence and emergency preparedness) are now defined.
- **Heliport- and helideck accidents** are now merged into a common accident category (and split into separate sub-categories.
- Accident due to **a critical technical failure** now is into **controlled emergency landing** and **uncontrolled collision with terrain or sea** (LOC-I in ICAO) depending on the accidental event after the technical failure. The technical failure is rather a cause than an accident. Upon a critical technical failure, the passengers and pilots can be saved only by performing a successful emergency landing into sea, terrain, or an alternative landing site (including landing on wrong helideck). LOC can be caused by both technical failures and other conditions such as weather or situational awareness (landing on wrong helideck).
- **MAC** now also includes unmanned aircrafts (as a separate sub-category). This is due to the potential increased future use of UAVs.
- The accident category **fire, explosion, smoke or toxic gas** has replaced the accident category related to persons inside helicopter from HSS-3.

- The HSS-3 category 'Other/unknown' is now replaced by **ground collision**. Other examples of accidents from the previous 'Other/unknown' category are now assumed to be covered by the defined accident categories or rather as influencing factors (e.g. weather, or intentional unwanted activity).

Despite the changes in accident categories from HSS-3 to HSS-4 it is still possible to compare risk estimates per accident category based on Figure B.1 (also including the references to the ICAO categories).



ARC – Abnormal runway contact
CFIT – Controlled flight into/toward terrain
CTOL – Collision with obstacle(s) during take-off and landing
DEV – Deviation from intended flightpath
F-NI – Fire/smoke (not impact of accident)
GCOL – Ground collision
LOC-I – Loss of control – Inflight
MAC – Mid-air collision
RAMP – Ground handling

Figure B.1: Comparison of accident categories in HSS-3, HSS-4, and ICAO.

B.2 RIF-diagrams

The following RIF updates have been performed in HSS-4:

Level 1 – General:

- Level 1 is renamed from 'Operational RIFs' to 'Technical and operational RIFs' to include the correlation between technical and operational conditions, and according to the commonly used system categories; technical, operational, and organizational (ref. also changes in level 2).
- The main cause (group of level 1 RIFs) 'Other factors' in HSS-3 is now renamed to 'External factors'. By external is meant that the conditions are beyond control for the industry. The RIFs grouped within 'External factors' are: 'Other airspace activities', 'Weather conditions', and 'Intentional adverse events'. Thee influence diagram for consequence includes one RIF ('Weather conditions') within the main cause 'External factors'.

Level 1 – Frequency:

- **NEW RIF** 1.12 'Intentional adverse events' in the influence diagram for frequency. In the HSS-3 model, this RIF was included within the accident category 'Other/Unknown'. However, this is rather a RIF that influence the accident frequency rather than an accident category itself. Also, intentional adverse events are considered as an increasing treath, e.g. due to cyber attacks, yamming, laser lights, UAVs, etc.

Figure B.2 illustrates the changes in level 1 frequency RIFs from HSS-3 to HSS-4.

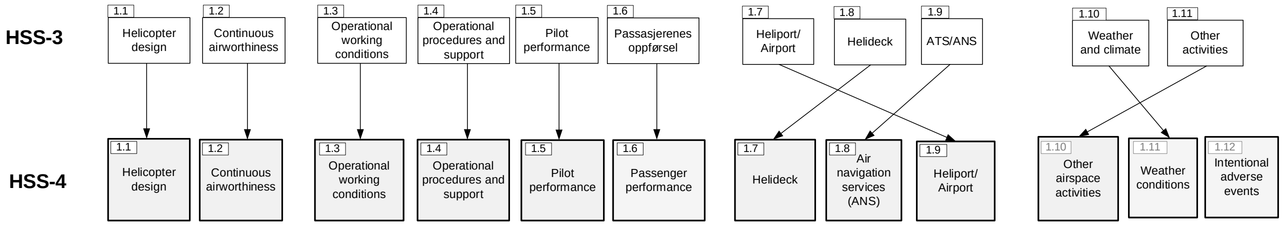


Figure B.2: Changes in level 1 frequency RIFs from HSS-3 to HSS-4.

Level 1 – Consequence:

- The two HSS-3 RIFs 'Impact absorption' and 'Cabin safety' have now been merged into a common RIF as these factors are partly overlapping.
- The HSS-3 RIF 'Helicopter design' is now considered as part of the 'Helideck emergency preparedness' RIF.
- The HSS-3 RIF 'SAR emergency preparedness' is renamed to 'SAR helicopters' to better fit into the boundary of a technical and operational RIF. The organizational part of the HSS-3 RIF 'SAR emergency preparedness' is now merged with the HSS-3 level 1 RIF 'Organization and co-ordination' and moved to level 2 within the RIF 'Search & Rescue organizations'.
- **NEW RIF** 'Other emergency preparedness', comprising emergency preparedness resources other than SAR helicopters, has now been established.
- 'Weather conditions' is now a separate RIF.
- Other activities (in HSS-3 merged with weather conditions) has now been included in the RIF 'Other emergency preparedness'. This is not considered as an external factor since the Norwegian rescue service organise the emergency preparedness and co-operates with both SAR helicopters and other emergency preparedness resources.

Figure B.3 illustrates the changes in level 1 frequency RIFs from HSS-3 to HSS-4.

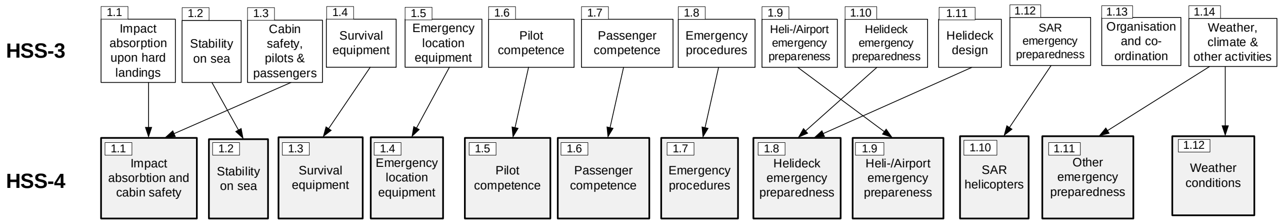


Figure B.3: Changes in level 1 consequence RIFs from HSS-3 to HSS-4.

Level 2 – General:

- 'Helicopter operators' and 'Maintenance organizations' (common RIF in HSS-3 model) is now split into separate RIFs as they may be separate organizations.
- 'Customers (oil and gas companies' is moved from level 3 to level 2 together with the other organizations such that only authorities are left on level 3.
- 'Heliport-/Helideck operators' that was a separate RIF in the HSS-3 model, is now part of 'Customers' (the helideck and HFIS part) and 'ANS organizations' (the heliport part) as there are no other heliport or helideck operators.

Level 3 – General:

- Now, as the 'Customers' RIF is moved to level 2, level 3 only includes authority RIFs.
- In the HSS-3 model, the influence on the technical and operational RIFs from national authorities (NA) and international authorities (EASA) were illustrated in the influence diagram. Now it is assumed that the authorities mainly influence the organizations (helicopter manufacturers, helicopter operators, customers, and ANS organizations) on level 2 rather than directly influencing the technical and operational RIFs on level 1.

In addition, there have been performed minor adjustments of the arrows illustrating the influence from and between the RIFs. Such influences are discussed in appendices A and B for level 2 and 3 RIFs (for frequency and consequence RIFs, respectively.

B.3 Quantification of the HSS-model – Method and data

The following parameters in the risk model are to be quantified (assuming a given total accident frequency for all accident categories, f):

- Accident frequency per accident category: $f_i; i = 1, \ldots, 8$
- Expected (mean) number of fatalities per accident category: $C_i; i = 1, \ldots, 8$
- RIF contributions (to increased risk / negative contribution) distributed on the frequency RIFs and accident categories, $B_i(f1.1), \ldots, B_i(f1.12); i = 1, \ldots, 8$.
- RIF contributions (to both increased and reduced risk / negative *and* positive contributions) distributed on the consequence RIFs and accident categories $B_i(C1.1), \ldots, B_i(C1.12) ; i = 1, \ldots, 8$.

Figure B.4 illustrates the RIF contributions.

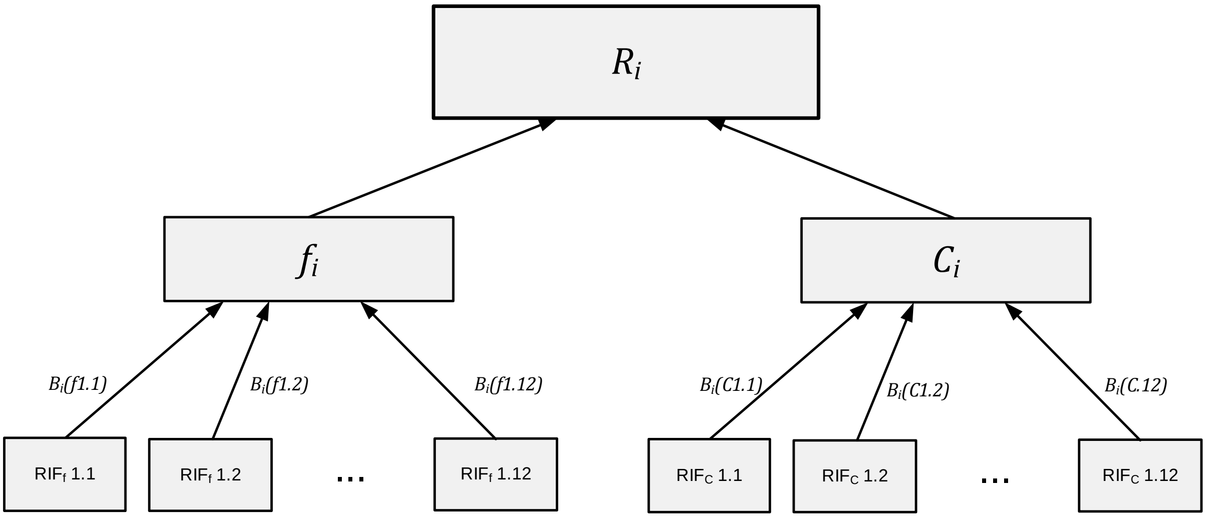


Figure B.4: Contributions from RIFs to risk.

B.3.1 Quantification of the HSS model based on historical data

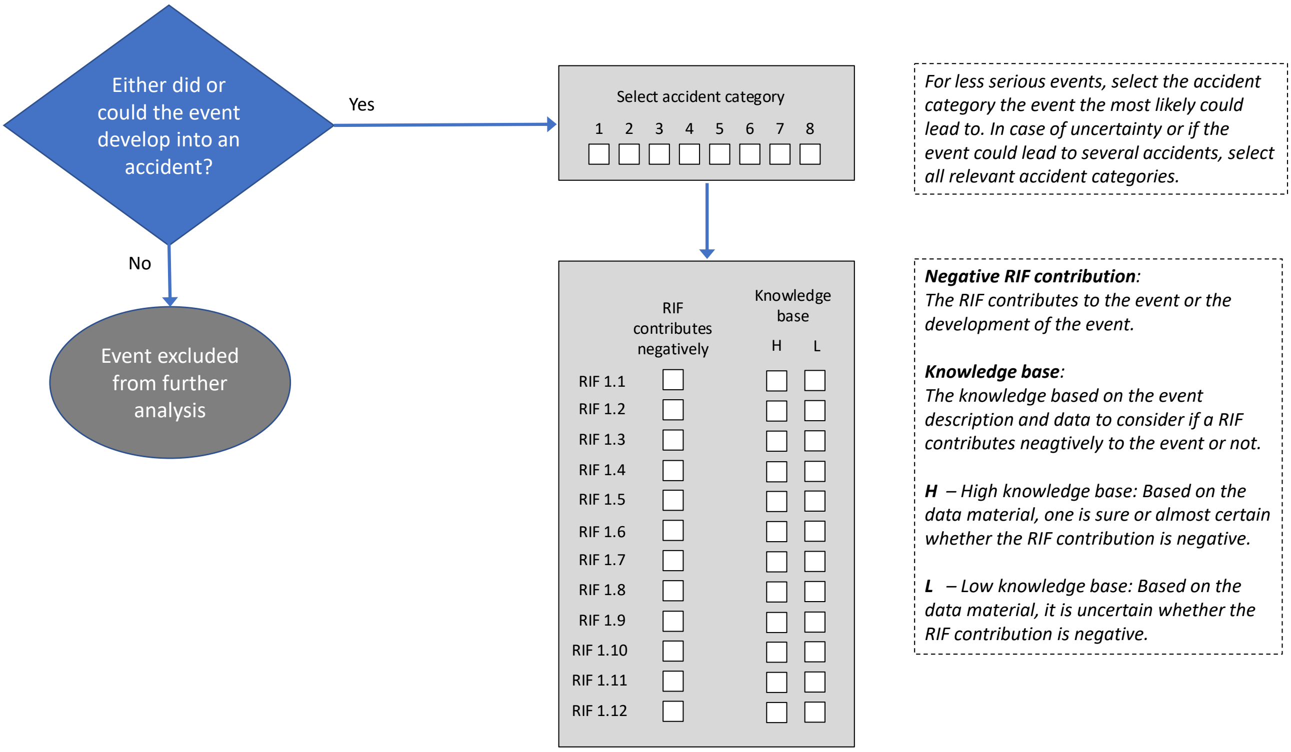
Frequency and consequence are quantified separately.

Frequency
For frequency quantification, historical data gives input to

- **Distribution of accident categories:** Each event is classified into one or more accident categories.
- **Distribution of RIF contributions:** One or more RIFs are identified to contribute to each event.
- **Weighting events:** Accidents and serious events are withed more heavily than less minor events.
- **Uncertainties** associated with the accident category and RIF distributions.

Consequence
Consequence estimation cannot be performed based on historical accidents alone, as there are rather few (fatal) accidents experienced. Hence, expert judgement must be used, in addition to statistics from both Norway and UK, to estimate the number of fatalities per accident category. Uncertainty is not assessed for consequence.

Flow diagram for frequency classification of events
The flow diagram in Figure B.5 illustrates the frequency classification of historical events.



For less serious events, select the accident category the event the most likely could lead to. In case of uncertainty or if the event could lead to several accidents, select all relevant accident categories.

***Negative RIF contribution**:*
The RIF contributes to the event or the development of the event.

***Knowledge base**:*
The knowledge based on the event description and data to consider if a RIF contributes neagtively to the event or not.

***H** – High knowledge base: Based on the data material, one is sure or almost certain whether the RIF contribution is negative.*

***L** – Low knowledge base: Based on the data material, it is uncertain whether the RIF contribution is negative.*

Figure B.5: Flow diagram for frequency classification of events.

B.3.2 Expert judgements in the quantification of the HSS model

Expert judgements have mainly been used to estimate:

- The expected consequence of each accident category.
- The importance of each consequence RIF.
- The influence from organizational RIFs to the operational RIFs.

B.3.3 Data sources

All events reported to CAA-N in the period 2010–2019 (ten years) are input the quantification of the HSS-4 model, and particularly to the frequency part. Table B.3 presents the number of accidents, serious incidents, and occurrences, per year for the period 2010–2019.

Table B.5 lists the information/parameters included for each event in the reported data. It should be noted that information is often missing for many of the parameters in the event data. However, the most important parameter, the free text fields, comprise valuable information for most of the events.

Table B.3: Number of accidents, serious incidents, and occurrences, in the period 2010–2019.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Totalt
Accidents	-	-	-	-	-	-	2	-	-	-	**2**
Serious incidents	1	-	1	-	-	-	-	-	-	-	**2**
Occurrences	628	541	411	512	539	460	283	248	283	253	4158
Total	**629**	**541**	**412**	**512**	**539**	**461**	**283**	**248**	**283**	**253**	**4161**

The CAA-N data are supplemented with RNNP data for the period 2010–2018. The RNNP data include events analysed with respect to remaining barriers (0, 1 or 2 remaining barriers from an accident). Information about events with 0 or 1 remaining barrier (Table B.4) are included in the total data set. It should be noted that six of the RNNP events with 0 or 1 remaining barrier are not found in the CAA-N data (ref. Table B.6 below).

Table B.4: Events from the RNNP data having 0 or 1 remaining barrier.

	2010	2011	2012	2013	2014	2015	2016	2017	2018	Totalt
0 barrierer	**-**	**-**	**-**	**-**	**1**	**-**	**2**	**2**	**-**	**5**
1 barriere	**5**	**6**	**1**	**2**	**-**	**-**	**-**	**2**	**1**	**17**
Totalt	**5**	**6**	**1**	**2**	**1**	**0**	**2**	**4**	**1**	**22**

Table B.5: Parameters and information included in the CAA-N data.

Title	**Information**
File number	Unique number for each event
Occurrence class	Accident / Serious incident / Occurrence
Local date	Date of event
Local time	Time of event
Occurrence category	ICAO categories (more than one category can be relevant for a single event)
Headline	Short description of event
Event type	Hierarchical categorisation of the event, where the top level is: Equipment/Operational/Personnel/Organizational/Consequential events
Phase	The phase of the aircraft when the event occurred, e.g. cruise, taxi, standing, initial climb, final approach, etc.
Highest damage	Destroyed/Substantial/Minor
Injury level	Fatal/Serious/Minor
Third party damage	Yes/No
Aircraft registration	Registration number for involved aircraft(s)
Manufacturer/model	Manufacturer(s)/Model(s) of involved aircraft(s)
Occ. on ground	Yes/No/Unknown
Aircraft altitude	Height above sea level when the event occurred (measured in feet)
Est minimum horiz sep	Minimum horizontal distance between aircrafts (measured in nm)
Est vert separation	Vertical separation between aircrafts (measured in feet)
Traffic info type	Visual/Radar/Essential/etc.
Traffic info quality	Complete/Incomplete/Incorrect/Late/etc.
Weather relevant	Yes/No/Unknown
Weather report	Description

Title	Information
Type of vehicle	Type of vehicle involved
Landing area	Aerodrome landing area (e.g. ship or movable helideck)
ATM contribution	Directly involved / Indirectly involved / Unknown
Workload controller	High/Medium/Low
Military a/c involved	Yes/No/Unknown
Narrative ATS	Description by ATN personnel
Narrative Occurrence	Description of event
Reporting entity	Entity reporting the event

B.3.4 Assumptions and data set for analysis

The CAA-N data includes much information for each event. However, there are limited explanations regarding the failure causes as these often are unknown at the time of reporting. Particularly, the events classified as SCF-NP and SCF-PP include very limited information regarding failure cause. Hence, many of these events are attached with low (L) knowledge base.

