

Risk and emergency preparedness analysis

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Foreword

The NORSOK standards are developed by the Norwegian petroleum industry to ensure adequate safety, value adding and cost effectiveness for existing and future petroleum industry developments.

The NORSOK standards are prepared to complement available international standards and to fill the broad needs of the Norwegian petroleum industry. Where relevant NORSOK standards will be used to provide the Norwegian industry input to the international standardisation process. Subject to development and publication of International Standard, the relevant NORSOK standard will be withdrawn.

The NORSOK standards are developed according to the consensus principle generally applicable for most standards work and according to established procedures defined in NORSOK standard A-001.

The preparation and publication of the NORSOK standards is supported by OLF (The Norwegian Oil Industry Association) and TBL (Federation of Norwegian Manufacturing Industries). NORSOK standards are administered and issued by NTS (Norwegian Technology Centre).

All annexes are informative.

Introduction

The purpose of this NORSOK standard is to establish requirements for effective planning, execution and use of risk and EPA. Also the use of RAC is covered, thus the standard covers some aspects of risk assessment. Guidelines are provided in the informative annexes.

These annexes are provided as supplementary information and check lists, which may be used by personnel in charge of evaluation and analysis of risk and emergency preparedness. The emphasis has therefore been to provide useful information, rather than to reduce the volume of these annexes.

This NORSOK standard includes a number of requirements from which no deviation is normally permitted ('shall' statements). A preferred action is recommended in other cases ('should' statements).

When this NORSOK standard is used in a way which implies deviation from a recommended course of action ('should' statements), the reasons for choosing this course shall always be stated.

1 Scope

This NORSOK standard presents requirements to planning, execution and use of risk and EPA, with an emphasis on providing insight into the process and concise definitions.

This NORSOK standard is structured around the following main elements:

- Establishment of risk acceptance criteria prior to execution of the risk analysis.
- The relation between the risk and EPA, especially the integration of the two types of analysis into one overall analysis process.
- Planning and execution of analyses.
- Further requirements to use of risk and EPA for different activities and life cycle phases.
- Establishment of requirements based on risk and EPA.

This NORSOK standard covers EPA, establishment of emergency preparedness, while maintenance and further development of emergency preparedness are not covered by the standard.

This NORSOK standard covers analysis of risk and emergency preparedness associated with exploration drilling, exploitation, production and transport of petroleum resources as well as all installations and vessels that take part in the activity.

This NORSOK standard does not cover onshore facilities.

Analysis of occupational fatality risk is covered in this NORSOK standard. It does not cover a number of occupational health risk aspects, including physical and psychological working environment, working environment mapping and analysis, and the use of risk acceptance criteria. Occupational injuries are not part of this NORSOK standard.

2 Normative references

The following standards include provisions which, through reference in this text, constitute provisions of this NORSOK standard. Latest issue of the references shall be used unless otherwise agreed. Other recognized standards may be used provided it can be shown that they meet or exceed the requirements of the standards referenced below.

IEC 61508	Functional safety of electrical/electronic/programmable electronic safety related systems(all parts)
IEC 61511	Functional safety instrumented systems for the process industry sector (all parts) (under development)
ISO 13702	Petroleum and natural gas industries - Offshore production installations - Control and Mitigation of Fires and Explosions - Requirements and guidelines.
ISO 17776	Petroleum and natural gas industries - Offshore production installations – Guidelines on tools and techniques for identification and assessment of hazards.
ISO 15544	Petroleum and natural gas industries - Offshore production installations – Requirements and guidelines for emergency response.

“OLF- Veiledning for gjennomføring av miljørisikoanalyser for petroleumsaktiviteter på norsk sokkel - Metode for Miljørettet Risiko Analyse (MIRA)” (OLF Recommended method for environmental risk analysis, MIRA, Norwegian only) Rev.1 OLF, November 1999

OLF Guidelines for Area-based Emergency Preparedness, 30.6.2000

OLF Guidelines for the application of IEC 61508 and IEC 61511 in the petroleum activities on the Norwegian continental shelf, 1.2.2001, OLF Guideline 66, Rev 1

NORSOK standard N-001 Structural design, Rev. 3, August 2000

NORSOK standard S-001	Technical safety
NORSOK standard S-002	Working environment
NORSOK standard Z-008	Criticality classification method
NORSOK standard Z-016	Regularity management & reliability technology

"Risikoanalysen som beslutningsstøtte under design av normalt ubemannede installasjoner" (Risk analysis as decision support for design of normally unmanned installations, Norwegian only), Aker report 58357, 21.9.1999

NPD Regulation for management of HES

European Commission: Model Evaluation Group, report of the Second Open Meeting, Cadarache France, 19 May 1994, Report EUR 15990 EN, ISBN 92-826-9549-2, 1995

"Design of Offshore Facilities to Resist Gas Explosion Hazard Engineering Handbook."

3 Definitions and abbreviations

3.1 Definitions

For the purpose of this NORSOK standard the following terms and definitions apply.

3.1.1

accidental event (AE)

event or chain of events that may cause loss of life, or damage to health, the environment or assets

NOTE 1 - The events that are considered in a risk analysis are acute, unwanted and unplanned. For instance; planned operational exposure that may be hazardous to health or to the environment, are usually not included in a risk analysis.

NOTE 2 - The term 'event' will have to be defined explicitly in relation to each analysis, in order to be consistent with the availability analysis, that is with production regularity.

3.1.2

as low as reasonably practicable (ALARP)

ALARP expresses that the risk level is reduced (through a documented and systematic process) so far that no further cost effective measure is identified

NOTE - The requirement to establish a cost effective solution implies that risk reduction is implemented until the cost of further risk reduction is grossly disproportional to the risk reducing effect.

3.1.3

can

verbal form used for statements of possibility and capability, whether material, physical or casual

3.1.4

defined situations of hazard and accident (DSHA)

selection of hazardous and AEs that will be used for the dimensioning of the emergency preparedness for the activity

NOTE 1 - The selection will be representative for possible hazards and AEs for the facilities and activities, and includes DAEs, hazardous and accidental situations associated with a temporary increase of risk and less extensive AEs, e.g. man overboard situations, limited oil spills exceeding the stipulated discharge limits, occupational accidents, etc.

NOTE 2 - Situations associated with a temporary increase of risk, may involve drifting objects, work over open sea, unstable well in connection with well intervention, 'hot' work, jacking up and down of jack-up installations, special operations and environmental conditions, etc.

3.1.5

dimensioning accidental event (DAE)

AEs that serve as the basis for layout, dimensioning and use of installations and the activity at large in order to meet the defined RAC

3.1.6**dimensioning accidental load (DAL)**

load (action) that is sufficient in order to meet the RAC

NOTE - It may be difficult to define the accidental load in relation to some types of AEs, for instance in relation to filling of buoyancy compartments that may lead to capsizing or loss of buoyancy. In these cases, the basis of dimensioning is given by the DAEs.

Tolerable damage or required functionality have to be defined in such a way that the criteria for dimensioning are unambiguous. The term 'withstand' in the definition may be explained as the ability to function as required during and after the influence of an accidental load, and may involve aspects such as:

- The equipment has to be in place, i.e. it may be tolerable that some equipment is damaged and does not function and that minor pipes and cables may be ruptured. This may be relevant for electrical motors and mechanical equipment.
- The equipment has to be functional, i.e. minor damage may be acceptable provided that the planned function is maintained. This may be relevant for ESVs, deluge systems, escape ways, main structural support system, etc.
- The equipment has to be gas tight. This may be relevant for hydrocarbon containing equipment.

3.1.7**effectiveness analysis**

analysis which documents the fulfilment of performance standards for safety and emergency preparedness

NOTE - Effectiveness analyses in relation to technical performance standards for essential safety systems are carried out in relation to risk analyses. It is therefore a prerequisite that quantitative risk analyses in relation to design include quantitative analyses of escape, evacuation and rescue. Similarly, effectiveness analyses of emergency preparedness measures are done in connection with emergency preparedness analyses. The analysis has to be traceable and will normally - though not necessarily - be quantitative.

3.1.8**emergency preparedness**

technical, operational and organisational measures that are planned to be implemented under the management of the emergency organisation in case hazardous or accidental situations occur, in order to protect human and environmental resources and assets

NOTE - The definition focuses on the distinction between dimensioning of emergency preparedness and dimensioning of essential safety systems (see also the definition of EPA and establishment of emergency preparedness). Dimensioning of essential safety systems is done in connection with the use of risk analysis, and minimum requirements by authority regulations, established practice, recognised norms, etc.

