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Offshore Risk Assessment vol 2

Principles, Modelling and Applications of QRA Studies

Third Edition

Springer

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ISSN 1614-7839
ISBN 978-1-4471-5212-5 ISBN 978-1-4471-5213-2 (eBook)
DOI 10.1007/978-1-4471-5213-2
Springer London Heidelberg New York Dordrecht

Library of Congress Control Number: 2013940076

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

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Preface to 3rd Edition

This is the third edition of the book; the first edition was published in 1999 and the second edition in 2007. The author has since then returned to an adjunct professorship at University of Stavanger, Norway, teaching a course in applied offshore risk assessment. Starting from January 2013, the author is also adjunct professor at NTNU, Trondheim in marine operational risk. The author has been involved in several significant research projects during the last few years. Several major accidents worldwide have had considerable effect on the HES performance and awareness, not the least the Macondo accident in 2010. This prompted a need for a further update of the book.

Norwegian offshore regulations were profoundly revised around the beginning of the new century, with new regulation becoming law from 2002. A limited revision was implemented from 2011, mainly limited to the integration of onshore petroleum facilities. This edition of the book captures some of the experience and challenges from the application of the new regulations. The important aspects of the new regulations are also briefly discussed, see Chap. 1.

About 30 major accidents and incidents are discussed at some length in Chaps. 4 and 5 (Macondo accident), in order to demonstrate what problems have been experienced in the past. I have increased the emphasis on this subject in both the second and third editions, because it is essential that also new generations may learn from what occurred in the past. Where available, observations about barrier performance are discussed in addition to the sequence of events and lessons learned.

It is often claimed "what is measured will be focused upon". This implies that even if QRA studies have several weaknesses and limitations, quantification is the best way to focus the attention in major hazard risk management. This is also one of the lessons from the Macondo accident, in the author's view. It has therefore been surprising to realise how strong the opposition to QRA studies still is at the end of 2012 from many professionals in major international oil companies. This has to some extent given further inspiration to update this book, about a topic I consider crucial for improvement of major hazard risk management in the offshore petroleum industry.

Thanks are expressed to Springer London publishers, in particular Senior Editor Anthony Doyle and his staff, for agreeing to publish the third edition of this book,

and for providing inspiring and valuable advice and assistance throughout the process.

Appendix A presents an overview of some of the important software tools that are commonly used in offshore risk assessment. Thanks to all the consultancies and software suppliers who have provided the information required for the update of this appendix.

There are also several people who have kindly contributed with relevant information on various aspects; Torleif Husebø, PSA; Prof. Stein Haugen, NTNU; Celma Regina Hellebust, Hellebust International Consultants, Prof. Bernt Aadnøy, UiS and Dr. Haibo Chen, Scandpower Inc. China. Many thanks for valuable assistance to all of you.

Meihua Fang has been my assistant during the final stages of the revision work, during her stay in Norway as the wife of a student at UiS in an international M.Sc. program in offshore risk management. Meihua has a M.Sc. degree in safety technology and engineering from China University of Geosciences in Beijing and HES management experience from SINOPEC in China and Latin America, and has been an ideal assistant. The main task has been the updating of Appendix A, in addition to several other editorial tasks, which has been very helpful to finish the revision work in a timely manner. I am very grateful for the excellent assistance provided by Meihua.

Last, but not least, I am very grateful to those companies that responded positively when asked for a modest support in order to cover the expenses involved in the production of this third revision. My warmest and most sincere thanks go to these companies:

- Faroe Petroleum Norway
- Norwegian oil and gas association
- Total E&P Norway
- VNG Norway

Bryne, May 2013

Jan-Erik Vinnem
Adjunct Professor
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Preface to 2nd Edition

This is the second edition of the book; the first edition was published in 1999. The author has since then taken up a full professorship at University of Stavanger, Norway, teaching courses in offshore risk analysis and management. This prompted a need for an update of the book. The fact that several important developments have occurred since 1999 also implied that a major revision was required.