The CAA-N data include quite a few events not relevant to offshore helicopter transport, e.g. training, SAR operations, transport to and from hangar, or maintenance operations. These are included in the data set for analysis.

The ICAO category OTHER is represented in a high number of events. Spot-checks of these events indicate that most of the events rather could have been categorised within a more specific ICAO category, and it is assumed that the OTHER events have the same distribution as the rest of the events (and are therefore excluded from the data set for analysis. In general, it is not recommended to use the OTHER category as there should be one category for each event. Alternatively, the UNKNONW (UNK) category could be used instead if it there are uncertainties regarding the event classification.

Many of the ICAO categories are difficult to distinguish from each other, for instance many events are reported as both MAC and ATM and many events are reported as both SCF-PP or SCF-NP. It is therefore recommended to introduce clear definitions and standardised classification of the categories MAC, NAV, and ATM, and for the categories SCF-PP and SCF-NP. In this report, the categories MAC, NAV, and ATM are merged, and the categories SCF-PP and SCF-NP are merged.

Table B.6 shows the number of events included in the data set for analsyis, sorted into (groups of) ICAO categories (or RNNP data only).

Table B.6: Number of events included in the data set for analysis, sorted into (groups of) ICAO categories (or RNNP data only).

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	SUM
ADRM	28	26	18	31	20	11	3	5	8	4	**154**
AMAN	0	0	0	0	1	1	0	0	0	0	**2**
ARC	0	1	1	0	0	0	0	0	1	0	**3**
ATM/MAC/NAV	71	89	50	49	68	60	48	52	80	71	**638**
BIRD	20	18	6	11	12	8	11	6	12	9	**113**
CABIN	2	0	0	3	1	0	2	0	0	0	**8**

CFIT	1	0	0	0	0	0	0	1	1	0	**3**
F-NI	7	5	1	2	5	4	1	0	0	0	**25**
FUEL	0	1	3	4	2	1	0	0	1	0	**12**
GCOL	0	0	0	0	0	0	1	0	0	0	**1**
ICE	2	0	1	0	4	1	0	0	0	2	**10**
LOC-G	1	0	0	0	2	0	0	1	0	0	**4**
LOC-I	0	0	1	0	1	0	4	0	0	0	**6**
RAMP	24	15	22	22	23	12	12	7	11	4	**152**
RI	1	3	4	7	8	6	2	8	8	1	**48**
SCF-NP/PP	278	229	159	194	211	187	107	82	75	78	**1600**
SEC	1	5	3	4	9	8	1	0	3	3	**37**
TURB	4	3	4	4	5	1	3	0	2	1	**27**
UNK	1	2	0	0	0	0	0	0	0	0	**3**
WILD	0	0	1	1	3	2	0	0	0	0	**7**
WSTRW	4	11	7	14	4	10	4	8	5	6	**73**
RNNP	2	0	0	1	0	0	0	2	1	0	**6**
SUM	**427**	**390**	**275**	**336**	**367**	**304**	**188**	**166**	**196**	**170**	**2819**

The figures below illustrate the frequency of each ICAO category, for all categories and when excluding the two most frequent (groups of) ICAO categories, respectively.

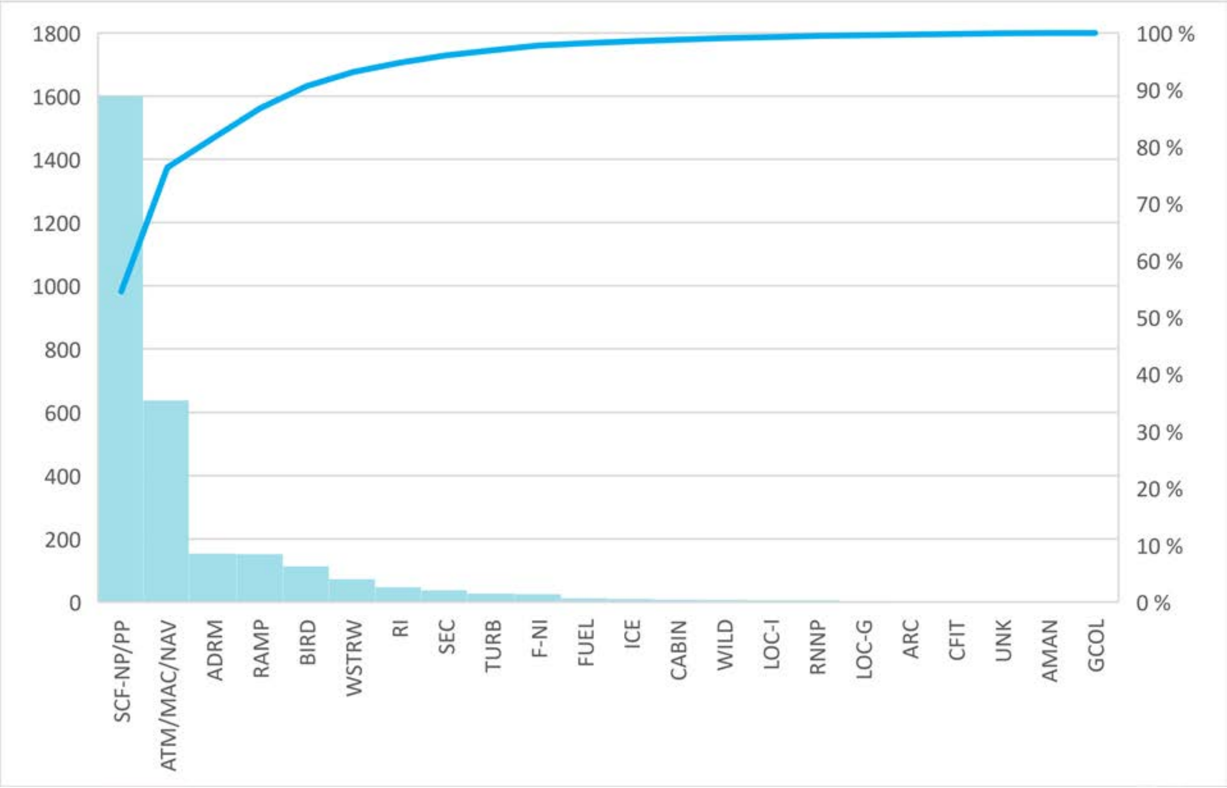


Figure B.6: Frequency of (groups of) ICAO categories – total for all years.

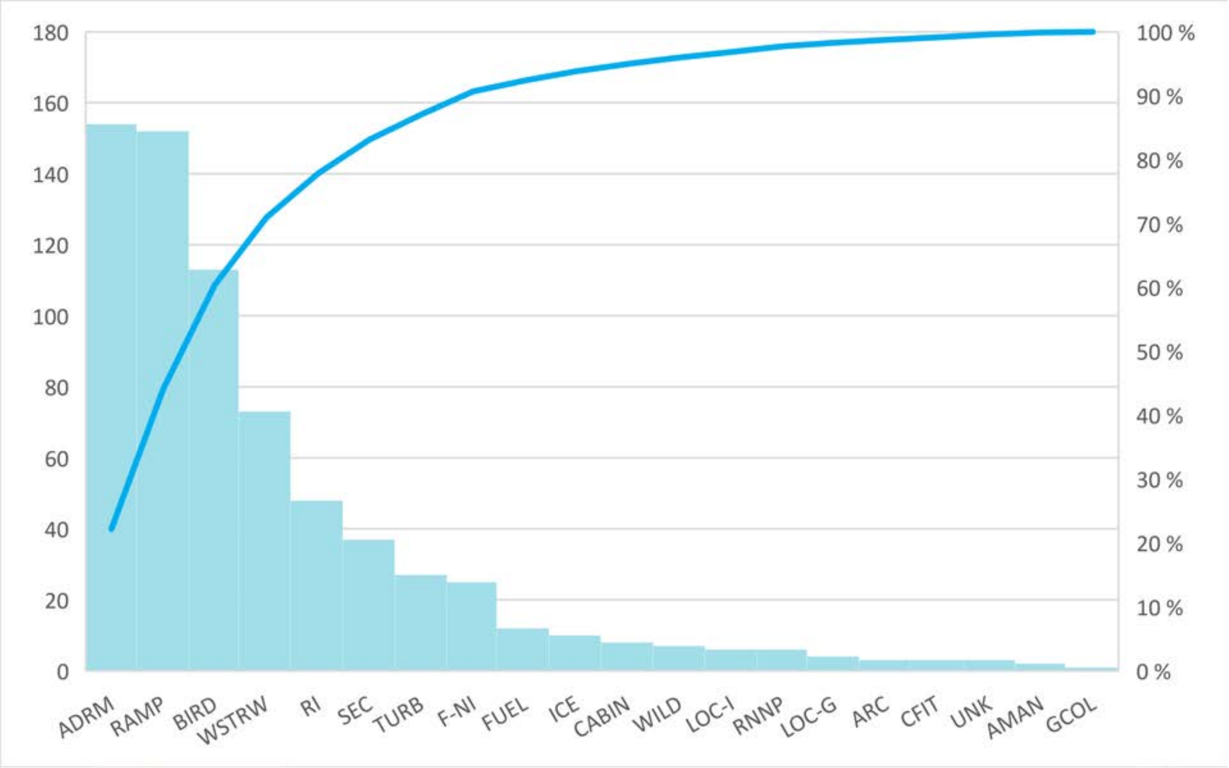


Figure B.7: Frequency of ICAO categories (the two most frequent ICAO category groups SCF-NP/PP and ATM/MAC/NAV) – total for all years.

B.3.5 Weighting events

In general, events closest to an accident are weighted the most. For RNNP events the number of remaining barriers indicates how close the event is to an accident.

All events included in the data set for analysis (CAA-N events and RNNP events) are weighted as follows:

Table B.7: Weighting of events.

Event	**Weight**	**Comment**	**Number of events included in data set**
Accident	1	An accident is considered as a complete accident.	2
Serious incident / RNNP event with 0 remaining barriers not defined as accident	1/3	'Serious incidents' and 'RNNP events with 0 remaining barriers not defined as accident' are equally weighted. Two out of nine of such events have evolved into an accident, resulting in a weight of 1/5. However, since only two accidents have been experienced, and to prevent their their corresponding accident categories and RIFs to dominate complitely, the weight is adjusted to 1/3.	7

Event	**Weight**	**Comment**	**Number of events included in data set**
ICAO categories classified as *accident* in HSS-4 (see comment) / RNNP event with 1 remining barrier	1/20	ICAO categories classifed as accidents in HSS-4, i.e. ARC, CTOL, LOC-I, CFIT and GCOL (Figure B.1), may not have developed into an accident, and is therefore compared with the events having 1 remaining barrier. 2 out of 39 events within this category has developed into accidents, and hence this cateory is weighted 1/20. $\left(\frac{2}{2+7+30}=\frac{2}{39}\right)$	30
ICAO categories classified as *event* in HSS-4 (see comment)	1/100	The ICAO categories RAMP, CABIN, LOC-G og F-NI are considered as events (neither accidents nor RIF contributions) in HSS-4. Based on the number of events in these categories, a weight of 1/100 is assumed: $\left(\frac{2}{2+7+30+184}=\frac{2}{223}\right)$	184
The following ICAO categories classified as *RIF contributions* in HSS-4: ADRM, AMAN, BIRD, FUEL, ICE, RI, SEC, TURB, WSTRW.	1/350	The rest of the ICAO categories are classified as RIF contributions in HSS-4. For the ICAO categoreis ADRM, AMAN, BIRD, FUEL, ICE, RI, SEC, TURB, and WSTRW, and based on their frequency, these are weighted 1/700. $\left(\frac{2}{2+7+30+184+485}=\frac{2}{708}\right)$	485
The following ICAO categories classified as *RIF contributions* in HSS-4: ATM, MAC, NAV, SCF-NP, SCF-PP.	1/1500	The rest of the ICAO categories included in the data set considered as RIF contributions, ATM, MAC, NAV, SCF-NP, and SCF-PP are based on their frequency weighted 1/1500. $\left(\frac{2}{2+7+30+184+485+2227}=\frac{2}{2935}\right)$	2227

B.3.6 Including UK accidents in the data set

In the period 2010–2019, a total of four UK accidents (two accidents in 2012, one accident in 2013, and one accident in 2016) have been registered and considered relevant for the Norwegian Continental Shelf. (The three accidents in 2012 and 2013 were in the HSS-3b study considered as accidents that also could have happened in Norway within the same period.

B.3.7 Including/excluding H225 data

H225 Super Puma is no longer in use for helicopter personnel transport in Norway after the Turøy accident in 2016. However, the data set includes a high number of H225 events for the period 2010–2016, including the UK accidents. Therefore, two data sets have been analysed for the period 2010–2019:

- A data set including *all events* and all helicopter types (about 2900 events).
- A data set including the helicopter type *S-92 only* (about 1700 events).

B.3.8 Knowledge base and estimation of RIF contributions to accident frequency

As in HSS-3, only negative contribution is considered when estimating the RIF contributions (and corresponding uncertainties) from frequency RIFs. Hence, one parameter (in addition to the corresponding uncertainty) is to be estimated for each RIF. A positive contributor may prevent an unwanted event or accident. A negative contributor may initiate or an accident or worsen an unwanted event. The historical events represent the data source for identifying negative RIF contributions (assuming that all events have been reported). The knowledge base for positive RIF contributions, on the other hand, is very limited and attached with great uncertainty, as there are no data for all "positive events".

For each event, one or more negative RIF contributions are identified based on the information or knowledge base in the reported event. The knowledge base for an event is selected as either *high (H)* or *low (L)*., i.e. all relevant RIFs for an event are based on the same knowledge base (high or low). When RIFs can be selected with certainty, the knowledge base is classified as high (H) and when RIFs are selected with uncertainty the knowledge base is classified as low (L).

EXAMPLE
An event upon aerodrome landing in harsh weather is described without giving information about the aerodrome, i.e. whether it was a helideck or a heliport landing. Possible RIFs for the event are: • 1.7 Helideck • 1.9 Heliport/airport • 1.11 Weather conditions As there are not sufficient information to select either 1.7 or 1.9, the knowledge base is considered as low (L). Even if it is obvious that RIF 1.11 is a negative RIF contribution in the event, low knowledge base is selected due to the missing information regarding the rest of the RIFs. Alle three listed RIFs are selected. The knowledge base is classified as low (L).

Note: For frequent ICAO categories, events with similar type of description/keyword have not been analysed separately. Rather, the same RIFs have been selected for all events in a group of events, and the knowledge base for the events are classified as low (even if only one RIF is selected).

The estimation of total frequency RIF contributions also considered the knowledge base:

- An RIF contribution attached with *high* knowledge base have a weight twice the RIF contributions attached with *low* knowledge base.
- For an event, the total RIF contribution is equally distributed on the RIFs selected.

EXAMPLE
Let us continue with the above example regarding landing on aerodrome upon harsh weather conditions. Assume now that we do have information about were the event occurred: The event occurred upon landing on helideck. Hence, we can identify the RIF contribution from RIF 1.7 and RIF 1.11 with high certainty, i.e. high knowledge base. Assuming the total RIF contributions for the event from each RIF are summarized to 1 (the corresponding total

RIF contribution from an event with low knowledge base is then 0.5). Since the individual RIF contributions, here from two RIF, are to be equally distributed, the RIFs 1.7 and 1.11 each gives a contribution of ½. $\left(\frac{1}{\text{Number of seelcted RIFs}} = \frac{1}{2}\right)$

Let us now reconsider the example above that was attached with low knowledge base. For this event each of the three RIFs, 1.7, 1.9, and 1.11, gives an individual contribution of 1/6. $\left(\frac{0{,}5}{\text{Number of seelcted RIFs}} = \frac{0{,}5}{3} = \frac{1}{6}\right)$.

B.3.9 Uncertainty of frequency RIF contributions

An uncertainty interval of a frequency RIF contribution is defined by a lower uncertainty limit and an upper uncertainty limit. The uncertainty limits are estimated based on different weighting of the L events (events attached with *low* knowledge base) and H events (events attached with *high* knowledge base). The degree of confidence in the L events forms the basis for the uncertainty limits:

- The lower uncertainty is estimated by giving each L event (and corresponding RIF contributions) a weight of 0.8 – assuming the H events have weight 1.
- The upper uncertainty limit is estimated by giving each L event (and corresponding RIF contributions a weight of 0.2 – assuming the H events have weight 1.
- The total RIF contribution from each event is still equally distributed on the RIFs selected for the event. This means that the total RIF contribution from a H event summarize to 1. For an L event the total RIF contribution are 0.5 for the mean estimate, 0.8 for the lower uncertainty limit and 0.2 for the upper uncertainty limit.

EXAMPLE

Remember the examples with the event classified with low knowledge base and with possible contributions from RIFs 1.7, 1.9 and 1.11. Each of these three RIFs has an individual contribution of 1/6 to the mean estimate, $\frac{0{,}2}{3} = \frac{1}{15}$ to the lower uncertainty limit, and $\frac{0{,}8}{3} = \frac{4}{15}$ to the upper uncertainty limit.