3.1.9**emergency preparedness analysis (EPA)**

analysis which includes establishment of DSHA, including major DAEs, establishment of performance standards for emergency preparedness and their fulfilment and identification of emergency preparedness measures

3.1.10**establishment of emergency preparedness**

systematic process which involves planning and implementation of suitable emergency preparedness measures on the basis of risk and EPA

3.1.11**emergency preparedness organisation**

organisation which is planned, established, trained and exercised in order to handle occurrences of hazardous or accidental situations

NOTE - The emergency preparedness organisation includes personnel on the installation as well as onshore, and includes all personnel resources that will be activated during any occurred situation of hazard or accident.

3.1.12**essential safety system**

system which has a major role in the control and mitigation of accidents and in any subsequent EER activities

3.1.13**informative reference**

reference used informative in the application of NORSOK standards

3.1.14**main safety function**

safety functions that need to be intact in order to ensure that pollution is controlled and personnel that are not directly and immediately exposed, may reach a place of safety in an organised manner, either on the installation or through controlled evacuation

NOTE - The main safety functions, including their required functionality, is to be defined for each installation individually in an unambiguous way.

EXAMPLES - Main support structure, escape ways, control centre, shelter area (temporary refuge) and evacuation means.

3.1.15**may**

verbal form used to indicate a course of action permissible within the limits of the standard

3.1.16**performance standards for safety and emergency preparedness**

requirements to the performance of safety and emergency preparedness measures which ensure that safety objectives, RAC, authority minimum requirements and established norms are satisfied during design and operation

NOTE - The term 'performance' is to be interpreted in a wide sense and include availability, reliability, capacity, mobilisation time, functionality, vulnerability, personnel competence, expressed as far as possible in a verifiable manner.

3.1.17**risk**

combination of the probability of occurrence of harm and the severity of that harm

NOTE - Risk may be expressed qualitatively as well as quantitatively. Probability may be expressed as a probability value (0-1, dimensionless) or as a frequency, with the inverse of time as dimension.

The definition implies that risk aversion (i.e. an evaluation of risk which places more importance on certain accidental consequences than on others, where risk acceptance is concerned) should not be included in the quantitative expression of risk. It may be relevant to consider on a qualitative basis certain aspects of risk aversion in relation to assessment of risk and its tolerability.

The implication of the definition is further that perceived risk (i.e. subjectively evaluated risk performed by individuals) should not be included in the expression of risk.

3.1.18**risk acceptance criteria (RAC)**

criteria that are used to express a risk level that is considered tolerable for the activity in question

NOTE - RAC are used in relation to risk analysis and express the level of risk which will be tolerable for the activity, and is the starting point for further risk reduction according to the ALARP-principle, see also 3.1.2. Risk acceptance criteria may be qualitative or quantitative.

3.1.19**risk analysis**

use of available information to identify hazards and to estimate the risk

NOTE 1 - The risk analysis term covers several types of analyses that will all assess causes for and consequences of AEs, with respect to risk to personnel, environment and assets. Examples of the simpler analyses are SJA, FMEA, preliminary hazard analysis, HAZOP, etc.

NOTE 2 - Quantitative analysis may be the most relevant in many cases, involving a quantification of the probability and the consequences of AEs, in a manner which allows comparison with quantitative RAC.

3.1.20**risk assessment**

overall process of risk analysis and risk evaluation

NOTE - See Figure 2.

3.1.21**safety objective**

objective for the safety of personnel, environment and assets towards which the management of the activity will be aimed

NOTE - Safety objectives will imply short or long term objectives that have been established for the activity, while the RAC express the level of risk (in relation to the risk analysis) that is currently acceptable.

3.1.22**shall**

verbal form used to indicate requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted, unless accepted by all involved parties

3.1.23**should**

verbal form used to indicate that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others, or that a certain course of action is preferred but not necessarily required

3.2 Abbreviations

AE	accidental event
AFFF	aqueous film forming foam
AIR	average individual risk
ALARP	as low as reasonably practicable
ALS	accidental collapse limit state
BDV	blowdown valve
BOP	blow out preventer
CBA	cost benefit analysis
CFD	computational fluid dynamics
CRA	concept risk analysis
DSHA	defined situations of hazard and accident
DAE	dimensioning accidental event
DAL	dimensioning accidental load
DNV	Det Norske Veritas
DP	dynamic positioning
EER	escape, evacuation and rescue
E&P	exploration and production
EPA	emergency preparedness analysis
EPCI	engineering, procurement, construction and installation
ERA	early risk analysis
ESD	emergency shutdown
ESV	emergency shutdown valve
F&G	fire and gas
FAR	fatal accident rate
FMEA	failure mode and effect analysis
GBS	gravity base structure
HAZID	hazard identification

HAZOP	hazard and operability study
HC	hydrocarbons
HCLIP	hydrocarbon leak and ignition project
HES	health, environment and safety
HIPPS	high integrity pressure protection system
HMSO	Her Majesty's Stationary Office
HRA	health risk assessment
HSE	health and safety executive
IR	individual risk
IRPA	individual risk per annum
JIP	Joint Industry Project
LCC	life cycle cost
LEL	lower explosive limit
LQ	living quarter
NCS	Norwegian Continental Shelf
NLFEM	non-linear finite element method
NMD	Norwegian Maritime Directorate
NPV	net present value
MODU	mobile offshore drilling unit
NPD	Norwegian Petroleum Directorate
NTS	Norwegian Technology Centre
OLF	The Norwegian Oil Industry Association
PDO	plan for development and operation
PFD	process flow diagram
PFEER	prevention of fire and explosion and emergency response
PLL	potential loss of life
QRA	quantitative risk analysis
RAC	risk acceptance criteria
RBI	risk based inspection
RCM	reliability centred maintenance
RRM	risk reduction measure
RV	relief valve
SAR	search and rescue
SBSD	scenario based system design
SDOF	single degree of freedom
SIL	safety integrity level
SINTEF	The Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology
SJA	safe job analysis
TBL	Federation of Norwegian Manufacturing Industries
TRA	total risk analysis
TREPA	total risk and emergency preparedness analysis

UEL upper explosive limit

4 Establishment and use of risk acceptance criteria (RAC)

4.1 General

Establishment and use of RAC are elements of HES management, which is not covered in full in this NORSOK standard. The E&P Forum document "Guidelines for Development and Application of Health, Safety and Environmental Management Systems" gives guidance for HES management.

4.2 Basis for RAC

Risk acceptance criteria illustrate the overall risk level which is determined as tolerable, with respect to a defined period of time or a phase of the activity. Annex A presents a comprehensive discussion of aspects related to defining and using RAC.

The RAC constitute a reference for the evaluation of the need for risk reducing measures and shall therefore be available prior to starting the risk analysis. The RAC should as far as possible reflect the safety objectives and the particularities of the activity in question.

The evaluations that form the basis for the statement of the RAC shall be documented. Distinct limitations for the use of the RAC shall be formulated. Data used during the formulation of quantitative RAC shall be documented. The manner in which the criteria are to be used shall also be specified, particularly with respect to the uncertainty that is inherent in quantitative risk estimates.

4.3 Qualities of RAC

In order for the RAC to be adequate as support for HES management decisions, they should represent a compromise where the following qualities are satisfied as far as possible:

- Be suitable for decisions regarding risk reducing measures.
- Be suitable for communication.
- a) Be unambiguous in their formulation (such that they do not require extensive interpretation or adaptation for a specific application).
- Not favour any particular concept solution explicitly nor implicitly through the way in which risk is expressed. (But the application of RAC in risk evaluation will usually imply that one concept (or concepts) is (are) preferred over others, due to lowest risk).

More in-depth discussion of these aspects is presented in annex A.

The RAC shall be consistent with the risk elements as outlined in 5.2.5.

If average fatality risk or AIR is used in the formulation of RAC, also criteria for areas or groups within the platform personnel shall be formulated. It is not sufficient just to have a platform average value as criterion. See also § 6 (Risk acceptance criteria for major hazard and environmental damage risk) in NPD *Regulations for management of HES*.

The risk estimates shall be considered on a 'best estimate' basis, when considered in relation to the RAC, rather than on an optimistic or pessimistic ('worst case') basis. The approach towards the best estimate shall however, be from the conservative side, in particular when the data basis is scarce.

4.4 Updating of RAC

The need for updating of RAC shall be evaluated on a regular basis, as an element of further development and continuous improvement of safety.