The oil price has reached its peak in 2006, at the highest level ever (nominally). But the economic climate is at the same time such that every effort is made to scrutinise how costs may be curtailed and profit maximised. This will in many circumstances call for careful consideration of risks, not just an 'off the shelf risk analysis', but a carefully planned and broad-ranging assessment of options and possibilities to reduce risk.

Norwegian offshore regulations were profoundly revised around the beginning of the new century, with new regulation becoming law from 2002. This second edition of the book captures some of the experience and challenges from the first 4-5 years of application of the new regulations. The important aspects of the new regulations are also briefly discussed, see Chapter 1.

The first Norwegian White Paper on HES management in the offshore industry was published in 2001, and the second in 2006. One of the needs identified in this paper was the need to perform more extensive R&D work in this field, and a significant programme has been running in the period 2002–2006. Some of the new results included in the second edition of the book result from that R&D initiative.

About 20 major accidents, mainly from the North Sea, are discussed at some length in Chapter 4, in order to demonstrate what problems have been experienced in the past. I have put more emphasis on this subject in the second edition, because it is essential that also new generations may learn from what occurred in the past. Where available, observations about barrier performance are discussed in addition to the sequence of events and lessons learned.

When it comes to management of risk and decision-making based upon results from risk analyses, this is discussed separately in a book published in parallel with my colleague at University of Stavanger, Professor Terje Aven, also published by

Springer in 2007. Interested readers are referred to this work, 'Risk Management, with Applications from the Offshore Petroleum Industry'.

Thanks are also expressed to Springer London publishers, in particular Professor Pham and Senior Editor Anthony Doyle, for agreeing to publish the second edition of this book, and for providing inspiring and valuable advice throughout the process. Simon Rees has given valuable assistance and support during production of the camera-ready manuscript.

Appendix A presents an overview of some of the important software tools that are commonly used. Thanks to all the consultancies and software suppliers who have provided the information required for this appendix.

In preparing the second edition of the book, I have been fortunate to have kind assistance from many colleagues and friends, who have provided invaluable support and assistance. First of all I want to express sincere thanks and gratitude to my friend David R Bayly, Crandon Consultants, who has also this time assisted with improvement of the English language, as well as providing technical comments and suggestions. I do not know how I could have reached the same result without David's kind assistance.

My colleague at UiS, Professor Terje Aven has contributed significantly to the discussion of statistical treatment of risk and uncertainty. I am very pleased that this important improvement has been made. Dr Haibo Chen, Scandpower Risk Management Beijing Inc has contributed valuable text regarding the analysis of DP systems on mobile installations.

Safetec Nordic AS has allowed use of several of their tools as input to the descriptions and cases. I want to express my gratitude for allowing this, and in particular express thanks to the following; Thomas Eriksen, Stein Haugen and Arnstein Skogset.

There are also several people who have contributed with relevant information on various technical details; Finn Wickstrøm, Aker Kvaerner and Graham Dalzell, TBS[3]. My daughter, Margrete, has assisted in the editing of the manuscript. Many thanks to all of you.

Bryne, January 2007

Professor Jan Erik Vinnem
University of Stavanger

Preface to 1st Edition

From a modest start in Norway as a research tool in the late 1970s, Quantified Risk Assessment (QRA) for offshore installations has become a key issue in the management of Safety, Health and Environment in the oil and gas industries throughout the entire North Sea. While the initiatives in the early stages often came from the authorities, the use is now mainly driven by the industry itself. The QRA is seen as a vehicle to gain extended flexibility with respect to achievement of an acceptable safety standard in offshore operations. The models may be weak in some areas and the knowledge is sometimes limited, but studies are nevertheless used effectively in the search for concept improvement and optimisation of design and operation.

This book results from working with offshore QRAs for more than 20 years. The author has, during this period, had the opportunity to practice and evaluate the use of such studies from different perspectives; the consultancy's, the operating company's, the researcher's and the educator's point of view.