For each of the 12 RIFs, the individual RIF contributions from each event are summarised (also taking into account the weighting of events in Table B.7). The sum of the different event contributions (mean, upper limit, and lower limit) to RIF *i* are summarised to U_i for the upper limit, M_i for the mean estimate and to L_i for the upper limit, respectively. The corresponding totals for all 12 RIFs are U_{tot}, M_{tot} and L_{tot}:

RIF	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	1.10	1.11	1.12	1.13	SUM
Upper limit (U)	U_1	U_2	U_3	U_4	U_5	U_6	U_7	U_8	U_9	U_{10}	U_{11}	U_{12}	U_{13}	U_{tot}
Mean estimate (M)	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	M_9	M_{10}	M_{11}	M_{12}	M_{13}	M_{tot}
Lower limit (L)	L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9	L_{10}	L_{11}	L_{12}	L_{13}	L_{tot}

The result of interest is a distribution of the RIF contributions and their corresponding uncertainty limits (all in percentage). The upper and lower uncertainty limit contributions in percentage for RIF *i* are then estimated by:

$U_i\ (\%) = U_i / (M_{tot} + U_i - M_i)$

and

$L_i\ (\%) = L_i / (M_{tot} + L_i - M_i)$.

B.3.10 Uncertainty of the frequency contributions from the accident categories

An uncertainty interval of the frequency contributions from the accident categories is also defined by a lower uncertainty limit and an upper uncertainty limit. In general, as few as possible accident category. However, for most of the events there are limited information regarding the accident category, particularly since the events often are initiating events several barriers from an accidental occurrence. Uncertainty of the frequency contributions from the accident categories are estimated based on the number of selected accident categories for each event:

- The upper uncertainty limit is estimated based on the assumption that events where several accident categories are selected have a higher weight than events where fewer accident categories are selected. It is here argued that events contributing to several accident categories also contribute to a higher accident frequency.
- The lower uncertainty limit is estimated based on the assumption that events where fewer accident categories are selected have a higher weight than events where more accident categories are selected. It is here argued that the events' uncertainty regarding the accident category increases with the number of selected accident categories.

Table B.8: Weighting table for accident categories and their contribution from a single event.

Number of selected accident categories	**Contributions from selected accident category to the *upper limit***	**Contributions from selected accident category to the *mean estimate***	**Contributions from selected accident category to the *lower limit***
8	1	1/8	1/30
7	1	1/7	
6	1	1/6	
5	1	1/5	
4	1	1/4	1/16
3	1	1/3	1/9
2	1	1/2	1/4
1	1	1	1

As for the RIFs, the result of interest is a distribution of the accident frequency contributions and their corresponding uncertainty limits (all in percentage). The upper and lower uncertainty limit contributions in percentage for accident category *i* are then estimated by:

$U_i\ (\%) = U_i / (M_{tot} + U_i - M_i)$

and

$L_i\ (\%) = L_i / (M_{tot} + L_i - M_i)$,

where M_{tot} is the sum of the contributions from all accident categories and M_i is the sum of mean contributions to accident category *i*.

B.4 Quantification of the HSS model – Results

B.4.1 Frequency distribution of accident categories

The frequency distributions of the accident categories are shown in Table B.9 for all events (frequency distribution 1) and for S-92 events only (frequency distribution 2).

Table B.9: Frequency distribution of accident categories.

	A1 Landing / take-off aerodrome	**A2** Controlled emergency landing	**A3** Collision terrain/sea (LOC)	**A4** MAC	**A5** CFIT	**A6** Fire / Explosion/ Gas	**A7** Personal accident / behavior	**A8** Ground collision
Frequency distribution 1: *All events*	31 %	24 %	17 %	3 %	9 %	3 %	5 %	7 %
Frequency distribution 2: *S-92 events*	46 %	14 %	15 %	4 %	3 %	3 %	8 %	7 %

The frequency distribution based on all events is also compared with the results from HSS-3 (Figure B.8).

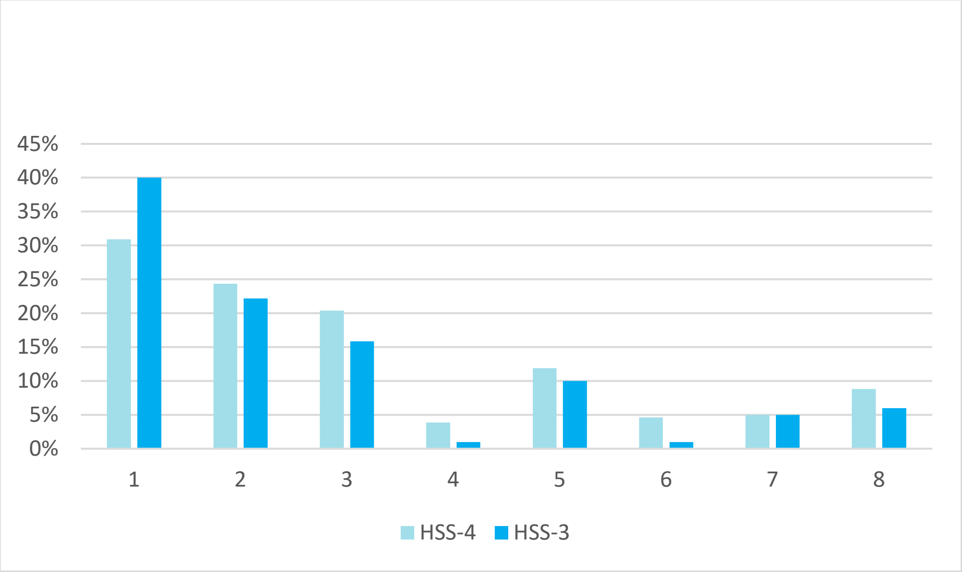


Figure B.8: Frequency distribution of accident categories compared with HSS-3.

B.4.2 Consequence contributions of the accident

Number of facilities in an arbitrary helicopter accident depends on the accident category – both whether the accident is fatal and with respect to the number of fatalities in a fatal accident. The *consequence* (measured in the number of fatalities) for each accident category is estimated by combining:

1. Mean fraction of fatal accidents of all accidents
2. Mean fraction of fatalities per accident

Both 1 and 2 are estimated by expert judgement documented below. The mean values for 1 and 2 are combined to estimate the number of fatalities in each accident category (and in total for all accidents). The results are presented in Table B.10.

Table B.10: Consequence contribution (number of fatalities per accident) from the accident categories.

	A1 Landing / take-off aerodrome	**A2** Controlled emergency landing	**A3** Collision terrain/sea (LOC)	**A4** MAC	**A5** CFIT	**A6** Fire / Explosion/ Gas	**A7** Personal accident / behavior	**A8** Ground collision
Fatal accident fraction *Example:* 1:10 – one out of ten accidents is fatal.	1:5	1:10	4:5	1:1	2:3	1:5	1:3	1:20
Fraction of fatalities in a fatal accident *Example:* 50 % - half of the people onboard die.	50 %	20 %	90 %	150 %	75 %	50 %	10 %	20 %

Comments to Table B.10:

- The HSS-3 estimates were based on a combination of statistics and expert judgements. The expert judgements were based on the HSS-3 estimates together with additional accident statistics from both Norway, UK, and Canada during the last ten years. The most recent accident statistics covers particularly the accident categories A2, A3, and A5. Some adjustments of the HSS-3 estimates were necessary due to updated accident categories, e.g. for A2 and A3 which in HSS-3 were defined as the same category.
- Comments to 'Fatal accident fraction':
  - The A4 and A6 estimates are unchanged from HSS-3.
  - A1 is assumed to occur significantly more frequent at helideck compared to heliport. The HSS-3 estimates are 1:4 (helideck) and 1:20 (heliport), respectively. The combined estimate has been assessed to 1:5.
  - A2 will in rather few scenarios lead to ditching (in the opposite to the assumption in HSS-3 that most of the scenarios involved ditching). A more realistic scenario is emergency landing on a landing site (helideck, ship, onshore, etc.). A2 is therefore considered as fatal only upon ditching in combination with harsh weather or helicopter roll (e.g. due to floating element fault). The fatal accident fraction for A2 has therefore been halved compared to HSS-3, from 1:5 to 1:10.
  - The A3 estimate is updated based on the changes in the accident categories from HSS-3 to HSS-4 and is somewhat higher compared to A5 (see next bullet). Four fatal A3 accidents have been experienced during the last ten years whereof three included loss of main rotor. Accidents without fatalities is assumed e.g. upon loss of tail rotor and when passengers are prepared for collision with sea and subsequent evacuation.
  - The A5 estimate is based on statistics from the last ten years where 2:3 accidents have been fatal. A5 accidents often occurs during approach and when both flying height and speed is low reducing the consequences compared to A3 accidents.
  - A7 includes scenarios such as persons being hit by tail rotor, persons being hit by flying objects, or falling accidents. In HSS-3, persons being hit by tail rotor was assumed as the main contributor to A7. Therefore, the fatal accident fraction has now been reduced from 1:2 to 1:3.
  - The A8 estimate is reconsidered since A8 is a new category in HSS-4 only covering collision on aerodrome ('Other accidents' in HSS-3). It is assumed low speed in most of the aerodrome collisions, however, fatal accidents may occur due to high speed or fire/explosion.

- Comments to 'Fraction of fatalities in a fatal accident':
    - The A1 and A6 estimates are approximately the same as in HSS-3. Typical A1 accidents with fatalities are helicopter rolling over helideck or helicopter collision or near-collision with sea upon take-off.
    - It is assumed that 20 % of the fatalities upon a ditching are under harsh environment (high waves, coldness, darkness, etc.)
    - There was only one survival from the four A3 accidents experienced during the last ten years. Compared to this statistic, the estimate is reduced from 100 % to 90 % to also include less serious accident scenarios such as loss of tail rotor.
    - It is assumed that none of the persons onboard the helicopter will survive an A4 accident. In HSS-3 it was assumed that the helicopter collided with another passenger transport helicopter in eight out of ten accidents. This probability is now reduced to 50 %, i.e. assuming on average 150 % fatalities of the passengers onboard a single helicopter.
    - The two fatal A5 accidents experienced during the last ten years had 7:7 and 4:18 fatalities, respectively. Based on this statistic, the fraction of fatalities in a fatal accident is reduced from about 90 % in HSS-3 to 75 % in HSS-4. Here also low speed and low height is assumed for most of the collisions.
    - It is assumed only 1–2 fatalities given a fatal A7 accident. The fraction of fatalities in a fatal accident is therefore halved from 20 % to 10 %.
    - A ground collision (A8) is assumed to cause 1–2 fatalities. Even in a fire or explosion accident it is assumed that most of the persons on board the helicopter survives. On average it is therefore assumed that about 20 % of the persons onboard the helicopter will not survive a ground collision.

B.4.3 Risk level and risk contribution from accident categories

The risk contribution from each accident category is estimated from the combination of the frequency contribution (Table B.9) and consequence contribution (Table B.10) together with the expected number of persons onboard a helicopter. Based on today's activity level (2010–2019), the mean number of persons onboard one helicopter flight is 14.

To quantify the (statistical) risk, we need in addition the estimated total accident frequency for all accident categories. This accident frequency is based on statistics from the Norwegian Continental Shelf from the period 2010–2019, During this period it has been experienced 2 accidents per 6 751 795 person flight hours (ref. chapter 5), i.e. *0.3 accidents per million-person flight hour*.

Table B.11 presents the risk contributions given by:

- Expected number of fatalities per accident category
- Risk distribution from the accident categories by percentage
- Absolut risk (number of fatalities per million-person flight hours) for each accident category based on all events and S-92 events, respectively.

A4 (MAC) has the highest number of fatalities per accident given that an accident has occurred. Here it is assumed that in about 50 % of the MAC accidents, the helicopter collides with another passenger helicopter such that the number of fatalities is higher than the number of persons onboard a single helicopter (ref. Table B.10). A3 (LOC) and A5 (CFIT) are also assessed to give a high number of fatalities.

The table also shows that the total number of fatalities per million-person flight hours is about 1 (sum of risk attached to each accident category) with today's activity level. A3 (LOC), A4 (MAC) and A1 (Landing/take-off) are the three accident categories contributing the most to the risk.

Table B.11: Risk contributions from accident categories.

	A1 Landing / take-off aerodrome	**A2** Controlled emergency landing	**A3** Collision terrain/sea (LOC)	**A4** MAC	**A5** CFIT	**A6** Fire / Explosion/ Gas	**A7** Personal accident / behavior	**A8** Ground collision	**Total**
Fatalities per accident	1,4	0,7	8,4	21,0	7,0	1,4	0,5	0,1	**3,4**
Fatalities per accident (normed)	3,5 %	1,7 %	21 %	52 %	17 %	3,5 %	1,2 %	0,3 %	**100 %**
Fatalities per million-person flight hours 1	0,13	0,05	0,43	0,19	0,19	0,01	0,01	0,00	**1,01**
Fatalities per million-person flight hours 2	0,19	0,03	0,38	0,27	0,06	0,01	0,01	0,00	**0,95**

B.4.4 Contributions from technical and operational RIFs to accident frequencies

The relative contribution from the 12 technical and operational frequency RIFs to the accident frequencies, is presented in Table B.12 (based on all events) and Table B.13 (based on S-92 events). The tables include both the total contributions and the contributions to each accident category.

Table B.12: Contributions from RIFs to accident frequencies – based on all events.

RIF		**Accident category**								**Sum**
		A1 Landing / take-off aerodrome	**A2** Controlled emergency landing	**A3** Collision terrain/sea (LOC)	**A4** MAC	**A5** CFIT	**A6** Fire / Explosion/ Gas	**A7** Personal accident / behavior	**A8** Ground collision	
1.1	Helicopter design	2,4 %	4,7 %	12,3 %	0,1 %	2,2 %	0,8 %	0,2 %	0,8 %	**23 %**
1.2	Continuing airworthiness	3,2 %	8,6 %	1,9 %	0,2 %	2,6 %	1,2 %	0,8 %	0,7 %	**19 %**
1.3	Operational working conditions	2,4 %	0,1 %	0,1 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	**3 %**
1.4	Operational procedures&support	2,2 %	2,0 %	0,1 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	**4 %**
1.5	Pilot performance	2,1 %	0,7 %	0,6 %	0,5 %	3,4 %	0,0 %	0,9 %	0,2 %	**9 %**
1.6	Passenger performance	0,1 %	0,2 %	0,0 %	0,0 %	0,0 %	0,1 %	0,5 %	0,0 %	**1 %**
1.7	Helideck	5,5 %	2,4 %	0,6 %	0,0 %	0,0 %	0,5 %	2,2 %	0,1 %	**11 %**
1.8	Air navigation services (ANS)	0,5 %	0,2 %	0,0 %	0,9 %	0,9 %	0,0 %	0,0 %	0,4 %	**3 %**
1.9	Heliport	7,9 %	0,8 %	0,2 %	0,0 %	0,0 %	0,5 %	0,4 %	4,3 %	**14 %**
1.10	Other airspace activities	0,1 %	0,0 %	0,0 %	1,1 %	0,0 %	0,1 %	0,0 %	0,2 %	**2 %**
1.11	Weather conditions	4,1 %	4,2 %	1,2 %	0,1 %	0,2 %	0,1 %	0,2 %	0,4 %	**10 %**
1.12	Intentional adverse events	0,5 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	**1 %**
Sum		**31 %**	**24 %**	**17 %**	**3 %**	**9 %**	**3 %**	**5 %**	**7 %**	**100 %**

Table B.13: Contributions from RIFs to accident frequencies – based on S-92 events.

RIF		Accident category								Sum
		A1 Landing / take-off aerodrome	**A2** Controlled emergency landing	**A3** Collision terrain/sea (LOC)	**A4** MAC	**A5** CFIT	**A6** Fire / Explosion/ Gas	**A7** Personal accident / behavior	**A8** Ground collision	
1.1	Helicopter design	1,0 %	1,2 %	1,1 %	0,1 %	0,3 %	0,3 %	0,1 %	0,1 %	**4 %**
1.2	Continuing airworthiness	5,0 %	7,9 %	7,4 %	0,4 %	1,1 %	1,8 %	2,0 %	0,2 %	**26 %**
1.3	Operational working conditions	5,4 %	0,0 %	0,5 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	**6 %**
1.4	Operational procedures&support	0,3 %	0,1 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	**0 %**
1.5	Pilot performance	2,1 %	0,3 %	1,3 %	0,4 %	1,1 %	0,0 %	0,4 %	0,2 %	**6 %**
1.6	Passanger performance	0,2 %	0,2 %	0,2 %	0,0 %	0,0 %	0,0 %	0,7 %	0,0 %	**1 %**
1.7	Helideck	9,1 %	1,3 %	1,4 %	0,0 %	0,0 %	0,3 %	3,8 %	0,1 %	**16 %**
1.8	Air navigation services (ANS)	0,5 %	0,1 %	0,0 %	1,3 %	0,4 %	0,0 %	0,0 %	0,2 %	**3 %**
1.9	Heliport	17,4 %	0,7 %	0,7 %	0,0 %	0,0 %	0,4 %	0,4 %	6,1 %	**26 %**
1.10	Other airspace activities	0,1 %	0,0 %	0,0 %	1,9 %	0,0 %	0,1 %	0,0 %	0,1 %	**2 %**
1.11	Weather conditions	4,1 %	2,0 %	2,7 %	0,1 %	0,0 %	0,0 %	0,3 %	0,1 %	**9 %**
1.12	Intentional adverse events	0,8 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	0,0 %	**1 %**
	Sum	**46 %**	**14 %**	**15 %**	**4 %**	**3 %**	**3 %**	**8 %**	**7 %**	**100 %**

The distribution of frequency RIF contributions based on all events is also compared to the HSS-results (Figure B.9).