4.5 Uncertainties

The results of risk assessments will always be associated with some uncertainty, which may be linked to the relevance of the data basis, the models used in the estimation, the assumptions, simplifications or expert judgements that are made. This uncertainty will be reduced as the development work progresses.

Uncertainties are usually most extensive in early concept study phases. This shall be reflected in these phases when RAC are used to judge the results of a QRA. The requirement may be satisfied in either of two possible ways:

- Apply more conservatism in the risk analysis.
- Make sure that RAC are satisfied with some margin.

5 Planning, execution and use of risk and emergency preparedness analysis (EPA)

5.1 General

The requirements in this clause are general and not connected to any particular life cycle phase. The phase specific requirements are given in clause 7. The description in clause 5 is mainly dealing with integrated risk and EPA. Specific requirements to QRA are presented in clause 6.

5.2 General requirements

5.2.1 Purpose and responsibility

The main purpose of using risk and emergency preparedness analyses is to formulate a decision-making basis that may contribute to selecting safety-wise optimum solutions and risk reducing measures on a sound technical and organisational basis.

The main results of any risk analysis shall be:

- Input to management of risk.
- Presentation of risk for the activity in question, in accordance with the structure of the RAC and for the relevant risk elements, see 5.2.5.
- Input to selection of development concepts, projects, construction and operation of facilities and installations to minimise risks, in accordance with what is relevant for the decisions to be taken.
- Ranking of risk contributors as basis for HES management.
- Identification of potential risk reducing measures, in accordance with what is relevant for the decisions to be taken.
- Important operational assumptions/measures in order to meet RAC.
- It is required to follow up results, recommendations and assumptions from the analysis. The documentation of these shall facilitate such follow-up.

The main results of a TRA (or other detailed risk analysis of similar nature) should in addition offer:

- The basis for establishment of performance standards.
- Establishment of requirements to emergency preparedness.
- Input to selection of development concepts, projects, construction and operation of facilities and installations to minimise risks.
- Identification of DALs.

The TRA will also be used for establishing performance standards for essential safety systems.

The main results of an EPA shall be:

- Basis for establishing emergency preparedness, including emergency preparedness plans and training and exercise plans.
- Selecting optimum solutions between available alternatives.

A number of aspects shall be clarified before an analysis is started:

- a) The purpose of the analysis has to be clearly defined and in accordance with the needs of the activity. The target groups for the results of the analysis have to be identified and described.
- b) The RAC for the activity shall be defined, see clause 4.
- c) The decision criteria for studies of limited extent need to be defined.
- d) The scope of the study and its limitations shall be clearly defined. The appropriate method is chosen partly on this basis.
- e) Preliminary statement on the types of analysis and the use of their results is made.
- f) Operational personnel inclusive of workers representatives, onshore and offshore, shall be involved in the work to the extent necessary.
- g) Relevant regulations, possible classification society rules and applicable standards and specifications that shall be the basis for design and operation. This applies particularly to the building of new mobile units and floating production installations.

Requirements f) and g) may not be fully achievable when a floating unit is built on speculation, without a specific operation nor continental shelf decided.

5.2.2 Planning and execution of risk analyses

Risk analyses shall be planned in accordance with the development and operation of the activity, ensuring that the risk studies are used actively in the design and execution of the activity:

- Risk analyses shall be carried out as an integrated part of the field development project work, so that these studies form part of the decision-making basis for i.a. design of safe technical, operational and organisational solutions for the activity in question.
- Risk analyses shall be carried out in connection with major modifications, change of area of application, or decommissioning and disposal of installations, as well as in connection with major changes in organisation and manning level. See 7.4 and C.6.

In order to achieve the overall objectives, the following general requirements to risk analyses shall apply:

- Planning of risk analyses:
 - The analyses shall be targeted and carried out in a systematic way as an integral part of HES management.
 - The studies shall be focused on identification of and insight into the aspects and mechanisms that cause risk.
 - The analyses must be carried out at an appropriate time, in order that the results of the studies can be timely taken into account in the relevant decision-making process.
 - The results from the studies shall not be used in a decision-making context that goes beyond the limitations that apply to QRA in particular (see 6.3).
- Execution of risk analyses:
 - The responsibility of the operator, owner, contractor/subcontractor shall be clearly defined (important for instance when operator is not involved in concept definition phase) with respect to the execution of the analyses and the implementation of their results.
 - Assumptions shall be identified, made visible and communicated to the users of the analysis results.
 - Experience has shown that the users of the analysis results need to be actively involved in the risk evaluation in order for it to be effective.

See also requirements for risk analysis as basis for EPA in 5.2.3.

5.2.3 Planning and execution of emergency preparedness analyses

It is important to focus on emergency preparedness as an integrated part of the work at an early stage in a field development project, in order to avoid major and costly changes at a later stage. See also C.2.

Therefore, when a risk analysis is carried out as a basis for EPA, the following aspects shall be focused on:

- a) DAEs (as part of the DSHAs) shall be identified and sufficiently described.
- b) Assumptions, premises and suppositions shall be identified and documented as a basis for establishing performance standards for emergency preparedness.

The following aspects shall be clarified prior to starting the EPA, in addition to the general requirements of 5.2.1:

When quantitative analyses are used, the data basis in the planning phase shall be adapted as far as possible to the purpose of the study.

5.2.4 Competence of analysis personnel

Requirements as to the competence of personnel carrying out and evaluating the risk and EPA shall be defined.

The analysis team for a quantitative (or an extensive qualitative) risk analysis shall have special competence in risk analysis methods and relevant consequence modelling, as well as relevant project and operational competence. The latter may include, when such activities are analysed, competence within fabrication and installation activities, relevant marine and manned underwater operations.

For EPA, personnel having competence in EPA as well as in project and operational work and operational emergency planning shall be included in the analysis team. Risk analysts should also participate, in order to facilitate the integration of risk and emergency preparedness analyses.

5.2.5 Risk elements

The following risk elements shall as a minimum be considered in a TRA, to the extent they are applicable:

- Blowouts, including shallow gas and reservoir zones, unignited and ignited.
- Process leaks, unignited and ignited.
- Utility areas and systems fires and explosions.
- Fire in accommodation areas.
- Falling/swinging objects.
- Transportation accidents:
 - Transport of personnel between installations shall be included in the risk levels when this is an integral part of the operations of the installations.
 - Transport of personnel from shore to the installation shall be included if required by the RAC.
 - Helicopter crash on the installation.
- Collisions, including fields related traffic, and external traffic, drifting and under power.
- Riser and pipeline accidents.
- Accidents from subsea production systems.
- Occupational accidents.
- Escape, evacuation and rescue accidents, i.e. until a so-called 'safe place' has been reached.
- Structural collapse, including collapse of bridges between fixed and/or floating installations.
- Foundation failure.
- Loss of stability/position.

The list above shall apply explicitly for a detailed risk analysis, to the extent they are applicable. For a less detailed analysis the entire list may not be applicable in detail, but it should be considered as a guidance for which risk elements that are addressed. An explicit list of the relevant risk elements to be considered shall be prepared as part of the definition of scope of work. The list may need to be updated through the HAZID.

5.2.6 Risk reducing measures

Risk reducing measures shall be identified as part of any risk or EPA.

Risk reducing measures involve probability-reducing measures, including inherently safe solutions, and consequence-reducing measures, including emergency preparedness measures. Further details on requirements are given in NPD Regulation for management of HES §§ 1 (risk reduction) and 2 (barriers). See also A.3.5.

Dependencies between risk reducing measures should be documented explicitly, if alternative measures are proposed. The choice of risk reducing measures should furthermore take into account the reliability and the vulnerability of the risk reducing measures and the possibility of documenting and verifying the estimated extent of risk reduction. The possibility of implementing certain risk reducing measures is dependent on factors such as available technology, the current phase of the activity and the results of cost benefit analysis. (see also annex E).

The choice of risk reducing measures shall be documented in relation to all relevant aspects.

5.3 Specific requirements to qualitative risk analysis

Examples of qualitative risk analyses are SJA, preliminary hazard analysis, coarse risk analysis with risk matrix presentation, 'Driller's HAZOP' and simple comparative studies. General requirements to the planning of risk analyses are presented in 5.2.1 and 5.2.2. Qualitative studies are usually carried out by a broad group of persons in order to reflect the relevant competencies, reference is made to 5.2.

The steps of a qualitative risk analysis depending on the level of detail, are:

- a) Planning of the analysis.
- b) System/Job description and limitation.
- c) Identification of hazards.
- d) Analysis of causes and potential consequences.
- e) Risk evaluation.
- f) Identification of possible risk reducing measures.

See annex A for discussion of qualitative RAC.