The author has for several years taught a course in risk analysis of marine structures at the Faculty of Marine Technology, NTNU, Trondheim, Norway. The starting point for the manuscript was the need to update the lecture notes.

It is hoped that this book in the future also may be a useful reference source for a wider audience. There has been for some years a rapid expansion of the use of risk assessments for the offshore oil and gas activities. It is expected that the expansion is going to continue for some time, as the offshore petroleum industry expands into new regions and meets new challenges in old regions.

The oil price reached its lowest level for many years, during the first quarter of 1999. One might be tempted to think that the economic climate may prohibit further attention to risk assessment and safety improvement. The opposite is probably more correct. As a friend in Statoil expressed not so long ago: 'Whenever the margins are getting tighter, the need for risk assessments increases, as new and more optimised solutions are sought, each needing an assessment of risk'.

In Norway, the beginning of 1999 is also the time when the Norwegian Petroleum Directorate is preparing a major revision of the regulations for offshore installations and operations, anticipated to come into effect in 2001. It has obviously not been possible to capture the final requirements of the new regulations,

but an attempt has been made to capture the new trends in the regulations, to the extent they are known.

There have over the last 10-15 years been published a few textbooks on risk assessment, most of them are devoted to relatively generic topics. Some are also focused on the risk management aspects, in general and with offshore applicability. None are known to address the needs and topics of the use of QRA studies by the offshore industry in particular. The present work is trying to bridge this gap.

The use of QRA studies is somewhat special in Northern Europe, and particularly in Norway. The use of these techniques is dominated by offshore applications, with the main emphasis on quantification of risk to personnel. Furthermore, the risk to personnel is virtually never concerned with exposure of the public to hazards. Thus, the studies are rarely challenged from a methodology point of view. Most people will probably see this as an advantage, but it also has some drawbacks. Such challenges may namely also lead to improvements in the methodology. It may not be quite coincidental that the interest in modelling improvement and development sometimes has been rather low between the risk analysts working with North Sea applications.

This book attempts to describe the state of the art with respect to modelling in QRA studies for offshore installations and operations. It also identifies some of the weaknesses and areas where further development should be made. I hope that further improvement may be inspired through these descriptions.

About the Contents

A Quantified Risk Assessment of an offshore installation has the following main steps:

1. Hazard identification
2. Cause and probability analysis
3. Accidental scenarios analysis
4. Consequence, damage and impairment analysis
5. Escape, evacuation and rescue analysis
6. Fatality risk assessment
7. Analysis of risk reducing measures

This book is structured in much the same way. There is at least one chapter (sometimes more) devoted to each of the different steps, in mainly the same order as mentioned above. Quite a few additional chapters are included in the text, on risk analysis methodology, analytical approaches for escalation, escape, evacuation and rescue analysis of safety and emergency systems, as well as risk control.

It is important to learn from past experience, particularly from previous accidents. A dozen major accidents, mainly from the North Sea, are discussed at the end of Chapter 4, in order to demonstrate what problems that have been experienced in the past.

The main hazards to offshore structures are fire, explosion, collision and falling objects. These hazards and the analysis of them are discussed in separate chapters. Risk mitigation and control are discussed in two chapters, followed by an outline of an alternative approach to risk modelling, specially focused on risk relating to short duration activities. Applications to shipping are finally discussed, mainly relating to production and storage tankers, but also with a view to applications to shipping in general.

Acknowledgements

Parts of the material used in developing these chapters were initially prepared for a course conducted for PETRAD (Program for Petroleum Management and Administration), Stavanger, Norway. Many thanks to PETRAD for allowing the material to be used in other contexts.

Some of the studies that have formed the main input to the statistical overview sections were financed by Statoil, Norsk Hydro, Saga Petroleum, Elf Petroleum Norge and the Norwegian Petroleum Directorate. The author is grateful that these companies have allowed these studies to be made publically available.