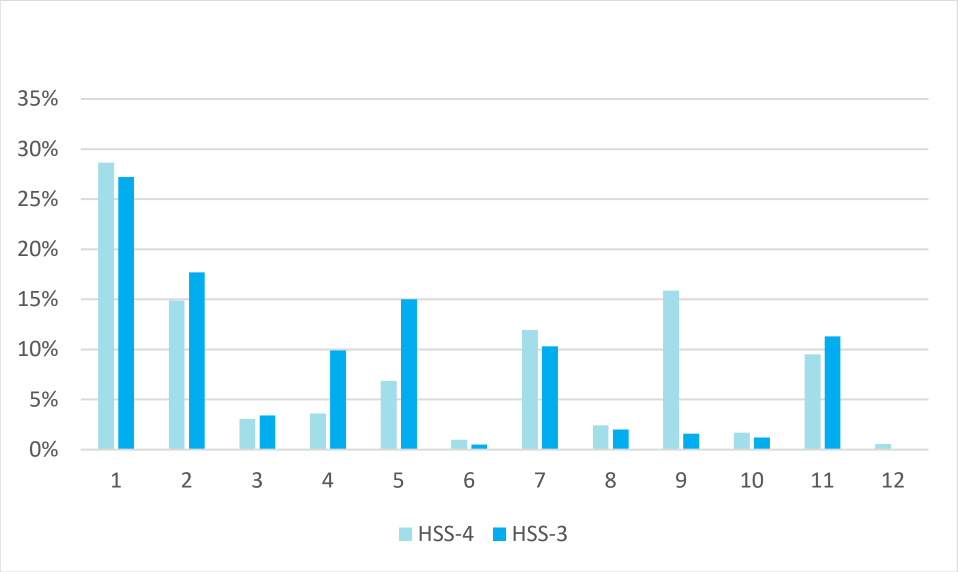


Figure B.9: Distribution of technical and operational frequency RIF contributions for all events – compared to HSS-3.

B.4.5 Uncertainty of the accident frequency contributions

The distribution of accident frequencies and their uncertainties are illustrated in Figure B.10 and Figure B.11.

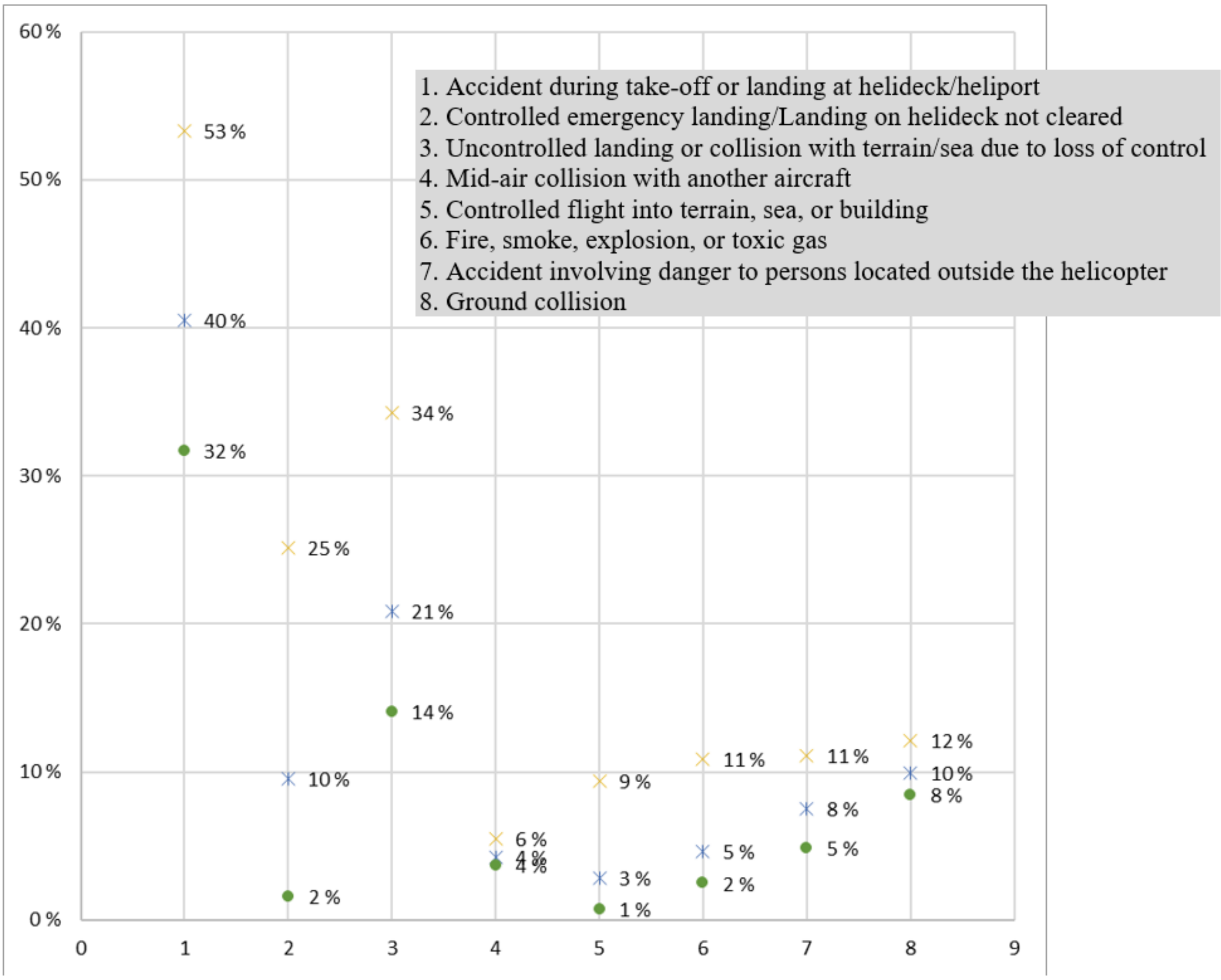


Figure B.10: Distribution of accident frequencies and corresponding uncertainties – based on all events.

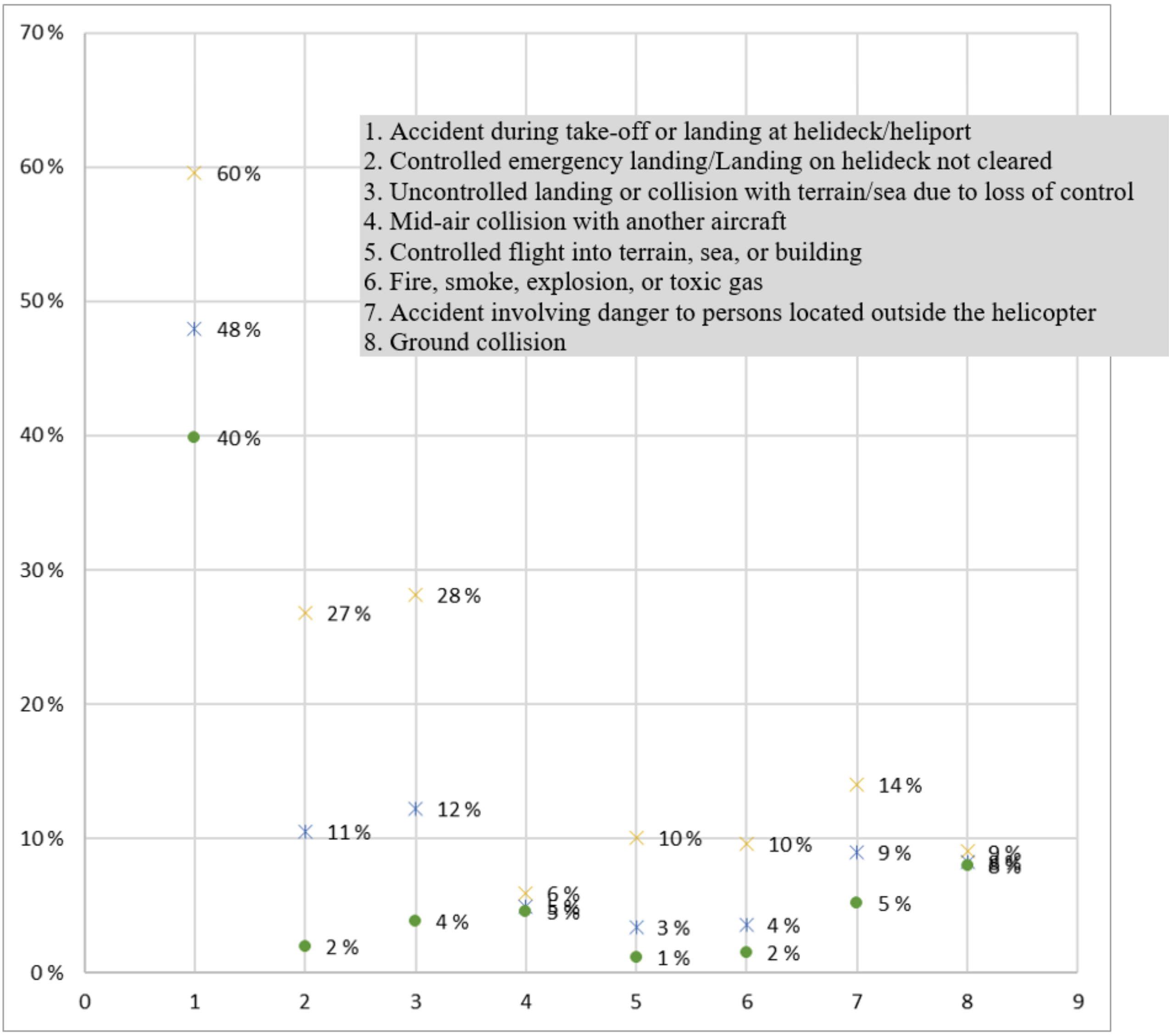


Figure B.11: Distribution of accident frequencies and corresponding uncertainties – based on S-92 events only.

Figure B.12 and Figure B.13 show the RIF contributions and their corresponding uncertainties.

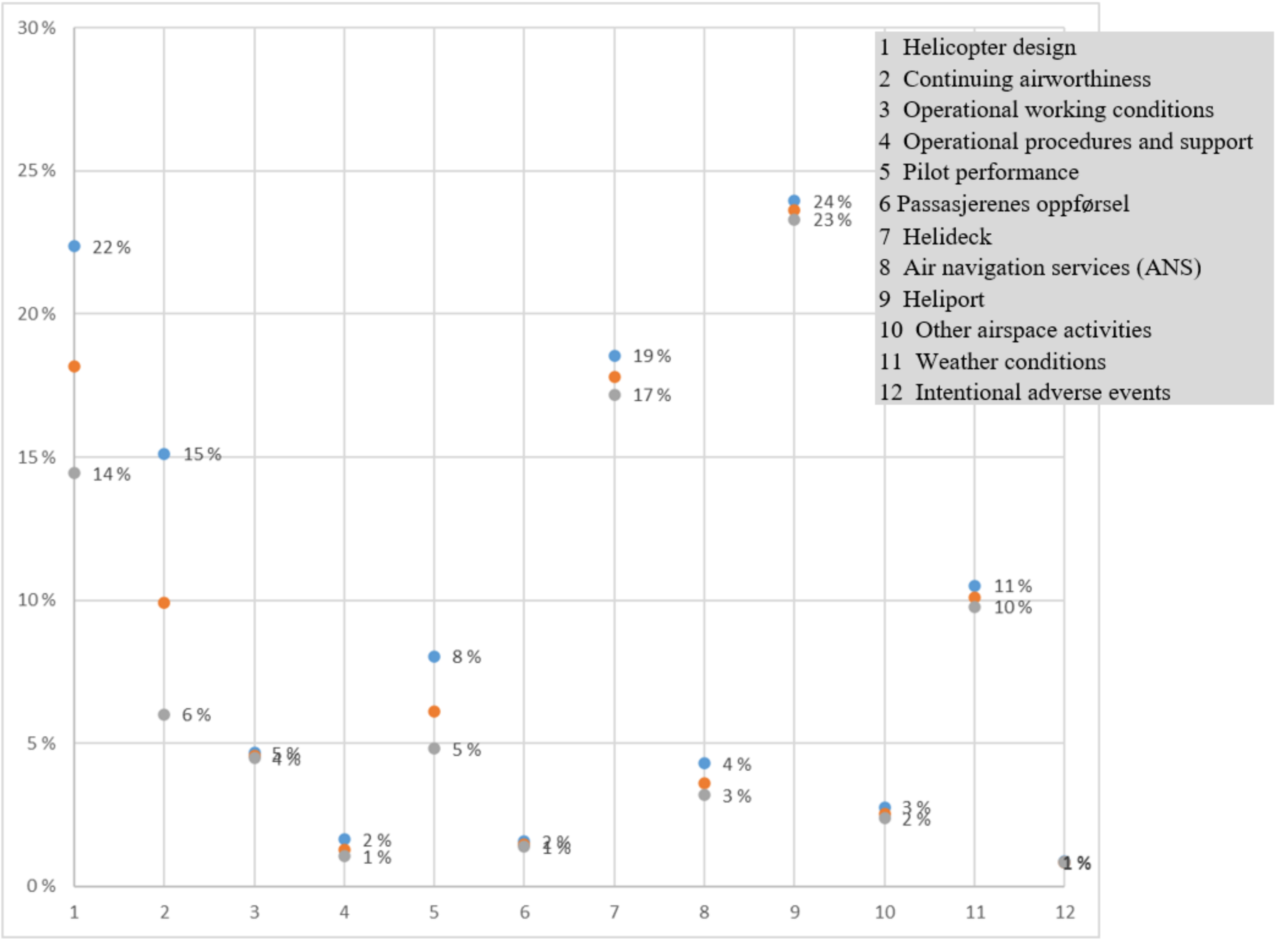


Figure B.12: RIF contributions and corresponding uncertainties – based on all events.

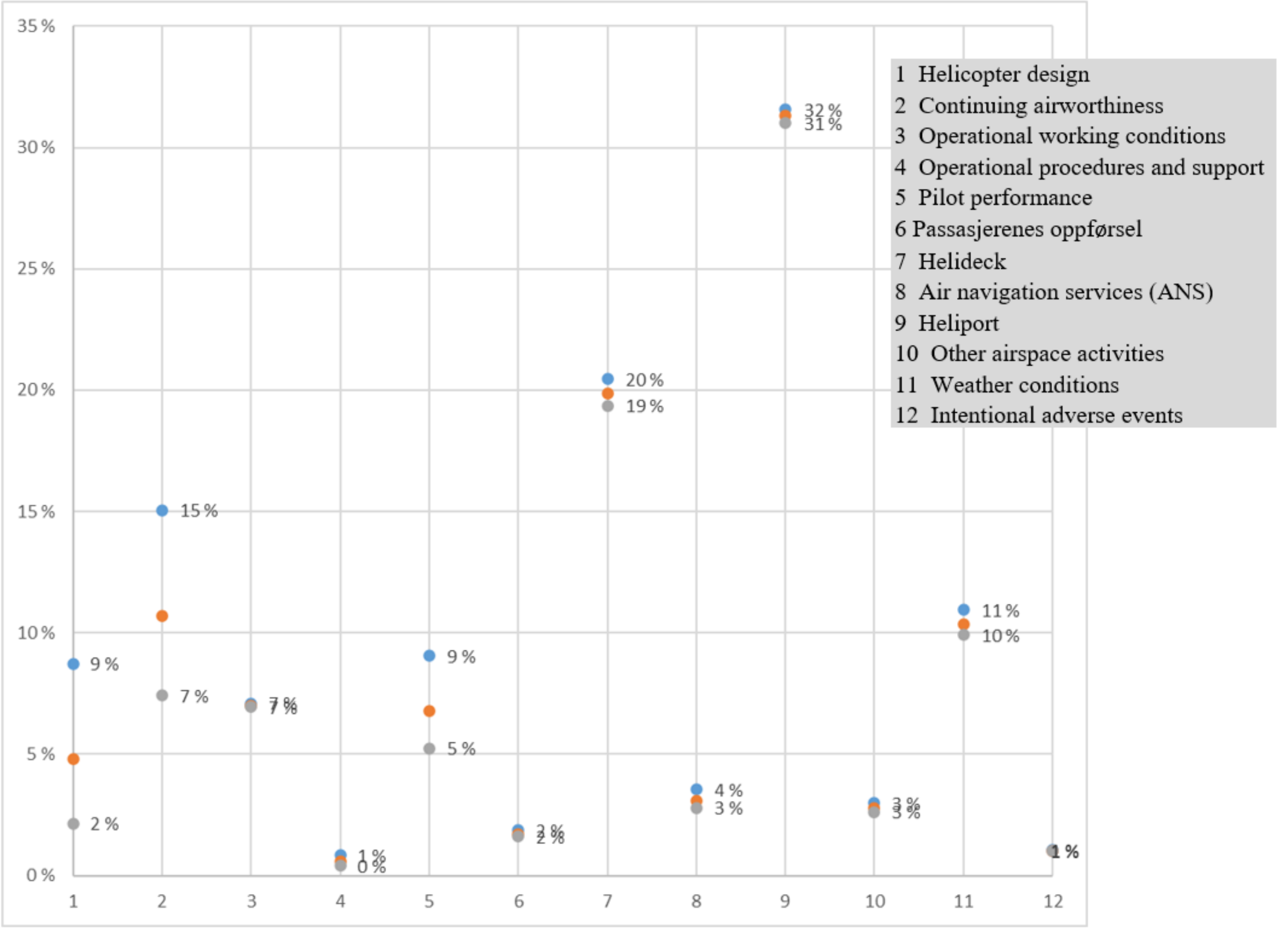


Figure B.13: RIF contributions and corresponding uncertainties – based on S-92 events only.

B.4.6 Analysis of the importance of the technical and operational consequence RIFs

The technical and operational consequence RIFs reflects the importance of each RIF to the number of fatalities for each accident category compared to the other RIFs. Each RIF has a value on the scale from 0 to 10, where 0 corresponds to a RIF without importance and 10 corresponds to a RIF with high importance. The results are presented in Table B.14 and are established based on expert judgements and the HSS-3 results combined with development trends in the period 2010–2020. The rightmost column gives a total value for each RIF and corresponds to a mean risk contribution (consequence value combined with frequency distribution 1 from Table B.9). It should be noted that a high importance of a consequence RIF corresponds to a "safety contribution" as well as a "risk contribution", while the contribution from a frequency RIF only refers to a "risk contribution".

The HSS-4 values are based on the HSS-3 values and the following adjustments:

- Two HSS-3 accident categories ('Landing/take-off heliport' and 'Landing/take-off helideck') are in HSS-4 merged into one accident category, A1. The RIF values for this accident category is estimated from the values of the two previous accident categories weighting 'Landing/take-off heliport' 20 % and 'Landing/take-off helideck' 80 %, as it is assumed that most of the landing/take-off accidents are related to helideck.