Experience from accidents and incidents from the company's own files and data bases and from public data bases, shall be available for the analysis team.

This revision of this NORSOK standard has placed the main emphasis on quantitative risk analysis. Hence, no specific requirements are formulated for qualitative risk analysis. The general requirements of 5.2 do apply.

5.4 Specific requirements to EPA

5.4.1 Scope of analysis

An EPA shall define the basis for DSHAs and document the choice of DSHA's. A systematic review of a possible development of a DSHA shall define and dimension required emergency preparedness measures to fulfil the established performance standards for safety and emergency preparedness. The effect of the emergency response measure shall be evaluated.

Emergency preparedness analysis should be an integral part of development and modification projects.

Emergency preparedness measures include measures directed at containing spills of oil and other pollutants, from minor or major releases. Dimensioning of medical preparedness is also part of the EPA.

Operational limitations will be taken into account when operational and environmental conditions are defined. Assumptions may have to be established, if the analysis is carried out prior to the formulation of such procedures. Any assumptions made in this respect shall be verified at the earliest possible convenience.

5.4.2 Steps in EPA

Figure 1 presents the steps of EPA and establishment of emergency preparedness, in relation to input from the QRA. The starting point of the presentation is the integrated risk and EPA, and it shows how the work may be carried out step by step in a field development project. This applicability is limited to DAEs.

The steps of the EPA are briefly described in 5.4.3 to 5.4.7.

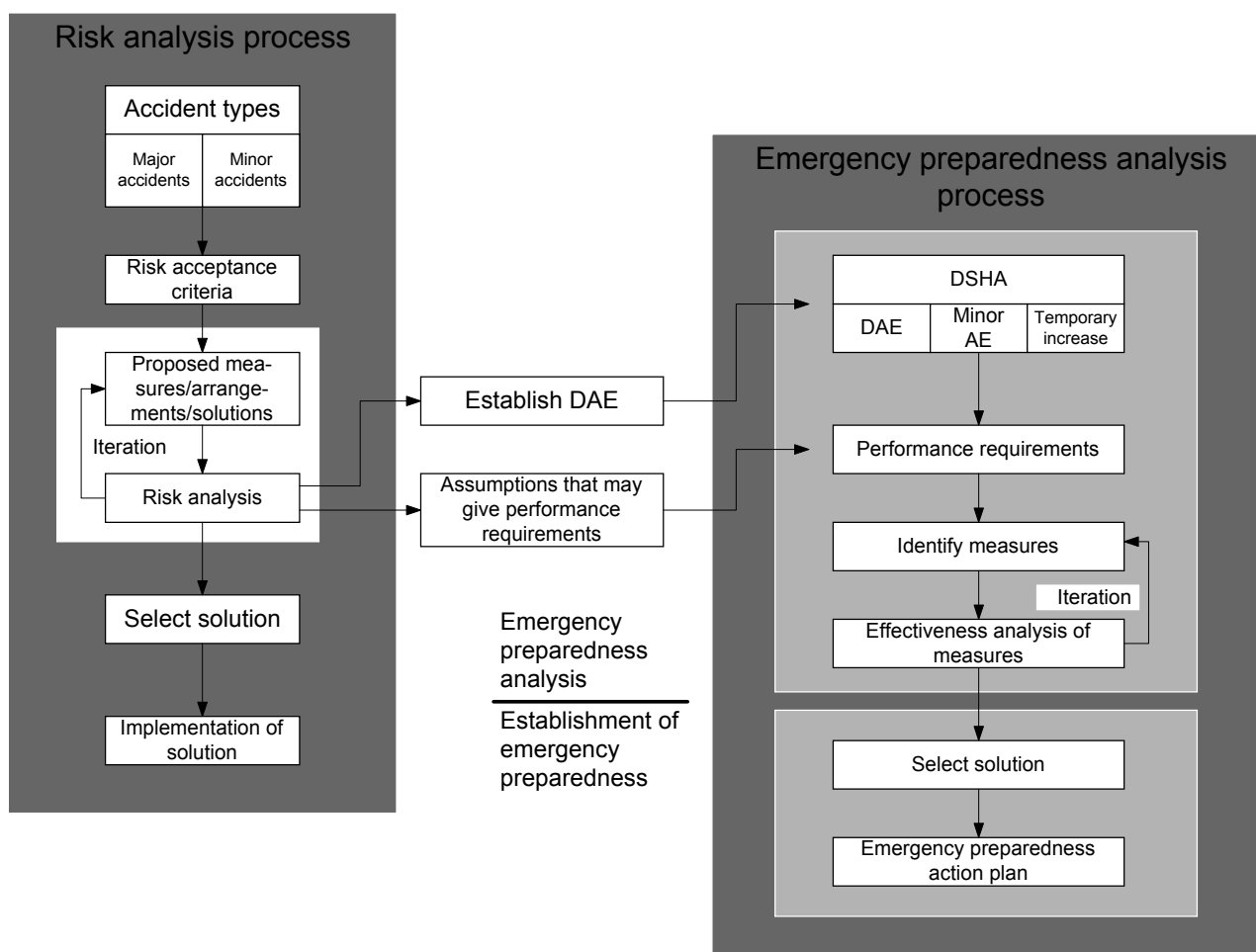


Figure 1 - Risk and EPA

Guidance to establish emergency preparedness plans is found in ISO 15544.

5.4.3 Establish DSHA

DSHA shall include the following event categories:

- DAEs, usually defined on the basis of DALs through QRA.
- Situations associated with temporary increase of risk.
- Less extensive AEs, including acute cases of illness.

DSHAs shall in addition be established on the basis of:

- Events that have been experienced in comparable activities.
- Accidental events that appear in QRA without being identified as DAEs, as long as they represent separate challenges to the emergency preparedness.
- DSHAs according to OLF *Guidelines for Area-based Emergency Preparedness* (30. 6. 2000).
- Events for which emergency preparedness exists according to normal practice.

Choice of DSHAs shall be documented, in particular in relation to why they are considered to make a representative selection, and also those events that have been omitted.

When DSHA are established, it is important to include events that may mainly cause damage to assets without risk to personnel, such as damage to pipelines and subsea production systems.

The need for description of DAEs (amongst DSHAs) is addressed in 5.2.3. In the description of situations associated with temporary increase of risk, or less extensive AEs, the following shall be included:

- A general description of the situation in terms of duration and extent.
- The number of persons that may be threatened or injured, as well as environmental resources and assets that may be threatened or damaged.
- Operational and environmental conditions that may be present when these AEs occur.

When dealing with normally unmanned installations, distinctions also have to be made between those DSHA that relate to personnel being present and those that relate to the installation being unmanned.

For normally unmanned installations, some DSHAs based upon DAEs which are commonly defined as DSHAs for manned installations, may be disregarded as DSHAs, if a low exposure (activity level) implies that the probability of occurrence is remote. This may be considered on a case by case basis.

5.4.4 Information from QRA

All relevant information and results from QRA shall form part of the EPA. Such information shall include:

- Description of those DAE for which organisational and operational measures shall be established.
- Time requirements that have to be satisfied.
- Required performance of systems that form part of the emergency preparedness.
- Assumptions on the success or suitability of emergency preparedness measures (such as assumptions on the possibility of assisting injured personnel on the installation or after initial escape).

5.4.5 Establish performance standards

Performance standards for emergency preparedness measures should be:

- Express a functionality, not a solution.
- Easy to understand.
- Explicit and measurable.
- Realistic.

The basis for establishment of the performance standards is indicated by Figure 1, and includes results and premises from risk analysis, DAEs and loads.

Performance standards shall be established in relation to competence of personnel and the following emergency phases:

- Alert
- Danger limitation
- Rescue
- Evacuation
- Normalisation

The performance standards shall be specified in a way which will allow those that are relevant to be validated and used as risk indicators during the operational phase, reference is made to 5.5.

5.4.6 Identification of measures and solutions

Measures and solutions to be considered in an EPA are:

- Organisational and operational measures related to DAEs, and technical measures not included in the risk analysis.
- Technical, organisational and operational measures related to less extensive AEs as well as to temporary increase of risk.

The principles stated in 5.2.4 shall be used for giving priority to the risk reducing measures.

The basis for the identification of possible measures and solutions is i.a. knowledge about internal and external emergency preparedness resources, which therefore shall be described or referred to. All relevant resources within the following categories should be considered:

- Installation's own resources.
- Resources in the area.
- External resources.