Direct financial support was received from Faculty of Marine Technology, NTNU, this is gratefully acknowledged. My part time position as Professor at Faculty of Marine Technology, NTNU, has also given the opportunity to devote time to prepare lecture notes and illustrations over several years. The consultancy work in Preventor AS has nevertheless financed the majority of the work, including the external services.

Thanks are also expressed to Kluwer Academic Publishers, Dordrecht, The Netherlands, for agreeing to publish this book, and for providing inspiring and valuable advice throughout the process.

Appendix A presents an overview of some of the important software tools that are commonly used. Thanks to all the consultancies and software suppliers who have provided the information required for this appendix. Appendix B is a direct copy of the normative text in the NORSOK Guideline for Risk and Emergency Preparedness analysis, reproduced with kind permission from the NORSOK secretariat.

Some of the consultancies have kindly given permission to use some of their material, their kind assistance is hereby being gratefully acknowledged. DNV shall be thanked for allowing their database Worldwide Offshore Accident Databank (WOAD) to be used free of charge, as input to the statistics in the book. The Fire Research Laboratory at SINTEF has given kind permission to use illustrations from their fire on sea research, and Scandpower has granted permission to use an illustration of the risk assessment methodology. Safetec Nordic has given kind permission to use results and illustrations from their software Collide.

I am particularly indebted to several persons who have offered very valuable help in turning this into a final manuscript. My colleague Dr. David Bayly,

Crandon Consultants, has reviewed the raw manuscript and contributed with many valuable comments of both a technical and linguistic nature. The importance of providing clear and concise text can never be overestimated, the efforts made in this regard are therefore of utmost importance. This unique contribution has combined extensive linguistic improvements with pointed comments and additional thoughts on the technical subjects. I am very grateful to you, David, for your extensive efforts directed at improvement of the raw manuscript.

My oldest son, John Erling, has helped me with several of the case studies that are used in the text, plus quite a few of the illustrations. My part time secretary, Mrs Annbjørg Krogedal, has had to devote a lot effort to decipher a challenging handwriting, thank you for enthusiasm and patience. Assistance with the proof reading has been provided by Ms Kjersti G. Petersen, thanks also to Kjersti for enthusiastic and valuable assistance. Finally, M.Sc. Haibo Chen has also helped with the proof reading and checking of consistency in the text, your kind assistance is gratefully acknowledged.

Bryne, May 1999 Jan Erik Vinnem

Contents

Abbreviations

AIBN	Accident Investigation Board Norway
AIR	Average Individual Risk
AIS	Automatic Identification System
ALARP	As Low As Reasonably Practicable
ANP	National Petroleum Agency
AR	Accident Rate
ARCS	Admiralty Raster Chart Services
ARPA	Automated Radar Plotting Aid
ATM	Air Traffic Management
bara	Bar absolute
barg	Bar gauge (overpressure)
BAST	Best Available and Safety Technology
BBD	Barrier Block Diagram
bbls	Barrels
BD	Blowdown
BDV	Blowdown Valves
BF	Barrier Function
BFETS	Blast and Fire Engineering for Topside Systems
BHP	Broken Hill Proprietary Company Limited
BLEVE	Boiling Liquid Expanding Vapour Explosion
BOE	Barrels of Oil Equivalent
BOEMRE	Bureau of Offshore Energy Management, Regulation and Enforcement
BOP	Blowout Preventer
BORA	Barrier and Operational Risk Analysis
BP	British Petroleum
BSEE	Bureau of Safety and Environmental Enforcement
CAA	Civil Aviation Authority
CAD	Computer Aided Design
CBA	Cost Benefit Analysis
CCA	Cause-Consequence Analysis
CCR	Central Control Room
CFD	Computational Fluid Dynamics