- The HSS-3 accident category 'System failure' has in HSS-4 been split into two accident categories, A2 and A3. The RIF values for 'System failure', have been evenly divided into the two accident categories A2 and A3. Hence, both A2 and A3 values are 50 % of the values from the former accident category 'System failure'.
- The HSS-3 RIF 'Weather, climate and other conditions' has in HSS-3 been split into two RIFs, 1.11 and 1.12. The RIF values for the HSS-3 RIF are distributed 20 % on RIF 1.11 and 80 % on RIF 1.12, as it is assumed that weather conditions have a significant influence on the consequence compared to other conditions.
- For accident category A8, no RIF values were specified in HSS-3. For this accident category, the values for the RIFs 1.1, 1.5, 1.6 and 1.7 are estimated from the mean value of the corresponding A1 and A4 values. RIF 1.9 is given a value of 10. The rest of the RIFs are given the value 0.
- In addition, **values in red** in Table B.14 are adjusted values due to identified development trends in the last ten years:
  - The values for RIF 1.6 are increased from 5 to 6 for accident categories A2 and A3 due to the new HOFO requirements related to evacuation and emergency landing on sea.
  - RIF 1.11 is also assumed to have an increased importance for the accident categories A1, A2, A3, and A5 compared to in HSS-3.
  - RIF 1.12 is expected to have a higher importance for offshore accidents compared to in HSS-3. For accidents categories that can occur offshore, i.e. A1, A2, A3, A5, A6, and A7, the values are therefore increased by 1.

Table B.14: Importance (0–10) of technical and operational consequence RIFs.

RIF		Accident category								Total
		A1 Landing / take-off aerodrome	**A2** Controlled emergency landing	**A3** Collision terrain/sea (LOC)	**A4** MAC	**A5** CFIT	**A6** Fire / Explosion/ Gas	**A7** Personal accident / behavior	**A8** Ground collision	
1.1	Impact absorption and cabin safety	9	4	4	2	9	6	0	5	**5,9**
1.2	Stability on sea	7	5	5	1	9	5	0	0	**5,4**
1.3	Survival equipment	6	5	5	2	8	6	0	0	**4,7**
1.4	Emergency location equipment	3	5	5	2	8	3	0	0	**3,8**
1.5	Pilots competence	7	5	5	3	7	10	8	5	**6,2**
1.6	Passenger competence	8	6	6	2	6	9	8	5	**6,5**
1.7	Emergency procedures	8	5	5	2	7	8	5	5	**5,9**
1.8	Helideck emergency preparedness	7	2	2	2	2	4	7	0	**3,5**
1.9	Heli-/Airport emergency preparedness	2	2	2	2	4	4	6	10	**2,8**
1.10	SAR helicopters	8	5	5	4	9	5	4	0	**5,6**
1.11	Other emergency preparedness	2	3	3	1	4	1	1	0	**2,2**
1.12	Weather conditions	5	5	5	3	7	4	3	0	**4,5**
	Sum	**66**	**48**	**48**	**25**	**80**	**65**	**45**	**30**	**57**

Det relative importance is more interesting, and is shown in Table B.15.

Table B.15: Relative importance of technical and operational consequence RIFs.

RIF		**Accident category**								**Total**
		A1 Landing / take-off aerodrome	**A2** Controlled emergency landing	**A3** Collision terrain/sea (LOC)	**A4** MAC	**A5** CFIT	**A6** Fire / Explosion/ Gas	**A7** Personal accident / behavior	**A8** Ground collision	
1.1	Impact absorption and cabin safety	2,5 %	1,1 %	1,1 %	0,4 %	2,3 %	1,6 %	0 %	1,5 %	**10 %**
1.2	Stability on sea	2,2 %	1,5 %	1,5 %	0,3 %	2,6 %	1,5 %	0 %	0 %	**9 %**
1.3	Survival equipment	1,6 %	1,2 %	1,2 %	0,5 %	2,1 %	1,6 %	0 %	0 %	**8 %**
1.4	Emergency location equipment	0,9 %	1,2 %	1,2 %	0,5 %	2,1 %	0,8 %	0 %	0 %	**7 %**
1.5	Pilots competence	1,6 %	1,1 %	1,1 %	0,6 %	1,5 %	2,1 %	1,7 %	1,1 %	**11 %**
1.6	Passenger competence	1,9 %	1,3 %	1,3 %	0,5 %	1,4 %	2,1 %	1,8 %	1,2 %	**11 %**
1.7	Emergency procedures	1,9 %	1,1 %	1,1 %	0,5 %	1,6 %	1,9 %	1,2 %	1,2 %	**10 %**
1.8	Helideck emergency preparedness	1,8 %	0,5 %	0,5 %	0,4 %	0,5 %	0,9 %	1,7 %	0 %	**6 %**
1.9	Heli-/Airport emergency preparedness	0,3 %	0,2 %	0,2 %	0,3 %	0,6 %	0,6 %	0,9 %	1,6 %	**5 %**
1.10	SAR helicopters	2,0 %	1,1 %	1,1 %	1,0 %	2,3 %	1,3 %	1,0 %	0 %	**10 %**
1.11	Other emergency preparedness	0,6 %	0,8 %	0,8 %	0,2 %	1,0 %	0,2 %	0,2 %	0 %	**4 %**
1.12	Weather conditions	1,2 %	1,1 %	1,1 %	0,8 %	1,8 %	1,0 %	0,8 %	0 %	**8 %**
	Sum	**18 %**	**12 %**	**12 %**	**6 %**	**20 %**	**16 %**	**9 %**	**6 %**	**100 %**

B.4.7 Organizational RIF contributons

The organizational RIFs on level 2 in the influence diagrams influence the technical and operational RIFs on level 1, and thereby influence the risk.

The simplified influence diagrams in Figure B.14 and Figure B.15 illustrate the influence from the organizational RIFs to the technical and operational RIF for frequency and consequence, respectively. The results are assessed by expert judgements and is common for all accident categories. Each arrow from an organizational RIF to a technical and operational RIF has a value in the area from 1 to 10, where 10 corresponds to significant contribution from the organizational RIF and 1 corresponds to limited contribution from the organizational RIF to the technical and operational RIF. The influences are also illustrated by the arrow thicknesses. It should be noted that the numbers are not normalised for each technical and operational RIF, since the contributions from the organizational RIF has been assessed by comparing contributions.

The values in Figure B.14 and Figure B.15 are based on the following considerations:

- The value from an organization to a technical and operational RIF is based on the extent of the technical and operational RIF the organization influences. E.g. for RIF 1.2 *Continuing airworthiness*, the maintenance organizations influence the Part-145 maintenance, and the helicopter operations influence the Part-M maintenance.

- The HSS-3 assessment was performed by a group of experts comprising experience from several organizations. First, a common understanding of the definitions of the RIFs was established. Then, a common value for each influence was achieved.
- The HSS-4 assessment is based on the HSS-3 values. Some values have been updated due to updates of the influence diagrams and RIFs, some values have been updated due to development trends since HSS-3 and some values have been updated from comparison with other values.

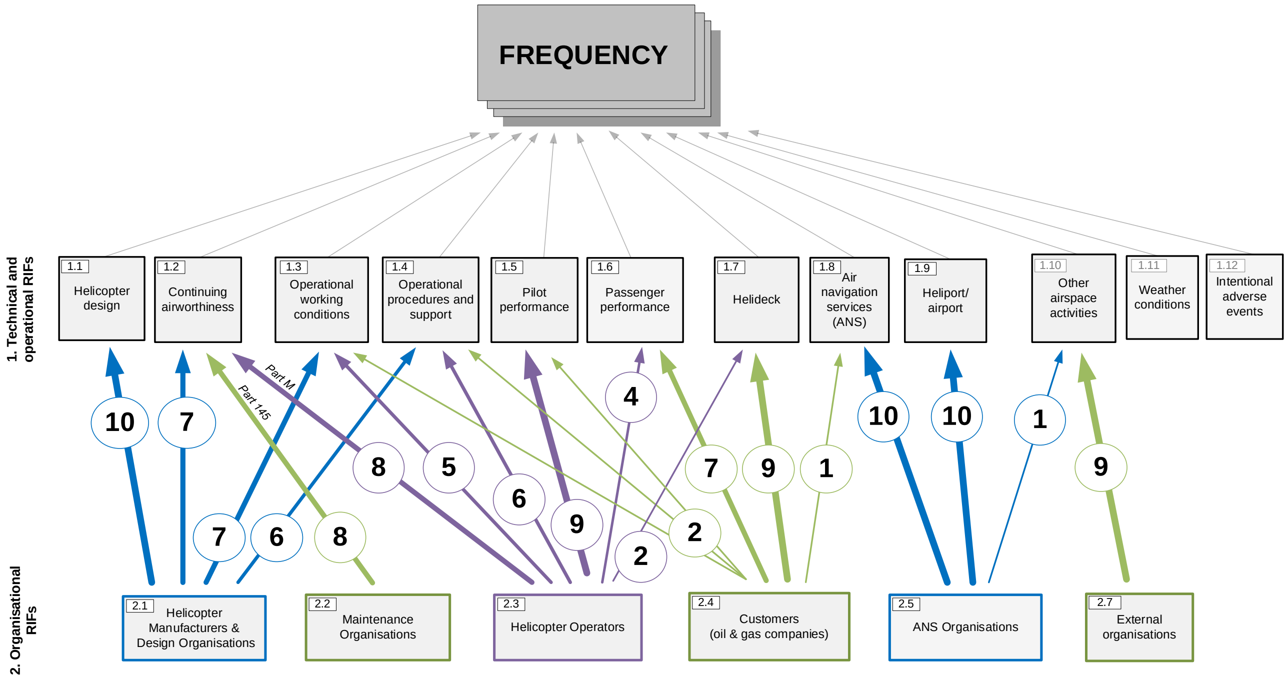


Figure B.14: Organizational RIFs contribution to technical and operational RIFs for frequency. (Arrow thickness reflects the significance of the contribution. Colours are used to increase readability).

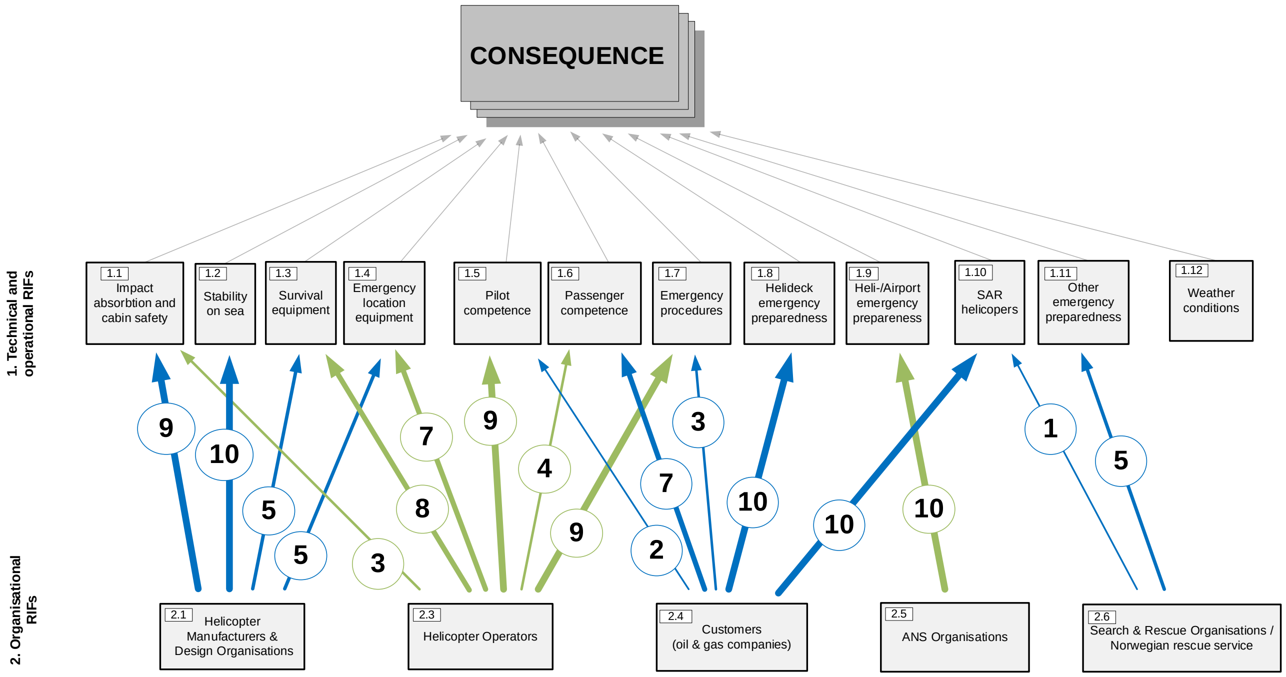


Figure B.15: Organizational RIFs contribution to technical and operational RIFs for consequence. (Arrow thickness reflects the significance of the contribution. Colours are used to increase readability).

The relative risk (frequency and consequence) influences of the organizational RIFs are quantified by combining the risk contribution from the technical and operational RIFs (on level 1) with the influence from the organizational RIFs. The result is presented in Figure B.16.

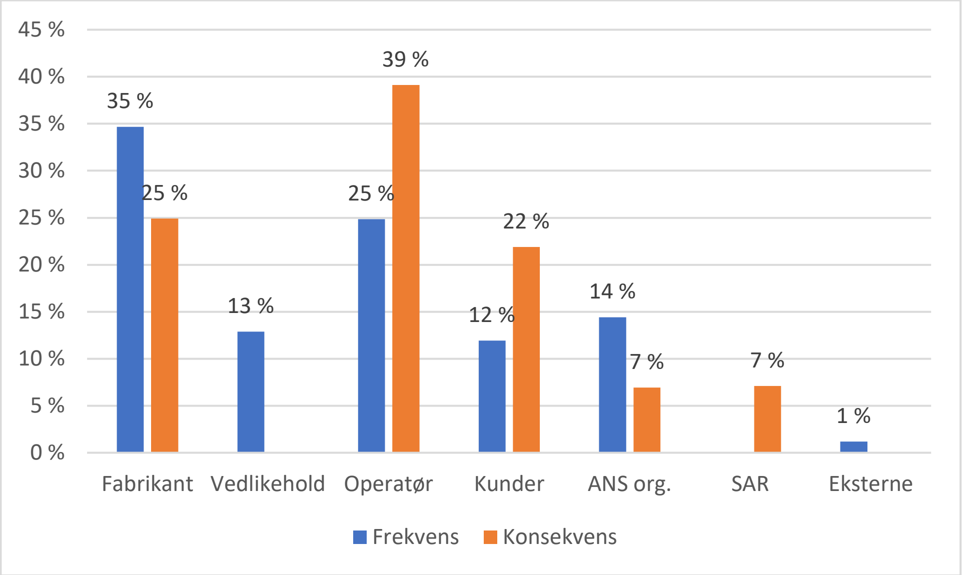


Figure B.16: Organizational RIFs influence on frequency and consequence.

B.5 References

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Flight Safety Foundation, 2016. Basic Aviation Risk Standard. Offshore Helicopter Operations. Safety Performance Requirements. Version 3, December 2016.

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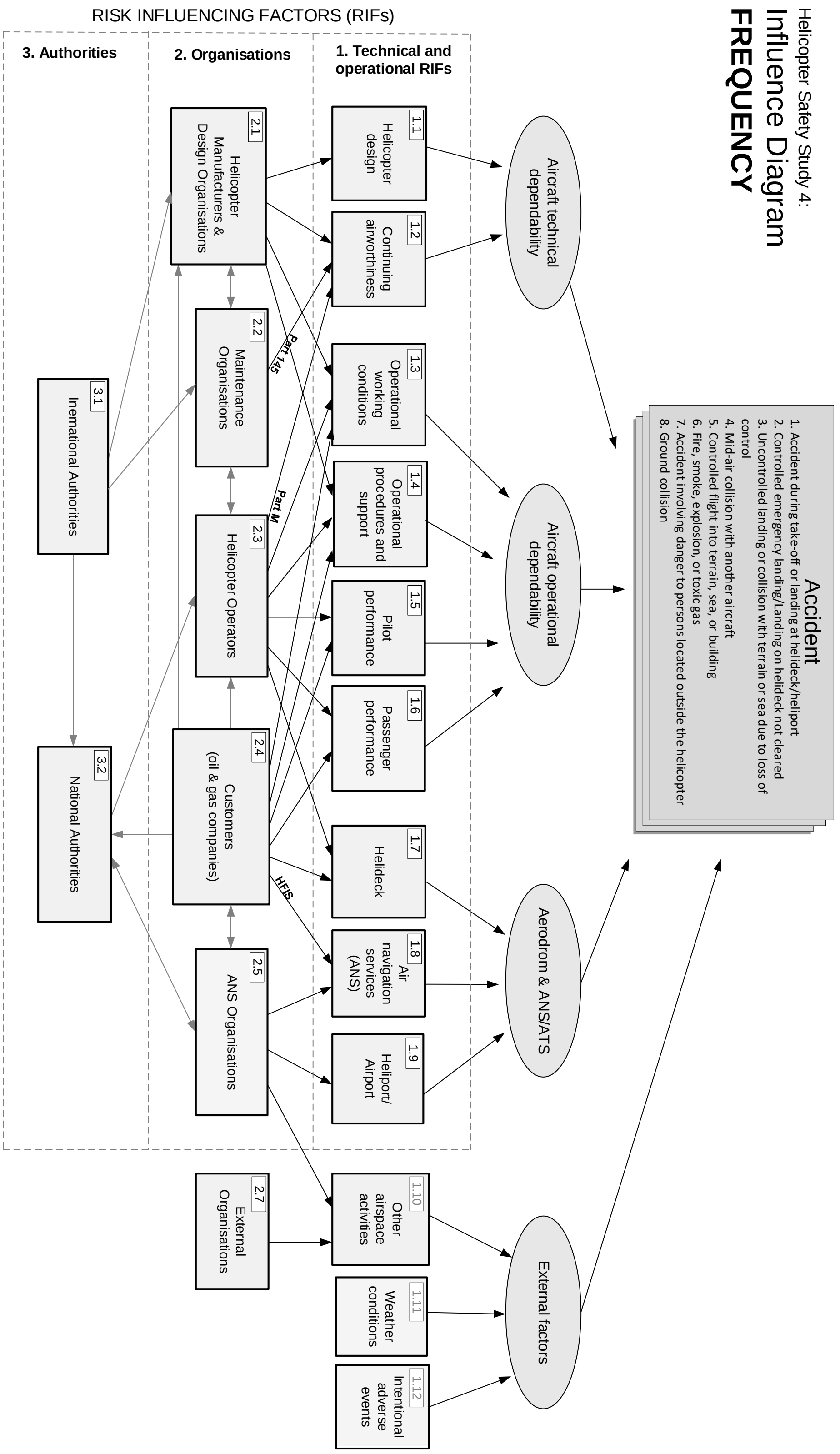
C DEFINITIONS AND DESCRIPTIONS OF RIFS FOR FREQUENCY



The technical and operational RIFs for frequency are described in detail below.