5.4.7 Effectiveness analysis

The performance of technical emergency preparedness measures may usually be documented through reliability or vulnerability studies. For the organisational or operational measures, the following methods may be applicable:

- Results of training.
- Experience from exercises.
- Calculation of capacities, response times, or similar.

It may be relevant to optimise the performance on the basis of documented results. This is discussed in annex E.

5.4.8 Documentation of EPA

Suitable information shall be provided in an understandable way for all relevant personnel, decision-makers as well as operating personnel.

The documentation and results of the EPA shall be used for:

- Stating the objectives, scope and limitations.
- Describing the object/installation in question, inclusive all phases.
- Identifying assumptions and premises, in particular those derived from the QRA.
- Giving detailed description of all relevant DSHA.

The presentation of results of an EPA shall be sufficiently comprehensive in order to allow good insight into the basis for the analysis.

The following documentation shall be available in addition to an updated version of the analysis and known to the operating personnel prior to start-up or operation of the installation/operation:

- Documentation of the measures that have been or will be implemented as a consequence of the analysis.
- Description of the emergency preparedness analyses that are planned to be carried out or updated for the installation in the subsequent life cycle phase, as part of the overall HES management documentation.

5.5 Verification of performance standards

Verification that performance standards for safety and emergency preparedness systems are met in the operational phase may be achieved through monitoring trends for risk indicators as explained in annex A, which should be monitored as a minimum once per year.

The risk analyses should therefore be capable of identifying the parameters or indicators which have a strong impact on the risk level and also the effect that changes will have on the risk level. This will enable an effective monitoring of the risk level in relation to the RAC. Examples of such indicators may be:

- Hydrocarbon leak frequencies.
- Extent of hot work.
- Availability of essential safety systems (see Figure 3).
- Mobilisation time for emergency personnel/teams.

- Aspects related to safety culture.

Site specific risk indicators should be defined for each installation or field, based upon these general recommendations.

The intention is therefore to get an early warning of any trends, which may result in inability to meet RAC. The risk indicators shall be monitored regularly, in order to identify unwanted development at an early stage.

Possible deviations between registered parameter values and performance standards shall be handled in accordance with the company's procedures for deviations. A possible action is to update the assumptions in the QRA, in order to identify the extent of the influence on overall risk.

5.6 Involvement of operation personnel

The involvement of the workforce in performance of quantified risk assessment should be as follows:

- During HAZID.
- In the review of system descriptions, assumptions and premises.
- In the review of the documentation from the analysis, including results and evaluation of risk reducing measures.

See also 5.2.1 and 6.16.

It may be required to prepare separate presentations of the results and conclusions from TRA studies, in order to communicate these to the entire workforce in an instructive and useful manner.

The involvement of operational personnel in performance of EPA offshore should be as follows:

- During HAZID.
- During evaluation of hazards.
- In the review of risk reducing measures.

6 Specific requirements to quantitative risk analysis (QRA)

6.1 Steps in a QRA

The elements in a QRA are presented in Figure 2, which shows four levels:

- Inner level: Risk estimation
- Second level: Risk analysis
- Third level: Risk assessment
- Outer level: HES management

Please note that these four levels do not reflect the sequence in which the tasks are carried out. The sequence starts at the top in Figure 2 and continues downwards.

Requirements to the risk analysis and the risk estimation are presented in the following text, 6.2 to 6.17. The formulation of the RAC will determine which of the requirements in 6.11 to 6.14 that are applicable.

This NORSOK standard covers the risk estimation, risk analysis, and risk assessment. HES management is not covered.

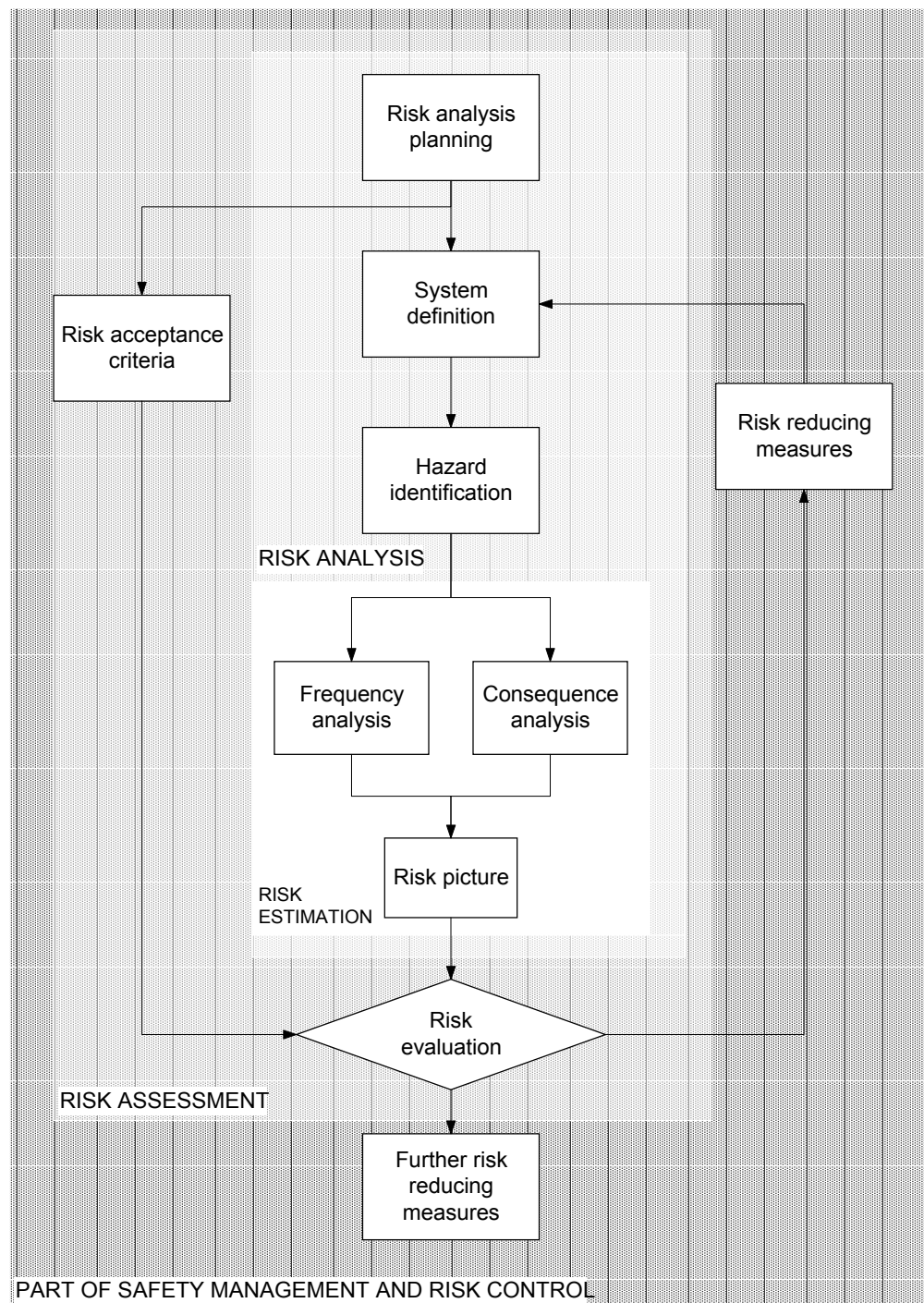


Figure 2 – Risk estimation, analysis and evaluation

6.2 Planning

General requirements to the planning of risk analysis are stated in 5.2.2. Additional requirements to the planning of QRA in relation to the use of data basis and models, are presented in 6.7.

6.3 Limitations

The limitations of a risk analysis shall be stated explicitly. They should be observed during planning of the studies.

Limitations on the use of risk analysis will result from the way the general requirements, as presented in this NORSOK standard, are adhered to. The general aspects for data basis and models shall be considered regarding limitations as detailed in 6.7.

The adequate level of precision in the results shall be evaluated explicitly, on the basis of the calculations, data and models which are available for the quantification of probability and consequence. Sometimes, it is required to express results with somewhat higher precision than what could be considered justifiable, based upon precision in calculations, data and models. This should be considered in the evaluation of uncertainties.

6.4 System definition

The system definition (or description) shall include:

- Description of the object of the analysis, i.e. the technical system (process, structure, utility, safety, emergency preparedness systems), including the relevant operations and phases.
- Statement of the period of time to which the analysis relates.
- Statement of current condition (in relation to possible degradation) for essential safety systems and safety functions (applies in particular to analyses in operations phase).
- Statement of the personnel groups, the external environment and the assets to which the risk assessment relates.