CNH	National Hydrocarbons Commission
CNLOPB	Canada-Newfoundland and Labrador Offshore Petroleum Board
CNSOPB	Canada-Nova Scotia Offshore Petroleum Board
CPA	Closest Point of Approach
CPP	Controllable Pitch Propeller
CSE	Concept Safety Evaluation
DAE	Design Accidental Events
DAL	Design Accidental Loads
DEA	Danish Energy Agency
DFU	Defined situations of hazard and accident
DHJIT	Deepwater Horizon Joint Investigation Team
DHSG	Deepwater Horizon Study Group
DHSV	DownHole Safety Valve
DNV	Det Norske Veritas
DOL	Department of Labor
DP	Dynamic Positioning
DSB	Directorate for Civil Protection and Emergency Planning (Direktoratet for samfunnssikkerhet og beredskap)
DWT	Dead Weight Tonnes
E&P	Exploration and Production
E&P Forum	Previous name of organisation now called OGPEER
	Escape, Evacuation and Rescue
EERS	Evacuation, Escape and Rescue Strategy
EESLR	Risk due to explosion escalation by small leaks
EGPWS	Enhanced Group Proximity Warning System
EFSLR	Risk due to fire escalation by small leaks
EIA	Environmental Impact Assessment
EIF	Environmental Impact Factor
EQDC	Emergency Quick DisConnector
ESD	Emergency Shut Down
ESV	Emergency Shutdown Valve
ETA	Event Tree Analysis
Ex	Explosion [protected]
FAR	Fatal Accident Rate
FCC	Frigg Central Complex
FEM	Finite Element Method
FES	Fire and Explosion Strategy
Fi-Fi	Fire Fighting
FLAR	Flight Accident Rate
FLACS	Flame Accelerator Software
FMEA	Failure Mode and Effect Analysis
FPS	Floating Production System
FPSO	Floating Production, Storage and Off-loading unit
FPU	Floating Production Unit

FRC	Fast Rescue Craft
FSU	Floating Storage Unit
FTA	Fault Tree Analysis
GBS	Gravity Base Structure
GIR	Group Individual Risk
GIS	Geographical Information System
GoM	Gulf of Mexico
GPS	Global Positioning System
GR	Group Risk
GRP	Glass fibre Reinforced Plastic
GRT	Gross Register Tons
HAZID	Hazard Identification
HAZOP	Hazard And Operability Study
HC	Hydrocarbon
HCL	Hybrid Causal Logic
HCLIP	Hydrocarbon Leak and Inventory Project
HCR	Hydrocarbon Release
HES	Health, Environment and Safety
HIPPS	High Integrity Pressure Protection System
HOF	Human and Organisational Factors
HR	Human Reliability
HRA	Human Reliability Analysis
HSE	Health and Safety Executive
HSS	Helicopter Safety Studies
IAEA	International Atomic Energy Agency
IEC	International Electro-technical Commission
IMEMS	International Marine Environmental Modeling Seminar
IMO	International Maritime Organization
IR	Individual Risk
IRIS	International Research Institute of Stavanger
IRF	International Regulators' Forum
IRPA	Individual Risk per Annum
ISO	International Organisation for Standardisation
JIP	Joint Industry Project
KPIs	Key Performance Indicators
LCC	Life Cycle Cost
LEL	Lower Explosion Level
LFL	Lower Flammability Level
LNG	Liquefied Natural Gas
MIRA	Environmental risk analysis (>Miljørettet risikoanalyse =)
MGB	Main Gearbox
MMI	Man–Machine Interface
MMS	Minerals Management Service
MNOK	Million Norwegian kroner