For each RIF a **definition** of the RIF is given together with a list of RIF **contributors** comprised by the given RIF and that may affect the accident frequency.

C.1 Level 1 – Technical and operational RIFs

F1.1: Helicopter design

Definition: The suitability, quality and reliability of the aircraft design and equipment delivered from the manufacturer (type certificate holder). Includes major repairs and modifications.

Contributors:
• Aircraft airframe and material quality. (NOTE 1) • Systems' and equipment's reliability, maintainability, and suitability. • Helicopter performance, i.e. suitability with regards to type of operation, location, meteorological conditions, weight capacity, distance capacity, manoeuvring, etc. • Spare parts' availability (and quality) from helicopter manufacturer. • Design and maintenance documentation quality. (NOTE 2) • Major design and modifications quality. (NOTE 3)

NOTE 1: User-friendliness of cockpit design and other elements pertaining to ergonomic design and physical work environment are considered as part of RIF F1.3. *Operations Working Conditions*. Consequence reducing factors such as crashworthiness and emergency equipment are considered as a *consequence* RIF, ref. RIF C1.1.
NOTE 2: Aircraft Flight Manual and other operations documentation issued by the manufacturer are considered as part of RIF F1.4 *Operations procedures*.
NOTE 3: Maintenance and repair is comprised by RIF F1.2 *Continuing airworthiness*, including maintenance procedures, working conditions etc.

F1.2: Continuing Airworthiness

Definition: *Continuing airworthiness* means all of the processes ensuring that, at any time in its operating life, the aircraft complies with the airworthiness requirements in force and is in a condition for safe operation (EASA Reg 2042/2003). The aircraft operators contribute to continuing airworthiness by maintenance and modification – either by its own maintenance organization, or by contracting out maintenance and inspection to an approved maintenance organization.
Maintenance is here defined as anyone or combination of overhaul, repair, inspection, replacement, modification or defect rectification of an aircraft or component, with the exception of pre-flight inspection[14] (EASA Reg 2042/2003).

Contributors:
• Scheduled maintenance activities; qualities of tasks specified on maintenance program and maintenance

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[14] Pre-flight inspection considered as part of RIF F 1.4 Operational procedures and support.

manuals.
- Unscheduled maintenance activities; organization support for aircraft on ground (AOG), access to spare parts and materials, quality assurance, etc.
- Maintenance programme, procedures, manuals, drawings and equipment – quality and availability.
- Maintenance Organization Exposition (MOE) quality and follow-up.
- Spare parts' availability (and quality) at maintenance organization.
- Quality assurance of maintenance tasks.
- Competence; knowledge, skills, experience, etc. of technicians.
- Education, (recurrent) training and licensing of technicians / engineering staff.
- Working conditions for technicians; health and safety regulations, ergonomics, etc.
- Physical working conditions; temperatures, noise, vibrations, etc.
- Psychological working conditions; fatigue, workload, working schedules, responsibility, stress, economic concerns within organization, negligence, etc.

F1.3: Operators working conditions

Definition: The pilots' ability to perform their assigned duties/operations.

Contributors:

- Working conditions within helicopter; man-machine interface, ergonomics, access to necessary equipment, etc.
- Pilot communication equipment.
- Physical working conditions within helicopter; temperatures, noise, vibrations, clothing, etc.
- Negative psychological working conditions; fatigue, workload, working schedules, responsibility, stress, economic concerns, etc. within organization.

F 1.4: Operational procedures and support

Definition: Flight operational procedures that cover all aspects of flying an aircraft (other than maintenance procedures which is part of RIF F1.2 *Continuing airworthiness*).

The most relevant procedures are:
- Operations Manual (Part A and Part B) incl. Standard Operating Procedures (SOPs)
- Quick reference handbook (QRH) incl. Checklists
- Aircraft/Helicopter Flight Manual (AFM)

Contributors:

- Quality, user-friendliness, availability, up to date, etc. of the relevant procedures.
- Reliability and user-friendliness of electronic flight bag (EFB) / electronic tablet
- Implementation and follow-up of operational restrictions related to helicopter activity (e.g. night operations).
- Pre-flight inspection before take-off – extent and quality. The *pre-flight inspection* is the inspection carried out before flight to ensure that the aircraft is fit for the intended flight (EASA Reg 2042/2003).

F1.5: Pilot competence

Definition: Factors affecting the performance of the pilots.

Contributors:

- Competence; knowledge, skills, experience, etc.
- Education and (recurrent) training.
- Situational awareness; e.g. reactions to unexpected events.
- Learning aptitude, communication ability and experience sharing.
- Individual physiological and psychological factors; fatigue, stress (tolerance), emotional state, hunger, thirst, negligence, etc.

F1.6: Passenger performance

Definition: The passenger's ability to adhere to procedures and norms for safe performance, both during flight, embarking and disembarking. Particularly related to handling of personal belongings on heliport/ helideck, opening/closing of helicopter doors and walking distance to helicopter and tail rotor on heliport/ helideck.

Contributors:

- Competence; knowledge, experience, willingness, etc.
- Situational awareness; e.g. reactions to unexpected events.
- Learning aptitude, communication ability and experience sharing.
- Individual physiological and psychological factors; fatigue, stress (tolerance), emotional state, negligence, etc.

F1.7: Helideck

Definition: The characteristics of the helideck and the ability of the helideck personnel (HLO, etc.) while the aircraft is operating on or near the helideck.

Contributors:

- Helideck design quality; size, railing, lighting, marking, mooring, etc.
- Helideck access.
- Moving helideck and possibility to compensate for helideck motions.
- Helideck operating procedures (e.g. ground handling and fuelling) and their quality.
- Availability and quality of helideck equipment, systems (incl. man-machine interface) and support.
- Helideck personnel availability and competence.
- Helideck personnel's ability to communicate with pilots (e.g. communication of weather information (METAR) or other information).
- Helideck personnel's individual physiological and psychological factors; fatigue, stress (tolerance), emotional state, negligence, etc. Situational awareness; e.g. reactions on unexpected events, of helideck personnel.
- Helideck location; turbulence, exhaust, obstacles, etc.

F1.8: Air navigation services (ANS)

Definition: The coverage and quality of air navigation services (ANS).

The ANS contributions relates to (ref. also Figure C.1 below):

- Air traffic services (ATS)[15]:
    - Air traffic control (ATC) service; to prevent collisions in controlled airspace by instructing pilots where to fly.
    - Flight information service (FIS) – helicopter flight information service (HFIS) and aerodrome information service (AFIS); to provide information useful for safe and efficient conduct of flights.
    - Air traffic advisory service; provided within advisory airspace to ensure separation, insofar as practical, between aircraft which are operating on instrument flight rules (IFR) flight plans.
- Communication, navigation, and surveillance (CNS) services (radio, radar).
- Meteorological services for air navigation.

NOTE: Search and rescue and ADS-B and alerting service are considered as consequence influencing factors, ref. RIF C1.9.

Contributors:
• Sufficient radio quality. • Sufficient radar coverage. • Sufficient extent of ATS airspace classes[16] and controlled airspaces[17] (CTAs). • Working conditions; man-machine interface, ergonomics, access to necessary equipment, etc. • Quality of operating procedures, equipment, systems, and instruments used by ANS personnel. • Competence; knowledge, skills, experience, etc. of ANS personnel. • Education and (recurrent) training of ANS personnel. • Stress tolerance. • Situational awareness; e.g. reactions to unexpected events, of ANS personnel. • Learning aptitude, communication ability and experience sharing by ANS personnel. • Traffic density and/or amount of specific types of operations – influencing workload for ANS personnel. • Physical working conditions; fatigue, temperatures, etc. • Psychological working conditions; workload, working schedules, responsibility, stress, economic concerns within organization, negligence, etc.

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[15] An ATS route is a specified route designed for channeling the flow of air traffic as necessary for the management of air traffic operations..

[16] https://www.skybrary.aero/index.php/Classification_of_Airspace

[17] Controlled airspace is an airspace of defined dimensions within which air traffic control services are provided to IFR flights and to Visual Flight Rules (VFR) flights in accordance with the airspace classification.

Figure C.1: The ANS system and its components according to ICAO.[18]

F1.9: Heliport

Definition: The characteristics of the heliport and the ability of the heliport/airport personnel while the aircraft is operating on or near the heliport.

Contributors:

- Heliport/airport design quality; layout, size, lighting, marking, etc.
- Heliport/airport operating procedures (e.g. ground handling and fuelling) and their quality.
- Availability and quality of heliport/airport equipment, systems (incl. man-machine interface) and support.
- Heliport/airport personnel availability and competence (e.g. with respect to assistance, fuelling, dangerous goods, etc.)
- Heliport/airport personnel's ability to communicate with pilots.
- Situational awareness; e.g. reactions to unexpected events, of heliport/airport personnel.
- Heliport location weaknesses; turbulence, obstacles, inference from other (ground) traffic, etc.
- Vehicles, trucks, and persons operating on the heliport.
- Human factors/errors of heliport/airport personnel.

NOTE: Air Traffic control activities are covered by RIF F1.8 *ANS*.

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[18] https://www.researchgate.net/figure/The-aviation-system-and-its-components-AnS-ATS-ATM-ATC-according-to-ICAO-2001-doc_fig1_270584102

F1.10: Other activities

Definition: Activities surrounding the helicopter route, such as other air and sea traffic, that affect the helicopter operation.

Contributors:

- Other air traffic that may influence the risk for mid-air collisions.
    - Other helicopters
    - Fixed-wings
    - Military air traffic
    - Drones
- Nearby facilities (NOTE):
    - Ships drifting into approach or climb-out areas that can be dangerous.
    - Short distances between facilities increases the probability for landing on wrong facility.
- Navigational aids (navaids).

* During an emergency landing, nearby rigs/ships are preferred above landing on sea.

F1.11: Meteorological conditions

Definition: Meteorological conditions affecting helicopter operation.

Contributors:

- Clouds, fog, precipitation, darkness/light, etc. influencing navigation.
- Wind, turbulence, polar lows, snow, etc.
- Ice build-up on rotors and airframe degrading aircraft performance.
- Lightning strikes or static discharge damaging the helicopter and/or upsetting navigational equipment.
- Sea state (high sea state endangers emergency landing on sea).

F1.12: Unwanted intended acts

Defintion: Unwanted intended acts threatening the helicopter safety; cyberattacks, terrorism, sabotage, etc.

Contributors:

- Cyberattacks, terrorism, sabotage, etc.
- Quality and follow-up of security, security risk analysis, security barriers, etc.
- Ability to reveal and act upon unwanted intended acts.

C.2 Level 2 – Organizational RIFs

There organizational RIFs on level 2 for frequency are described below. For each RIF the definition and a table of (positive) contributors are presented. In addition, for each contributor of the RIF is the affected (influenced) RIFs on level 1 is ticked off in the contributor table. The influence on other level 2 RIFs and on level 3 RIFs are also described.

F2.1: Helicopter manufacturers & Design organizations

Definition: The way the helicopter manufacturers or product and design organization plan and carry out their business in general, to the extent that this has a direct or indirect influence on offshore helicopter flight safety.

Contributors and influence on level 1:

Contributors	⇨ Frequency RIFs			
	1.1	**1.2**	**1.3**	**1.4**
• Workforce and level of competence and experience. • Management practices. • Safety culture. • Quality system. • Safety management system (SMS). • Quality of follow up on customers and products. • Development of new helicopter types, cockpit, and equipment design. • Quality of learning / continuous improvement processes. • Influence from trade unions.	x	x	x	x
• Good financial situation and market situation (demand for new helicopters).	x	x	x	
• Quality of instructions and drawings for installation/repair work.	x	x		
• Quality of analysis, calculations and tests.	x			
• Development of basic maintenance programs. • Quality of maintenance manuals and maintenance programmes.		x		
• Quality and timeliness of safety related information to the maintenance organizations (and helicopter operators). • Development of aircraft flight manuals.		x		x
• Pilot and operator involvement. • Man-machine interface.			x	x
• Quality of operational procedures and support.				x

Influence on level 2:

The manufacturers and design organizations influence the maintenance organizations (RIF F2.2) mainly through the required maintenance, recommended maintenance programmes and support.

F2.2: Maintenance organizations

Definition: The way the helicopter operators plan and carry out their business in general, to the extent that this has a direct or indirect influence on offshore helicopter flight safety.

Contributors and influence on level 1:

	⇨ Frequency RIFs
Contributors	**1.2**
• Workforce and level of competence and experience. • Management practices. • Safety culture and policy (willingness to pay for extra safety) • Quality system. • Safety management system (SMS). • Acceptance of contractual conditions with the operator (economical compensation, regularity and punctuality requirements, obligation to satisfy customer's immediate needs, etc.) • Quality of establishing and updating of maintenance procedures. • Regime for selection, training and recurrent training of technicians and other personnel involved in the maintenance. • Implementation of maintenance program and its further adaptation, revision, and follow-up. • Responsibility to ensure that modifications and repairs are in compliance/conformance with EASA CS-29. • Extent of in-service experience reporting to the Authority. • Quality of learning / continuous improvement processes.	**x**

Influence on level 2:
The maintenance organizations influence the helicopter manufacturers & design organizations mainly by feedback and the helicopter operators mainly by the quality and ability to perform the required maintenance.

F2.3: Helicopter operators

Definition: The way the helicopter operators plan and carry out their business in general, including the control of maintenance.

Contributors and influence on level 1:

	⇨ Frequency RIFs				
Contributors	**1.2**	**1.3**	**1.4**	**1.5**	**1.6**
• Workforce and level of competence and experience. • Management practices. • Safety culture and policy (willingness to pay for extra safety). • Quality system. • Safety management system (SMS). • Safety risk management. • Extent of in-service experience reporting to the Authority.	**x**	**x**	**x**	**x**	**x**

• Quality of learning / continuous improvement processes. • Influence from trade unions.					
• Flight data analysis and operational flight data monitoring (FDM).	**x**		**x**	**x**	
• Attention on maintenance. • Implementation of maintenance program and its further adaptation, revision and follow-up. • Responsibility and capability to ensure that modifications and repairs are in compliance/conformance with EASA CS-29.	**x**				
• Crew seats and cockpit equipment.		**x**			
• Quality of establishing and updating operational manuals and procedures.			**x**		
• Regime for selection, training and recurrent training of pilots. • Crew resource management (CRM). • Planning and scheduling of flights. • Acceptance of contractual conditions with the customer (economical compensation, regularity and punctuality requirements, obligation to satisfy customer's immediate needs as opposed to regularly planned flights, long term/short term contract period, penalties, etc.)				**x**	
• Quality of passenger briefing.					**x**

Influence on level 2:
The helicopter operators influence the maintenance organizations mainly by contracts, follow-up of maintenance programs and support request.

F2.4: Customers

Definition: The way the customers plan and carry out their business in general, to the extent that this has a direct or indirect influence on offshore helicopter flight safety.

Contributors and influence on level 1:

Contributors	**⇨ RIFs**				
	1.3	**1.4**	**1.6**	**1.7**	**1.8**
• Management practices. • Quality system. • Safety culture; including willingness to invest in safety measures and to pay for extra safety. • Safety management system (SMS). • Helicopter transport contracts. • Co-operation with the operators. • Formulation of safety objectives. • Quality of learning / continuous improvement processes. • Organizations performing education and coursing. • Influence from trade unions.	**x**	**x**	**x**	**x**	**x**
• Regime for training and retraining of passengers. • Quality of passenger information.			**x**		
• Quality and follow-up on helideck design, procedures and other activities affecting helicopter operations at/near helideck. • Helideck personnel requirements.				**x**	
• Quality and follow-up on HFIS organizations.					**x**

Influence on level 2:
The customers influence the helicopter operators mainly by two main aspects. The first is the attention and follow-up on helicopter flight safety (flight safety report requirements, quality audits, safety reviews, corrective action requirements). The second is the contractual conditions imposed (economical compensation, regularity and punctuality requirements, obligation to satisfy customer's immediate needs as opposed to regularly planned flights, long term/short term contract period, penalties). This is to some extent affected by the financial situation of the customers, the demand for new helicopters and helicopter types/technology driven by the customers. The demand for new helicopters and new technology driven by the customer may also influence the manufacturers to some extent.

The customers cooperate with the ANS organizations with respect to HFIS.

Influence on level 3:
The customers influence the authorities through Offshore Norge and their guidelines (e.g. ON-066), from which several recommendations have now been adopted by the authorities.

F2.5: ANS organizations

Definition: The way the ANS organizations plan and carry out their tasks in general, to the extent that this has a direct or indirect influence on offshore helicopter flight safety.

Contributors and influence on level 1:

	⇨ Frequency RIFs	
Contributors	**1.8**	**1.9**
• Quality of learning / continuous improvement processes.	x	x
• Workforce and level of competence and experience. • Follow-up of working conditions (e.g. working schedules, workload, access to necessary equipment, resting shelter, ergonomics, man-machine-interface, temperature, light, noise). • Management practices. • Safety culture. • Quality system, including deviation control. • Safety management system (SMS). • Programme and regime for selection, training and retraining of ANS personnel. • Attention and follow-up on helicopter flight safety. • Financial situation and the ability to implement new systems and instruments.	x	
• Authority to instruct the personnel on heliports.		x

Influence on level 2:
The ANS organizations influences the customers through the HFIS units where ANS personnel is hired by the customers.