The system description should for a QRA in addition to the general requirements above, include capabilities of the system in relation to its ability to tolerate failures and its vulnerability to accidental effects.

6.5 Identification of hazard

Hazard identification shall include:

- A broad review of possible hazards and sources of accidents, with particular emphasis on ensuring that relevant hazards are not overlooked.
- Internal/external incident reports that are applicable.
- A rough classification into critical hazards (as opposed to non-critical) for subsequent analysis.
- Explicit statement of the criteria used in the screening of the hazards.
- Explicit documentation of the evaluations made for the classification of the non-critical hazards.

Possible tools for the HAZID may be:

- Use of check lists and accident statistics, e.g. use of lists in ISO 17776, annex D, or similar, se.g. as outlined in ISO 17776, annex C.
- b) Experience from previous analyses, safety inspections and audits.

6.6 Analysis of causes and frequency of initiating events

Explicit analysis of possible causes of initiating events should be preferred to assessment of initiating event frequency based on accident and failure statistics. The cause analysis gives the best basis for identifying measures that may prevent occurrence of these events and thus prevent accidents.

Possible tools that may be used for the analysis of causes of initiating events are:

Fault tree analysis.

- FMEA

Cause analysis and frequency data for initiating events shall contain an evaluation of the need to include evaluations of human and organisational factors. This is particularly important where accidents may be caused directly by human or organisational errors.

For the analysis of causes/frequency of initiating events in a QRA, an explicit human reliability analysis should as far as possible be carried out.

Reference is made to the NPD Regulation for management of HES, §15 (QRAs and EPAs).

6.7 Data basis and models

The following requirements apply:

- Both the data and the models into which the data are applied, shall be suitable in relation to the context of the study.
- Data that are used should be consistent with relevant operations and phases.
- If trends in data are used, they will need to be substantiated.

Analytical models and computer codes have to be suitable for the purpose and have a resolution which is adapted to the objectives of the analysis. The models must also comply with the requirements to input data, assumptions, etc. see also 6.15 on sensitivity studies and annex D for further details.

The modelling of the potential incident/accident sequence shall be detailed enough in order to suit the purpose of the analysis, e.g.:

- Estimate the risk picture.
- Estimate the performance of the barriers.
- Establish performance standards for the essential safety systems.
- Show the dependency between the physical barriers.
- Reflect explicitly common cause and mode failures.

As the risk analysis forms an important part of the basis for the decision-making process, the input data, models and assumptions shall be considered in relation to the need for verification. See also annex D and NORSOK standard Z-016, clause 6.

Qualified methods should as far as possible be used, applying to analytical models, computer codes and data, which should be qualified by the operator/owner or by recognised institutions on his behalf. This may for instance be achieved through use of the 'Model Evaluation Protocol' established by the 'Model Evaluation Group' under the EU Commission.

When unqualified methods are used, the effects on the uncertainties in the results shall be considered.

6.8 Consequence and escalation analysis in TRA

The term consequence analysis is used in a wide sense, including both consequence modelling (i.e. estimation of accidental loads), modelling of escalation and estimation of response to accidental loads. The distinction between cause analysis and consequence analysis may vary somewhat according to the purpose and the nature of the analysis.

The requirements of this subclause shall apply explicitly for a detailed risk analysis. For a less detailed analysis the entire list is not applicable in detail, but it should be considered as a guidance for which risk elements that are addressed.

For a TRA, the consequence analysis shall include but not be limited to the following sub-studies (either as part of the TRA or through separate studies), when the hazards are relevant:

- Leakage of inflammable substances:
 - Calculation of release (amounts, rates, duration, etc.).
 - d) Calculation of spreading of leakage and gas dispersion.
- Calculation of ignition potential.
- Fire load calculation.
- Explosion load calculation.
- Response calculation.

- Blowouts (with respect to environmental loads):
 - e) Calculation of release rate, duration, etc.
 - Spill drifting calculation.
- Blowouts (non environmental effects):
 - Consequences related to ignition and subsequent effects are calculated as for leakages of inflammable substances.
- External impact (collision, falling/swinging load, helicopter crash on installation):
 - f) Calculation of energy distribution.
 - Calculation of load distribution.
 - Calculation of impulse distribution.
 - Response calculation.
- Falling loads on subsea installations and pipelines:
 - Consequence calculations as for external impacts in general.
- Loss of stability and buoyancy, catastrophic loss of anchor lines:
 - Calculation of residual buoyancy and stability in damaged condition.
 - Calculation of load distribution in damaged condition.
 - Response calculations.

The stability and buoyancy calculations are usually carried out by the relevant discipline as part of the marine studies, and the results from these studies may be integrated into the risk analysis.

Further details are presented in annex B.

Relevant tools for consequence modeling in relation to fire and explosion are:

CFD-methods

- Analytical methods, reference is made to industry procedure, see annex G.
- Simulation methods (based on CFD or analytical methods).

Non-linear structural analyses are often used for external impacts, thereby making it possible to reflect structural reserve capacity beyond yield.

Escalation analysis includes consequence modelling and response calculation. Analysis or evaluation of essential safety systems forms part of the escalation analysis (see 6.9), in order to assess the possibility or the premises for maintaining control of the sequence of AEs.

As far as possible, contribution to escalation from human and organisational factors should be explicitly analysed, together with the contribution from such failures to dependent failures, reference is made to 6.6.

The most important barriers shall be explicitly modelled in an event tree (or corresponding). This does not necessarily require that all barriers are modelled as nodes in the event tree, but the models will need to be available for analysis of dependencies.

6.9 Essential safety systems

Analysis or evaluation of essential safety systems is an important part of the consequence analysis, and is also carried out as an assurance activity for these systems.

When required/requested by relevant authority or contract requirements an escalation analysis shall be made and shall as a minimum include a classification of the essential safety systems based on vulnerability to AEs. A comprehensive analysis shall include identification and analysis of mechanisms of failure of these systems and their dependencies, in relation to relevant AEs. Emphasis shall be given to analysis of the total system and dependent failures shall be integrated in the analysis of the essential safety systems.

This is further discussed in 8.7 and 8.9.

6.10 Risk analysis of well and drilling activities

Blowouts represent a major risk contributor to installation risk, but detailed evaluation is also required for a specific well program.

On an overall level, risk evaluations for planned drilling and well activities shall be performed such that the effect of the activities is determined as part of the total risk on the installation.

The remainder of this subclause applies to detailed analyses of well activities for specific wells or groups of wells, and can only be carried out when detailed programs, equipment specifications and procedures have been proposed. The risk analysis shall provide the basis for:

- Operational planning.
- Planning of well control activities.
- Selection of and requirements to barriers.
- Requirements for training and organisation of the activities.
- Restrictions (if any) applicable to simultaneous operations.

The detailed risk analysis of well activities should usually include:

- Probability of blowout and its consequence in terms of appropriate categories according to what is relevant and what is required by RAC.
- Probabilities of occupational accidents and their consequences.
- Probabilities of different amounts of oil spilled, as input to the environmental risk analysis (see 8.2).

The risk analysis can cover several drilling and well activities as long as presumptions and basis are the same. Regardless, an evaluation of the activity shall be done to ensure a consistent basis.

6.11 Estimation of fatality risk

The risk to personnel is often expressed as fatality risk, sometimes also as risk in relation to personal injury. The following fatality risk contributions are often estimated separately:

- h) Immediate fatalities.
- Transportation fatalities including shuttling.
 - Escape fatalities.
 - Evacuation and rescue fatalities.

The fatality risk contributions shall be split into areas or exposed personnel groups according to where the fatalities occur.

In a TRA, the fatality calculations shall include:

- Response of personnel to accidental loads:
 - Heat radiation.
 - Toxic gas, smoke, etc.
 - Primary and secondary (usually most important) effects of blast/impulse loads.
- Analysis of evacuation and rescue operations (preferably with a probabilistic modeling).

An estimate of the number of personnel injured in accidents is often required as input to EPA. This may imply that the consequence analysis for personnel is extended to include injuries. The analysis may also be used for dimensioning of evacuation and rescue capacity, as outlined in B.9.

Fatality risk results should be subjected to extensive validation, due to the absence of experience data for judgement of realism. Presentation of intermediate results may be used for this purpose, as outlined in B.9.

6.12 Loss of main safety functions

When required/requested by relevant authority or contract requirements, the analysis shall include evaluations of possible loss or impairment of main safety functions, such as main support structure, escape ways, shelter area, control room function and evacuation means, due to accidental loads. This may be achieved by carrying out separate response studies, as outlined in 6.7 or in other ways. Main safety functions are discussed in A.1.2, A.2.8 and A.4.2.2.