M&O	Management and Operation
MOB	Man Over Board
MOC	Management of Change
MODU	Mobile Offshore Drilling Unit
MOEX	Mitsui Oil EXploration
MP	Main (propulsion) Power
MSF	Module Support Frame
MTO	Man, Technology and Organisation
MUSD	Million US Dollar
NCS	Norwegian Continental Shelf
NEA	National Environment Agency
NORSOK	Norwegian Offshore standardisation organisation (>Norsk Sokkels Konkurranseposisjon =)
NM	Nautical Mile
NGOs	Non-governmental organizations
NMD	Norwegian Maritime Directorate
NOPSA	National Offshore Petroleum Safety authority (Australia)
NOPSEMA	National Offshore Petroleum Safety and Environmental Management Authority
NOU	Norwegian Offshore Report (Norges Offentlige Utredninger)
NPD	Norwegian Petroleum Directorate
NPPs	Nuclear Power Plants
NPV	Net Present Value
NTNU	Norwegian University of Science and Technology
NTS	Norwegian Technology Standards Institution
OCS	Outer Continental Shelf
OGP	International Oil and Gas Producers Association
OIM	Offshore Installation Manager
OLF	The Norwegian Oil Industry Association (Oljeindustriens Landsforening)
OMT	Organisational, Human & Technology
ONGC	Oil and Natural Gas Corporation
OR	Overall risk
OSD	Offshore Division
OSPAR	Oslo and Paris Convention
OSRA	Oil Spill Risk Analysis
OTS	Operational Condition Safety (‘Operasjonell Tilstand Sikkerhet’)
PDQ	Production, Drilling and Quarters
P&ID	Piping and Instrumentation Drawing
PETRAD	Program for Petroleum Management and Administration
PFEER	Prevention of Fire and Explosion and Emergency Response
PFP	Passive Fire Protection

PGS	Petroleum Geo-Services ASA
PHA	Preliminary Hazard Analysis
PLATO	Software for dynamic event tree analysis
PLL	Potential Loss of Life
PLS	Progressive Limit State
POB	Personnel On Board
PR	Performance Requirements
PRS	Position Reference System
PS	Performance Standards
PSA	Petroleum Safety Authority [Norway]
PSD	Process Shut Down
PSV	Pressure Safety Valves
QA	Quality Assurance
QC	Quality Control
QM	Quality Management
QP	(Frigg) Quarters Platform
QRA	Quantified Risk Assessment
R&D	Research and Development
RABL	Risk Assessment of Buoyancy Loss
RAC	Risk Acceptance Criteria
RACON	Radar signal amplification
RAE	Residual Accidental Events
RAMS	Reliability, Availability, Maintainability, Safety
RIDDOR	Reporting of Injuries, Diseases and Dangerous Occurrences Regulations
RIF	Risk Influencing Factor
RNN	Risk Level [project] (‘Risiko Nivå Norsk Sokkel’)
RNNP	Risk level in the Norwegian petroleum activity (Risikonivå i norsk petroleumsvirksomhet)
ROS	Risiko-og sårbarhetsstudier
ROV	Remote Operated Vehicle
RRM	Risk Reducing Measure
SAFOP	Safety and Operability Study
SAR	Search and Rescue
SBV	Standby Vessel
SCR	Safety Case Regulations
SIL	Safety Integrity Level
SJA	Safe Job Analysis
SLR	Risk due to small leaks
SOLAS	Safety of Life at Sea
SSIV	SubSea Isolation Valve
SSM	State Supervision of Mines
ST	Shuttle tanker
SUPER-TEMPCALC	Software for 2D temperature analysis
TASEF-2	Software for 2D temperature analysis

TCAS	Traffic Collision Avoidance System
TCP2	(Frigg) Treatment Platform 2
TH	Thruster
TLP	Tension Leg Platform
TP1	(Frigg) Treatment Plat form 1
TR	Temporary Refuge
TRA	Total Risk Analysis
TST	Technical Safety Condition ('Teknisk SikkerhetsTilstand')
TTS	Technical Condition Safety ('Teknisk Tilstand Sikkerhet')
UEL	Upper Explosive Limit
UFL	Upper Flammability Limit
UKCS	UK Continental Shelf
UPS	Underwater Production System
USFOS	Software for non-linear and dynamic analysis of structures
VEC	Valued Ecological Component
VHF	Very High Frequency
VOC	Volatile Organic Compounds
VTS	Vessel Traffic System
WOAD	Worldwide Offshore Accident Database (ref. DNV)
WP	Work Permit