Influence on level 3:
The ANS organizations influence mainly the authorities by development of new safety solutions (e.g. ADS-B) that are considered/adapted as requirements. Also, the ANS organization may ask the authorities to deny ANS related dispensations from the operators.

F2.8: External organizations

Definition: The way other external organizations, influencing the surrounding activities, plan and carry out tasks that can affect the helicopter operation, to the extent that this has a direct or indirect influence on flight safety.

Contributors and influence on level 1:

Contributors	⇨ Frequency RIFs
	1.10
• The Air Forces (national and international) carrying out military exercises in the same airspace as helicopter activity takes place • Organizations responsible for ship traffic in areas where helicopters are flying. • Organizations responsible for crane activities around heliports/airports. • Quality of learning / continuous improvement processes.	**x**

C.3 Level 3 – Regulatory related RIFs

There RIFs on level 3 for frequency are described below.

F3.1: International authorities

Definition: The influence of international authorities on offshore helicopter safety.

Contributors:

Main contributor:	• The European Aviation Safety Agency (EASA)
Other major contributors:	• The International Civil Aviation Organization (ICAO) • European Organization for the Safety of Air Navigation (Eurocontrol)
Minor contributors:	• The Federal Aviation Administration (FAA) • Civil Aviation Authority (CAA) UK • Air Accident Investigation Branch (AAIB) UK

Most of the contributors in the above table are presented below.

EASA

EASA is an agency of the European Union established in 2002 by Regulation (EC) No 216/2008 of the European parliament and the Council in order to ensure a high and uniform level of safety in civil aviation, by the implementation of common safety rules and measures. EASA has taken over the responsibilities of the former Joint Aviation Authorities (JAA) system which ceased on 30 June 2009. However, it is not a successor agency in legal terms since it functions directly under EU statute. The main difference between EASA and the JAA is that EASA is Regulatory Authority which uses National Aviation Authorities (NAAs) to implement its Regulations whereas the JAA relied upon the participating NAAs to apply its harmonised codes without having any force of law at source.

The main responsibilities of EASA include:

Contributors
• Expert advice to the EU on the drafting new legislation. • Developing, implementing and monitoring safety rules, including inspections in the Member States. • Type-certification of aircraft and components, as well as the approval of organizations involved in the design, manufacture and maintenance of aeronautical products. • Certification of personnel and organizations involved in the operation of aircraft. • Certification of organizations providing pan-European ATM/ANS cervices. • Safety analysis and research, including publication of an Annual Safety Review.

Norway is a member of EASA and part of the European Common market in the field of aviation through the European Economic Area (EEA) Agreement. Within the EEA all countries have common safety regulations issued by the European Parliament and Council as well as the European Commission.

EASA regulations of particularly interest with respect to offshore helicopter are:

- CS-29 – Certification specifications large rotorcraft

- CS-FSTD(H) – Helicopter Flight Simulation Training Devices
- Annexes of Continuing Airworthiness Regulation (EU) No 1321/2014[19]:
    - Part-M – Continuing airworthiness requirements
    - Part-145 – Maintenance organization approvals
    - Part-66 – Maintenance certifying staff
    - Part-147 – Organizations training Part 66 licence applicants
- Annexes of Commission Regulation on Aircrew (No 1178/2011):
    - Part-FCL – Flight Crew Licencing
- Annexes of Commission Regulation on Air Operations (No 965/2012) or EASA OPS:
    - Part-ORO – Organisational requirements
    - Part-CAT – Commercial air transport
    - Part-SPA – Operations requiring specific approvals
- Commission Regulation EU No.748/2012[20] Part-21 on acceptable means of compliance and guidance material for the airworthiness and environmental certification of aircraft and related products, parts and appliances, as well as for the certification of design and production organizations.
    - DOA (Design Organization Approval).
    - POA (Production Organization Approval).

ICAO

ICAO is a united nation specialized agency for civil air traffic. ICAO works with the 193 Member States and industry groups to reach consensus on international civil aviation Standards and Recommended Practices (SARPs) and policies in support of a safe, efficient, secure, economically sustainable and environmentally responsible civil aviation sector. These SARPs and policies are used by ICAO Member States to ensure that their local civil aviation operations and regulations conform to global norms. The European regulations prevailing in Norway are mainly based on the SARPs recommendations. SARPS are contained in 19 Annexes[21]:

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[19] This regulation has been implemented in Norwegian law by regulation no. 488 of 7 May 2015 on continuing airworthiness for aircrafts and aircraft products, parts, and equipment, and on the approval of organizations and personnel participating in these tasks (the maintenance regulations).

[20] This regulation has been implemented in Norwegian law by regulation 4 March 2013 no. 252 on airworthiness and environmental certification of aircrafts and design and production organizations (certification regulations).

[21] The ICAO SARPS Annexes (2019):

- Annex 1 - Personnel Licensing
- Annex 2 - Rules of the Air
- Annex 3 - Meteorological Services
- Annex 4 - Aeronautical Charts
- Annex 5 - Units of Measurement
- Annex 6 - Operation of Aircraft
- Annex 7 - Aircraft Nationality and Registration Marks
- Annex 8 - Airworthiness of Aircraft
- Annex 9 - Facilitation
- Annex 10 - Aeronautical Telecommunications
- Annex 11 - Air Traffic Services
- Annex 12 - Search and Rescue
- Annex 13 - Aircraft Accident and Incident Investigation
- Annex 14 - Aerodromes
- Annex 15 - Aeronautical Information Services
- Annex 16 - Environmental Protection

ICAO has seven regional offices to follow up the implementation of the Air Navigation Plans, and the European and North Atlantic (EUR/NAT) office is located in Paris. The Nordic countries, together with Latvia and Estonia, have a separate delegation to ICAO, NORDICAO.

Aviation safety is at the core of ICAO's fundamental Objectives. This includes development of global strategies contained in the Global Aviation Safety Plan and Air Navigation Plan, monitoring of safety trends and indicators, implementation of targeted safety programmes to address safety and security.

Eurocontrol

Eurocontrol is an intergovernmental organization with about 40 member states, including Norway, that supports the European Commission, EASA and National Supervisory Authorities in their regulatory activities. Eurocontrol is committed to building a Single European Sky that will deliver the air traffic management (ATM) performance required for the twenty-first century and beyond. The objective is to harmonise and integrate air navigation services in Europe, aiming at the creation of a uniform ATM system for civil and military users, in order to achieve the safe, secure, orderly, expeditious and economic flow of traffic throughout Europe, while minimising adverse environmental impact.

In order to achieve a uniform European air traffic management system, Eurocontorl Member States agreed in 1997 to "implement a mechanism, separate from the service provision, for the multilateral development and harmonization of a safety regulatory regime in the field of air traffic management within a total aviation safety system approach". This mechanism established a Safety Regulation Commission (SRC) as an independent body to Eurocontrol. The SRC is responsible for development and uniform implementation of harmonised safety regulatory objectives, development of target levels of safety and standards of safety performance. Eurocontrol approves European Safety Regulatory Requirements (ESARRs)22. Where necessary, SRC establishes procedures for the uniform national application of ESARRs. The Eurocontrol member states are responsible for the transposition of the ESARR provisions into national safety regulatory requirements. The ESARR implementation process is supported by dedicated guidance and support material developed by the SRC and Eurocontrol.

FAA

FAA is the agency of the United States Department of Transportation responsible for the regulation and oversight of civil aviation within the U.S., as well as operation and development of the National Airspace System. Its primary mission is to ensure safety of civil aviation. Along with EASA the FAA is one of the two main agencies world-wide responsible for the certification of aircraft.

- Annex 17 - Security
- Annex 18 - The Safe Transportation of Dangerous Goods by Air
- Annex 19 - Safety management

Annexes 2, 5, 7 & 8 contain international standards and no recommended practices. The remaining 15 Annexes contain both. It should be noted that ICAO Standards do not preclude the development of national standards which may be more stringent than those contained in an Annex.

[22] ESARRs in force 2019:

- ESARR1: Safety Oversight in ATM.
- ESARR2: Reporting and Assessment of Safety Occurrences in ATM.
- ESARR3: Use of Safety Management System by ATM Service Providers. BSL A 1-9. Forskrift om bruk av system for sikkerhetsstyring innen flysikringstjenesten og bakketjenesten
- ESARR4: Risk Assessment and Mitigation in ATM. BSL A 1-10. Forskrift om bruk av system for sikkerhetsvurdering og sikkerhetsoppfølgingsplaner innen flysikringstjenesten
- ESARR5: ATM Services' Personnel
- ESARR6: Software in ATM Systems

The responsibilities of the FAA include encouraging and developing civil aeronautics, new aviation technology, and systems of air traffic control and navigation for both civil and military aircraft.

Part 29 of standard airworthiness certification regulations (title 14) is titled 'Transport category rotorcraft for helicopter'. FAA has also published a technical manual for applicants who are preparing for their helicopter pilot certificate, 'Helicopter Flying Handbook' (2012).

UK CAA
UK CAA is a public corporation, established as an independent specialist aviation regulator. Most aviation regulation and policy are harmonised across the world to ensure consistent levels of safety and consumer protection. Offshore helicopter operation is an important area of attention for safety improvement for UK CAA. Recognising the continuing economic pressures on oil and gas production, specifically the focus on reducing operational costs, operators and regulators must ensure safety remains a focus and priority for continuous improvement. UK CAA continues the work with industry and regulators to ensure that the actions and recommendations from the UK CAA offshore helicopter safety review (CAP 1145) are completed and embedded in normal working practices.

Influence on level 2:
The international authorities influence the helicopter manufacturers, design organizations and maintenance organizations by regulations and recommendations.

Influence on level 3:
The international authorities influence the Norwegian authorities, CAA Norway. National regulations are usually founded on international safety regulations and standards which CAA Norway is responsible for issuing and enforcing.

It is the responsibility of each national authority to participate in the issuing and to enforce national safety regulations and standards within their area of authority. The effect of these regulations and standards should be regularly monitored and analysed. Adjustments of the regulations and standards should be made on a proactive basis, rather than as a reactive approach regarding aircraft safety.

F3.2: National authorities

Definition: The influence of Norwegian authorities on offshore helicopter safety.

Contributing organizations:

Main organization:	• CAA Norway
Minor organizations:	• Norway's Ministry of Transport and Communications • The Petroleum Safety Authority (PSA) Norway • The Norwegian Maritime Directorate (NMD) • Accident Investigation Board (AAIB) Norway

Contributors and influence on level 1:

Contributors	⇨ Frequency RIFs					
	F1.1	**F1.2**	**F1.5**	**F1.7**	**F1.8**	**F1.9**
• Workforce and level of competence and experience. • Management and organization. • Implementation and update of regulations and standards. • Interface between different regulations (petroleum and aviation), and the integration of risk analyses/assessments for helicopter and petroleum activities. • Co-operation between the oversight authorities.	**x**	**x**	**x**	**x**	**x**	**x**
• Ensuring continuing airworthiness and design requirements are met both prior to, and subsequent to, approval of major modifications/repairs, ref. EASA requirements for the design and production organizations.	**x**					
• Distributing Airworthiness Directives on necessary continuing airworthiness information (on modifications) to every operator of relevance. • Approval and survey of modifications and repair.		**x**				
• Approval and survey of pilot performance (license issuing) and training system and programs.			**x**			
• Approval and survey of Helideck design, operating procedures and personnel.[23]				**x**		
• Approval and survey of ANS installations and personnel.					**x**	
• Approval and survey of heliports/airports design, operating procedures and personnel.						**x**

Influence on level 2:
CAA Norway are responsible for certification and oversight of helicopter operators and ANS organizations.

Influence on level 3:
CAA Norway and Norway's Ministry of Transport and Communications take part in international authorities such as EASA and to promote Norwegian interests. However, this influence is considered as limited compared to the influence the opposite way.

Within offshore helicopter transport, Norway and UK have a common interest to reflect the special aspects of offshore helicopter transport. Thus, it is beneficial if both countries co-ordinate their work within and towads EASA and Eurocontrol.

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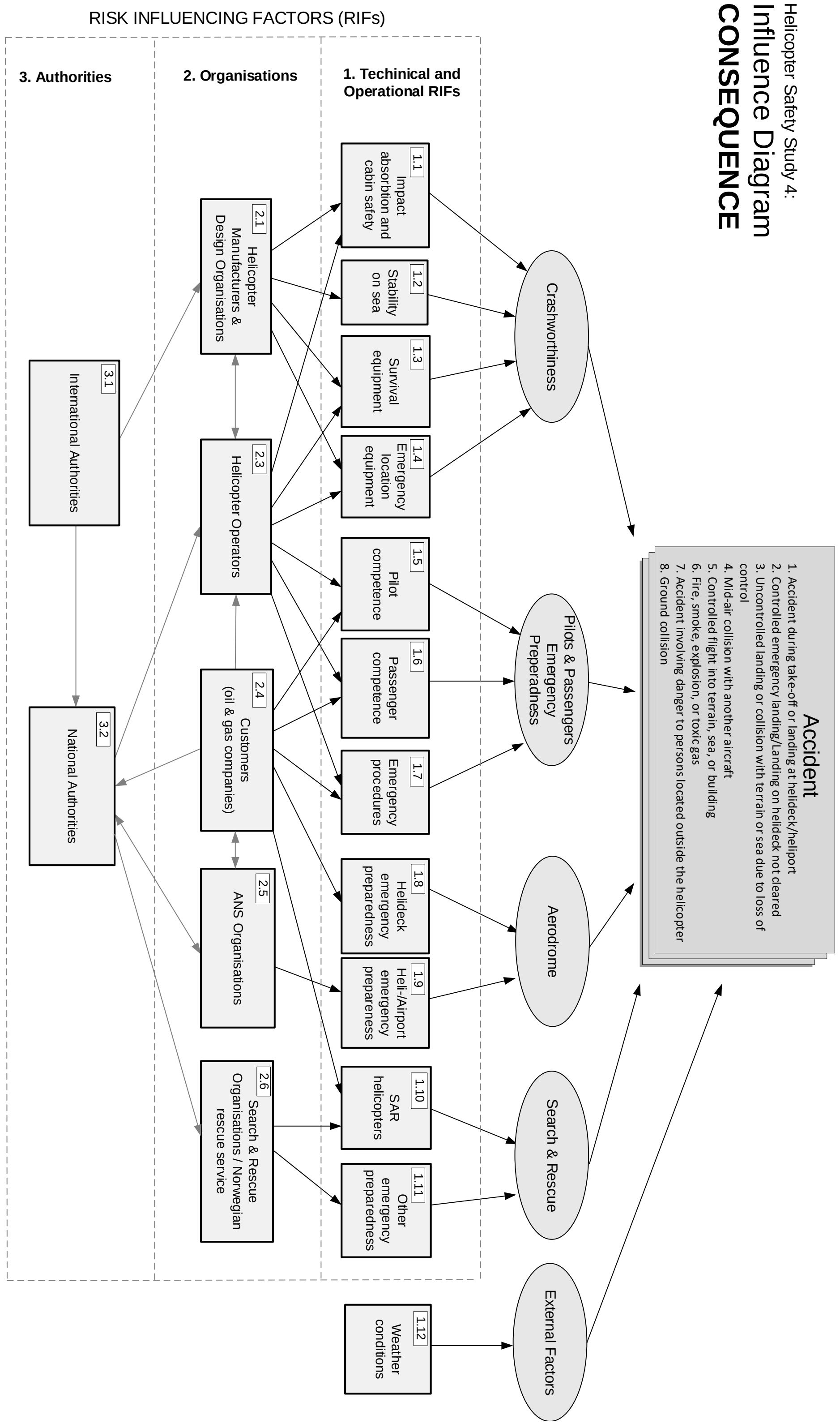
[23] Helidecks on fixed facilities are approved by the PSA. Helidecks on floating facilities/ships are approved by NMD.

D DEFINITIONS AND DESCRIPTIONS OF RIFS FOR CONSEQUENCE



The four main impacts are *not* RIFs, they represent a *grouping* of the operational RIFs on level 1.

D.1 Level 1 – Technical and operational RIFs

The technical and operational RIFs for consequence concern the ability to minimise/prevent further injuries or fatalities of those that have survived / been injured in the first impact of a helicopter accident on, or in the close vicinity of a heliport/airport or helideck, and to prevent injuries or loss of life of third persons.

The technical and operational RIFs (level 1) for consequence are described below.

C1.1: Impact absorption upon hard landings and cabin safety

Definition: Helicopter design with regards to protection of passengers and pilots against impact trauma injuries and/or injuries from crash and post-crash smoke, toxic fumes and fire, restraint from static loads, and protection against exposure to dynamic loads after an emergency landing or a crash.

Contributors:
• Aircraft airframe and quality of materials.
• Seat construction.
• Fire suppression and resistance of cargo holds and cabin interiors against fire development while in the air, during landing/crash or emergency evacuation.
• Suppression of smoke and toxic fumes while in the air, during landing/crash or emergency evacuation.
• Emergency evacuation both with the helicopter in an upright position, and with a submerged or sinking cabin; passenger briefing cards, markings and placards, escape ways, emergency egress lightning, numbers of and ease of operation of emergency exits.
• External assistance of emergency evacuation; markings and placards and operation of emergency exits from the outside.

C1.2: Stability on sea

Definition: The ability of the helicopter to remain afloat in an upright position for a sufficient duration after ditching on sea in any reasonably probable water conditions (sea states) en route.

Contributors:
• Helicopter design.
• Flotation equipment.
• Cargo.

C1.3: Survival equipment

Definition: Survival equipment for passengers and crew inside/on helicopter.

Contributors:

- Adequate equipment/gear to protect pilots and passengers from:
    - drowning (survival suits, life wests, dingies, and other floatation equipment)
    - hypothermia
    - serious physical deterioration due to injuries, dehydration, or hunger (first aid equipment, emergency food and water rations).

C1.4: Emergency location equipment

Definition: Emergency location equipment for passengers and crew inside/on helicopter.