6.13 Establishment of DALs

Accidental events and DALs are closely related. The establishment shall start with the completion of a risk analysis and the comparison of estimated risk with RAC.

The risk analysis will have to establish sets of AEs and associated accidental loads, and possibly also associated probability. The DALs are chosen from these sets, such that the RAC are complied with.

6.14 Estimate risk for asset damage/production disruption

The following additional steps should be carried out in order to estimate the risk for asset damage and deferred production:

- Establish the distribution for duration of AEs (often an extension beyond the period of exposure of personnel).
- Calculate responses for equipment and structures.
- Estimate required man hours and duration of restoration work.
- Estimate cost of restoration and duration of operations shut down including possible temporary solutions, as by-pass, temporary equipment, substitution, etc.

Further details are presented in annex E and NORSOK standard Z-016.

6.15 Sensitivity analysis

The need for sensitivity studies shall always be considered. Uncertainties shall be evaluated on this basis.

Sensitivity analysis presents robustness (i.e. to what extent the conclusions depend on variability in the input values and assumptions) in the results based on variances in:

- Risk modelling data.
- Design parameters.
- Operational parameters.

Sensitivity analysis will be particularly important if the data basis has an insufficient number of occurrences. Sensitivities will then have to be considered in order to limit the uncertainties and produce robust conclusions.

6.16 Documentation

The information shall be understandable to all relevant personnel, decision-makers as well as operating personnel. The list below shall be considered relevant for the analysis in question and level of detail.

The documentation of a QRA shall as a minimum include the following:

- Statement of objectives, scope and limitations.
- Description of the object (or system) of the analysis, the phases and operations that the analysis is valid for, the categories of defined accidental hazards/events that are covered and the dimension of risk. The descriptions should preferably be accompanied by drawings or similar.
- Statement of the assumptions, presumptions and premises on which the study is based, so that they may be evaluated and accepted.
- Data basis.
- Description of the analytical approach used.
- Quality assurance, including personnel competence.
- Presentation of conclusions from the study.
- Presentation of possible measures that may be used for reduction of risk and their risk reducing effect.

The documentation for a TRA shall in addition to the general requirements presented in 5.2.1 as a minimum include the following:

- Extensive presentation of results in relation to objectives, scope and limitations. The presentation shall include the main contributions to the risk levels.
- Presentation of the sensitivity in the results with respect to variations in input data and crucial premises.
 - i) Specify performance standards, in a way that makes them suitable for being used as dimensioning requirements.
- Description of DAEs and DALs.

Assumptions and premises stated in the overall risk analyses (those that are carried out in order to compare results against RAC, see 3.1.18 at an early stage of the design), shall be included as performance standards for safety and emergency preparedness measures for later phases of the design project.

A plan for follow-up of the analysis shall be prepared, containing an assessment of the study's conclusions and recommendations as well as plans for implementation of risk reducing measures, including emergency preparedness measures.

6.17 Update of analysis

Studies shall be updated in connection with major modifications or changes to area of application. Further the effect on the risk levels of following aspects shall be considered and the studies updated when relevant:

- Experience from accidents that have occurred, in particular with respect to analysis of causes.
- Organisational changes.
- Changes to regulations.
- Changes in data basis, models or risk estimating methods.
- Minor modifications, which in sum does represent a major modification.

The updating of analyses shall include updating of the following when relevant:

- The description of the installation and operations in accordance with the development of the activity .
- Assumptions and premises that the earlier analysis has been based on, and possibly further development (of these).
- Whether risk associated with special operations or new equipment that are being planned, has been assessed at an earlier stage.
- The data basis in the light of to new experience, new knowledge or changes in the data bases that have been used, including revision of experience data from own operations.
- The methodology which is used.
- The analysis results in the light of possible changes to the operator's/owner's RAC for the installation or operations.

The operator/owner shall formulate minimum requirements to the frequency of updating of the QRA and EPA, unless technical or operational circumstances in the meantime have necessitated more frequent updating.

7 Risk and emergency preparedness analysis (EPA) in life cycle phases

7.1 General

This clause is based on the general requirements outlined in the previous clause and defines their implications for risk and EPA in each life cycle phase. The use of RAC in the various life cycle phases is not discussed, this is presented in annex A. See also ISO 17776, annex C.

An existing mobile unit that is brought into the Norwegian sector, will usually have applicable risk analyses prepared under foreign legislation. The specific and itemised studies of the tables in clause 7 may be departed from for a mobile unit, as long as the available studies cover the requirements of clause 5, clause 6 and clause 7.

7.2 Analyses during concept development

Table 1 presents an overview of the main analyses which shall be conducted during concept development phases, including their timing, main purpose and focus. Further details are provided in annex C.

Table 1 – Summary of main risk analyses during field development phase

Analysis	Timing	Main purpose	Main focus
ERA	Selection of main concept, pre-conceptual phase	• Comparison and ranking of field development concepts • Optimisation of chosen concepts • Identify all major hazards.	• All installations that are part of production system, including mobile units and vessels that are involved in the operations • HAZID of all risk aspects • Non-traditional safety aspects • Identification of potentially extra costs for achieving an acceptable solution
Concept TRA	When layout drawings and PFD's have been made. Before issue of invitation to tender. Before submission of PDO	• Assessment of compliance with acceptance and design criteria • Identify functional requirements as input to design specification • Establish dimensioning accidental loads	• HAZID • Identify aspect which need detailed analysis • Identify design or operational challenges • Identify design or operational assumptions • Establishment of DALs • Give recommendations to design
Design TRA	When layout drawings, P&ID's for process and essential safety systems have been made.	• Verification of design • Check of compliance with overall RAC (assumptions for safe operation) • Establish performance standards and requirements from assumptions and premises in analysis	• Update DALs • Decide about the need for and the extent of further risk reducing measures • Analysis of performance of safety barriers • Identify risk indicators and their importance • Review and update assumptions made • Verify and confirm DALs • Detailing of the analysis for achieving more accurate results
As-built TRA	When final design of systems	• Update TRA with as-built information and reflect any changes to risk levels • Provide input to operations	• As for design TRA

Table 2 presents an overview of the additional analyses which should be considered during development phases. When performed their timing, main purpose and focus shall be as given in Table 2. Further details are provided in annex C.

Table 2 – Summary of optional additional risk analyses during field development or operational phase

Analysis	Timing	Main purpose	Main focus
Detailed risk analysis and analyses in connection with design change proposals, handling of deviations and project phases (TRA extension)	After concept risk analysis	- Evaluate special risk aspects on the basis of performed risk analysis in order to give design input - Evaluate how changes etc. affect risk - Evaluate effects of deviations from statutory requirements	- HAZID - Reflect design details/specifications - Reflect detailed/special analysis performed - Provide operational recommendations - Update DAL (if required) - Assessment of compliance with acceptance and design criteria - Input to DSHA (when required/requested)
Quantitative/Qualitative studies (FMEA, HAZOP, etc)	When appropriate or requested during engineering phases, in order to evaluate systems designs	Identification of required improvements in system design	- Processing systems - Utility systems - Drilling fluid systems - Essential safety systems - Loss of barriers - Human factors
Integrated risk and EPA of fabrication and installation	Prior to decision on concepts for fabrication and installation	- Provide input to concept and methods for fabrication and installation - Identify operational limitation and environmental envelopes to be observed during fabrication and installation	- Fabrication of equipment and structures, hooking up, towing of modules, installation, commissioning and start-up preparations - All installations and vessels engaged in the installation and hook-up operations - Nearby installations and vessels, if they are close enough to be affected by accidental effects - Aspects of the fabrication and installation that may severely affect the entire installation and/or risk to personnel - Determine the emergency preparedness level for the fabrication, installation and commissioning work

7.3 Use of SBSD

During development of special concepts, such as normally unmanned installations, it may be required to adopt SBSD as a means to fulfil the intentions of applicable requirements through non-traditional solutions, which may depart from the detailed requirements in regulations and standards. Annex F describes how this may be carried out in practice.

The use of SBSD shall meet the following main requirements:

- Quantitative risk analysis shall always be carried out in relation to RAC.
- High level RAC shall be complemented by decision criteria relating to performance of barriers.
- The barriers gas detection, fire detection and HC potential limitation/isolation should always satisfy a set of basic functional requirements, even when SBSD is used.

7.4 Analyses in operations

Table 3 presents an overview of the main analyses which shall be conducted during the operations phase, including their timing, main objectives and focal points. Further details are provided in annex C.