Contributors:

- Adequate equipment/gear to alert rescuers, i.e.:
    - emergency location transmitters
    - emergency radios
    - flares
    - lightning on survival suits, life wests, dingies, or other floatation equipment
    - water dye
    - brightly coloured survival suits, life wests, dingies, or other floatation equipment
    - ADS-B or other tracking system.

C1.5: Pilot competence

Definition: The ability of the pilots to help minimise/prevent injuries or loss of life of persons when a helicopter emergency landing is unavoidable, and/or after an accident has occurred.

Contributors:

- Briefing of passengers before take-off.
- Warning of passengers when an emergency landing/accident is imminent.
- Evacuating the helicopter themselves.
- Directing/assisting passenger emergency egress.
- Directing/assisting passengers away from the helicopter in case of fire or fire hazard is present.
- Directing/assisting passengers into dingies/floatation equipment.
- Knowledge about first aid treatment.
- Knowledge and competence about emergency procedures and how to utilise any type of emergency equipment provided.
- Establishing contact with rescue services.

C1.6: Passenger competence

Definition: The ability of the passengers to preserve their own lives, and to assist others, in case of a helicopter accident or emergency landing, including situations where the crew is incapacitated.

Contributors:

- Personal protecting equipment (e.g. survival suits).
- Ability to ensure that the survival suit is undamaged and properly worn (zipped up).
- Knowledge on how to operate all applicable types of emergency exits.
- Knowledge on how to perform underwater escapes.
- Knowledge on how to utilise dingies and other floatation gear.
- Knowledge about first aid treatment.
- Knowledge and competence about emergency procedures and how to utilise any type of emergency equipment provided.
- Knowledge about establishing contact with rescue services.

C1.7: Emergency procedures

Definition: Emergency procedures/descriptions/directions, including markings and labels, for the use of every item of emergency equipment provided.

Contributors:

- The emergency procedures':
  - sufficiency
  - access
  - comprehensibility

C1.8: Helideck emergency preparedness

Definition: The preparedness for emergency activities of the helideck crew and adequate equipment/gear to minimise/prevent injuries or loss of life.

Contributors:

- Location of helideck, e.g. to have a safe distance to other vulnerable areas as building quarters.
- Nets to prevent helicopters or escaping personnel from falling off the deck.
- Draining system (capacity and design) for spilled fuel from ruptured tanks.
- Safe storage of any explosive, flammable, or otherwise hazardous liquids and material.
- Personnel protection design measures; rescue nets, rails, etc.
- Emergency exits.
- The sufficiency and adequacy of plans, procedures, and number of designated personnel.
- The ability, preparedness, and awareness of designated personnel to react to and deal with emergency situations (e.g. training).
- The ability and preparedness of personnel not directly involved in emergency/rescue work to avoid hampering such operations, while still being available to assist on request.
- Quality and accessibility to emergency equipment such as fire-fighting equipment, cutting tools, oxygen masks, fire protective clothing, stretchers and first aid equipment.

C1.9: Heliport/airport emergency preparedness

Definition: The helideck emergency preparedness characteristics and the preparedness for emergency activities of the ground crew and adequate equipment/gear to minimise/prevent injuries or loss of life.

Contributors:
• ANS search and rescue; ADS-B and alerting service. • The sufficiency and adequacy of plans, procedures, and number of designated personnel. • The ability, preparedness, and awareness of designated personnel to react to and deal with emergency situations (e.g. training). • The ability and preparedness of personnel not directly involved in emergency/rescue work to avoid hampering such operations, while still being available to assist on request. • Quality and accessibility to emergency equipment such as fire-fighting equipment, cutting tools, oxygen masks, fire protective clothing, stretchers and first aid equipment.

C1.10: SAR helicopters

Definition: The quantity, quality and vicinity of SAR helicopters that are financed by the customers and operated by the helicopter operators.

Contributors:
• The sufficiency/adequacy of plans, procedures, number of SAR units and their equipment, suitable localisation of the SAR units and number of designated personnel. • The ability, preparedness, readiness and capacity of SAR service and designated personnel to deal with emergency situations.

C1.11: Other emergency preparedness

Definition: Other SAR resources than SAR helicopters.

Contributors:
• State SAR (Sea King / SAR Queen / AS332) helicopters • Coast guard • Nearby air traffic • Nearby ships and sea traffic, incl. standby vessels

C1.12: Weather

Definition: The influence from the weather condition that affect the ability of the SAR activities.

Contributors:
• Visibility (darkness/light, fog, snow, etc.) • Wind, polar lows, etc. • Sea temperatures. • High waves / sea state.

D.2 Level 2 – Organizational RIFs

The organizational RIFs for consequence and their influence on level 1 RIFs are as follows:

- C2.1: Helicopter manufacturers & Design organizations ⇨ **RIFs 1.1, 1.2, 1.3 and 1.4**
- C2.3: Helicopter operators ⇨ **RIFs 1.1, 1.2, 1.3, 1.4, 1.5, 1.6. and 1.7**
- C2.4: Customers ⇨ **RIFs 1.8 and 1.10**
- C2.5: ANS organizations ⇨ **RIF 1.9**
- C2.6: SAR services ⇨ **RIF 1.11**

All except C2.6 are similar as for the corresponding organizational RIFs for frequency (except the influence on RIFs). C2.4 is described below:

C2.6: Search & rescue services

Definition: The organization of the SAR services, the way communication is performed with other organizations, and the way the SAR services plan and carry out their business in general, to the extent that this has a direct or indirect influence on the organization and co-ordination of a search and rescue operation.

Contributors:
• The Rescue Coordination Centres (JRCC) • Internal organization (authority, responsibility, and procedures) • External co-ordination/co-operation between SAR units, and between SAR services and any other related services and/or authorities

D.3 Level 3 – Regulatory related RIFs

Level 3 – Regulatory related RIFs are similar to the regulatory and customer related RIFs for frequency:

- C3.1: International authorities, ref. F3.1
- C3.2: National authorities, ref. F3.2

E Specifications for a digital solution for following up safety measures

This appendix gives a description of a suggested tool for follow-up of safety measures recommended in HSS-4 in addition to other measures (e.g. from NSIA or AAIB). The purpose of the tool is to structure the follow-up of safety measures. The tool could be either web based (and available for several organizations) or locally available within an organization (e.g. an Excel tool).

E.1 Prerequisites

A number of prerequisites have been identified for such a digital solution to be implemented and used by most of the organizations within offshore helicopter transport (helicopter operators, maintenance organizations, CAA-N, customers, research organizations, etc.). The digital solution should be:

- Easy to implement and use – to ensure that it will be used by the organizations involved.
- Based on the HSS-4 report, including information, data, and methodology – to ensure today's state of the art.
- Possible to update based on publication of new studies or research – to ensure state of the art in the future.
- Supplemented with relevant information from former HSS studies – to include all relevant knowledge.
- Available for all (e.g. web-based) – to ensure everyone can read the information.
- Restricted to dedicated persons or organizations for editing – to quality assure content.
- Adapted to both PC and pads – to ensure readability from all units.
- Updated regularly, e.g. annually – to ensure necessary updates without requiring continuous updates.

E.2 Characteristics/Specification

A follow-up tool for safety measures is a presentation of the status of implementation of the measures. The tool may include the following characteristics:

- Status of each measure (e.g. if a measure is 'open', 'closed', or 'under implementation).
- Status of all measures with respect to implementation (e.g. fraction of measures that are 'closed').
- Theory regarding safety measures and implementation of measures. This includes the three phases of implementation and particularly information regarding closing criteria (see below).
- Comparison of measures with respect to a set of parameters.
- Differentiate between technical, operational, and organizational measures (and relevant RIFs for the measures).
- Visualisation of the measures' predicted risk reduction, cost, cost-effect, implementation duration, etc.
- Possibility to define responsible persons for implementation of a measure.
- Possibility to edit text (for restricted group of persons).
- User manual.

All measures should be followed-up according to a standardised process for follow-up of measures, including the three phases *define*, *implement*, and *close* measures:

- *Definition* of a measures includes information regarding necessary prerequisites for implementation of the measure, possible adjustments of the measure, and definition of closing criteria.
- *Implementation* of a measure includes a plan for the implementing, time schedule, necessary actions, responsibilities, allocation of resources, etc.
- *Closing* a measure includes information regarding whether activity or result criteria are fulfilled (see below), evaluation of the implementing process, and identification of necessary additional measures.

Based on the above, the following information is relevant for each safety measure:

- *Purpose*: A brief description of the purpose of the measure, which problems the measure are intended to solve, or a description of the problem to be solved and corresponding challenges or reasons why the problems previously has not been solved.
- *Clarifications and prerequisites:* Information regarding clarifications and necessary prerequisites that must be in place prior to implementation.
- *Closing criteria*: An overview of closing criteria that must be fulfilled to close the measure. There are two main criteria; activity criteria and result criteria. Activity criteria defines necessary activities to be performed to close the measure. Result criteria defines certain results to be achieved to close the measure.
- *Cost*: A description of possible costs.
- *References*: All references (data, studies, presentations, etc.) used to describe and analyse the measure.
- *Responsible:* Organizations and/or individuals responsible to follow-up the measure.

E.3 Two alternative solutions

Two (levels of) web-based solutions of follow-up are considered:

1. Possibility for follow-up and edit status of measures (by The Committee for Helicopter Safety on the Norwegian Continental Shelf).
2. Possibility for follow-up and edit status of measures, in addition to add and analyse measures. (This requires an underlaying model).

E.3.1 Solution 1

A main page view for solution 1 is suggested in Figure E.1. From the main page the user can get information about:

- Status for all measures.
- Each separate measure, either by searching for the measure or from a list of alphabetically sorted measures and/or measures sorted into technical, operational, and organizational measures.
- The process of follow-up and implement measures.

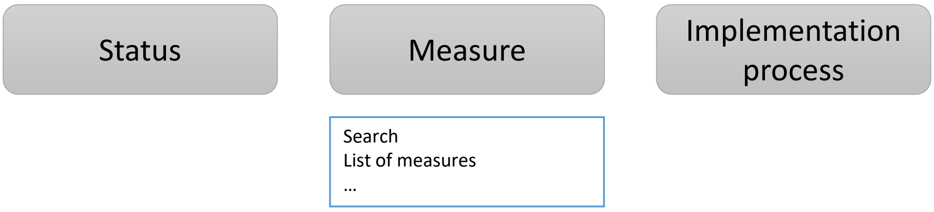


Figure E.1: Main view (solution 1).

Figure E.2 illustrates a suggested view for a single measure. This includes name and a traffic light illustrating the status of the measure (green means that the measure is closed, yellow means that the measure is under implementation, and red means that the measure implementation has not yet started.), purpose of measure, description of measure, responsible, references, etc. This information is possible to edit for those with right to edit (The Committee for Helicopter Safety on the Norwegian Continental Shelf), see Figure E.3.

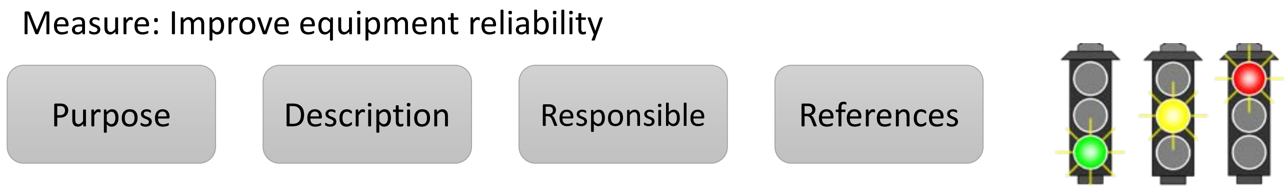
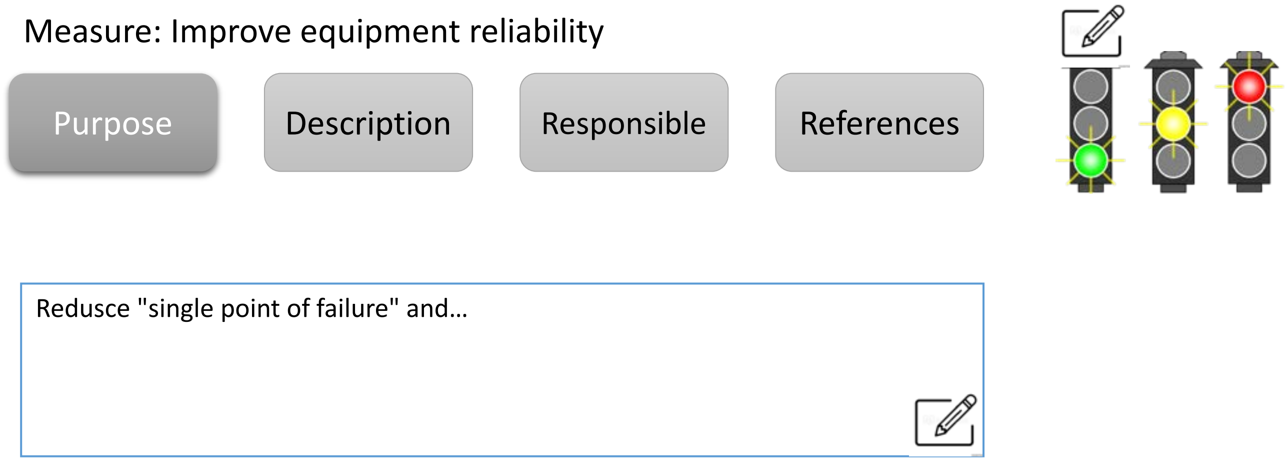


Figure E.2: Measure view – solution 1.



Redusce "single point of failure" and…

Figure E.3: Possibility to edit text and status of measure.

E.3.2 Solution 2

Solution 2 includes the following additional possibilities:

- Add new measures.
- Define closing criteria.
- Assess cost-effect (included predicted risk reduction) and other parameters such as implementation duration and business needs (based on the method in HSS-4).
- Edit costs and implementation duration along with the implementation process and compare with planned time schedule and costs.
- Establish groups of two or more measures, e.g. prioritised measures within an improvement area. Cost-effect can also be analysed for groups of measures (aggregated from the individual measures). It is also possible to compare groups of measures.

A suggested main page for solution 2 is illustrated in Figure E.4. Figure E.5 illustrates the view for a single measure.

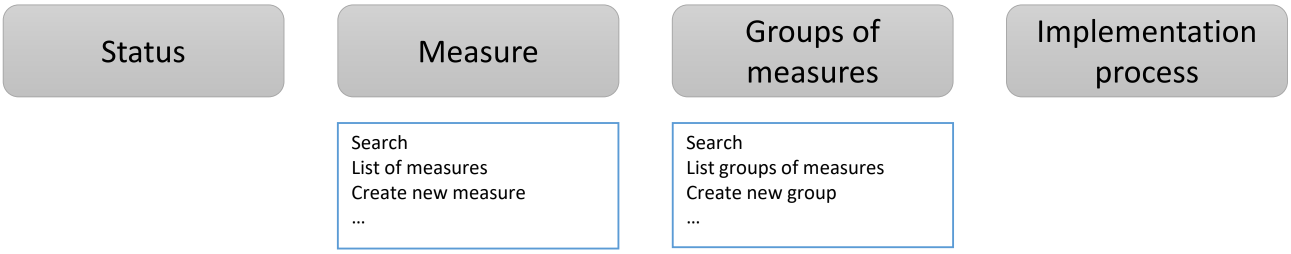


Figure E.4: Main view – solution 2.

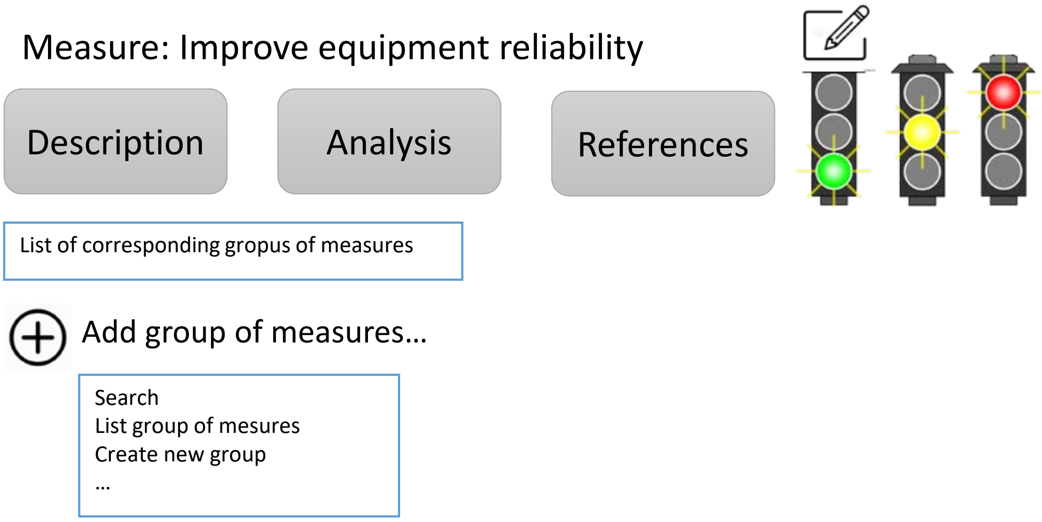


Figure E.5: Measure view – solution 2.

When adding new measures for analysis, the measures can be compared by comparing their cost-effect, i.e. expected cost per risk reduction. A prerequisite is that the HSS model and corresponding methodology is implemented in the tool. This requires some knowledge and information from the user, e.g.:

- What accident categories the safety measure will affect [ALL/SPECIFIC]
- What RIFs (frequency and consequence), the measure will affect [ALL/SPECIFIC]

A cost-effect matrix comparing three measures is shown in Figure E.6. In addition to cost-effect, other parameters (e.g. implementation duration) can be illustrated by the size of the measure circle in the matrix).

Groups of measures can be compared in the same way as comparing single measures. This requires that the measures in the groups are analysed. It must also be defined how to aggregate the information form each of the measures within a group of measures, e.g.:

- Cost-effect: Total cost / Total predicted risk reduction.
- Implementation duration: Maximum duration of the measures in the group.

Figure E.6: Comparison of measures.

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