Table 3 – Summary of main risk analyses during operations phase

Analysis	Timing	Main purpose	Main focus
TRA updates	During operations phase	Update of risk levels due to experience, modifications, model improvements, changes in criteria, operational mode, manning level, maintenance philosophy, etc	- Update design TRA - Eliminate assumptions - Reflect operational experience - Reflect modifications - Reflect new knowledge - Establish basis for risk communication with operational personnel - Present a detailed risk picture - Present input to scenarios for DSHA
Risk analysis of critical operations, including SJA	Planning of the operations	- Identification of hazards - Identification of risk reducing measures, in order to achieve safe job performance	Necessary risk reducing measures shall be implemented
TRA adaptation for operations phase	Regularly during operations phase	- Ensure that the risk level is kept under control. - Ensure that operational personnel are familiar with the most important risk factors and their importance - Identify and follow up of assumptions made in earlier phases - Update DSHA	- Follow up of TRA during operations phase - Status and condition of critical safety aspects
Integrated TREPA of modifications	Prior to deciding on details of modifications	- Evaluate the operational phase with the modifications implemented - Identification of hazards - Identification of possible risk reducing measures	As for engineering phases to the extent relevant
Integrated TREPA of modification work	Prior to deciding on the way in which the modification shall be implemented	- Evaluate the operational phase during modification work - Identification of hazards - Identification of possible risk reducing measures	- Simultaneous activities - Increase in risk level during modifications work - Need for additional emergency actions during modifications work - Establish emergency preparedness requirements for the modifications work

7.5 Analyses of emergency preparedness

Table 4 presents an overview of the main analyses which shall be conducted during the development phase, including their timing, main objectives and focal points. Further details are provided in annex C.

Table 4 – Summary of main emergency preparedness analyses

Analysis	Timing	Main purpose	Main focus
Early EPA	Before decision to start preparations of PDO.	- Comparison and ranking of field development concepts - Optimization of chosen concepts - Identification of initial performance standard for emergency preparedness	- Possible emergency preparedness aspects that may require extra costs in order to achieve an acceptable solution - Non-traditional emergency preparedness aspects - Escape and evacuation aspects
Concept EPA	When layout drawings, P&ID's for process and essential safety systems have been made. Before submission of PDO.	- Assessment of compliance with acceptance and design criteria. - Provide input to design and operational procedures - Establish performance standards for technical, operational and organisational emergency preparedness.	- Identify aspects which need detailed analysis - Identify design or operational assumptions - Give recommendations to design - Relevant installations that are part of the production system, including mobile units and vessels that are involved in the operations, nearby vessels and installations
As-built EPA	When final design has been made	- Update EPA with as-built information and reflect changes to risk levels - Establish performance standards	- As for concept EPA - Input to emergency preparedness plans, procedures and emergency organisation.

It should be emphasised that the main emphasis should be placed on the aspects listed above, which analysis that they are included into, are of less importance.

8 Interfaces

8.1 General

Several assessments will affect risk analysis or vice versa. This clause gives an overview of studies, which may provide input to or require results from the risk analysis.

8.2 Relations to other NORSOK standards

Analyses for safety, reliability and maintenance are related. Three NORSOK standards deal with these issues.

- Z-CR-008 Criticality classification method
- Z-013 Risk and emergency preparedness analysis
- Z-016 Regularity management and reliability technology

The relations between the standards in terms of exchange of information are depicted in Figure 3.

Reference is also made to NORSOK standard N-001 and NORSOK standard S-001.

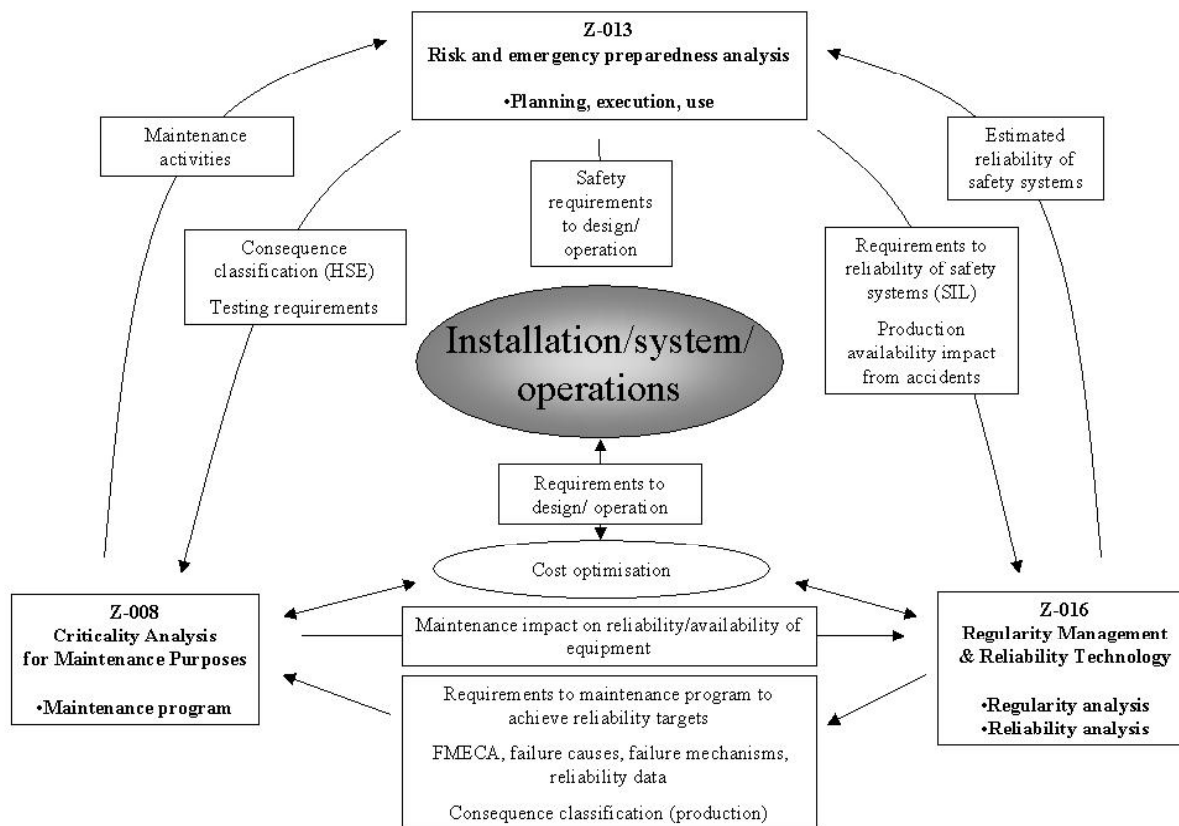


Figure 3 – Relations between NORSOK standards Z-008, Z-013 and Z-016

8.3 Estimate environmental risk

The MIRA method is established by OLF and has several interfaces with a risk analysis. The following steps form part of an environmental risk assessment:

- Establish the distribution of release duration.
- Simulation of the drifting of oil spill for relevant scenarios.
- Estimate the effects on environmental resources.
- Estimate restoration times.

The main inputs from risk analysis are:

- Frequency of blowouts.
- Release scenarios, including rates, duration, dispersion, etc.

The main output from MIRA to a risk analysis is basis for an EPA.

Reference is made to OLF Recommended method for environmental risk analysis, MIRA.

8.4 Regularity analysis

Reference is made to NORSOK standard Z-016 where regularity, availability and reliability analysis functions of any type of systems and operations are outlined. Risk and emergency preparedness analyses link many aspects of regularity and reliability analysis. NORSOK standard Z-016, clause 5, outlines important interface issues between these two types of analyses, such as summarised below:

- The risk and EPA may impose reliability requirements on certain equipment, typically essential safety systems.
- The risk and EPA may impose requirements to equipment configuration that will affect regularity.
- Production unavailability due to catastrophic events.
- Assumptions and premises in the risk and emergency preparedness analyses may influence the regularity analysis and its operational and maintenance strategies. Examples are manning levels, logistics and equipment test strategies.
- Study assumptions and data in reliability analyses and risk and emergency preparedness analyses shall be consistent.

8.5 Reliability centred maintenance (RCM)

The purpose of an RCM analysis is to establish the (preventive) maintenance programme in a systematic and optimal way. This is described in NORSOK standard Z-016, 8.4.2 from which the following text has been summarised.

The interfaces between RCM analysis and risk and emergency preparedness analyses are:

- Input to RCM analysis in terms of reliability requirements for essential safety systems (fire water system, F&G detection system, ESD system), based on assumptions used in the QRA studies.
- Input to RCM analysis in terms of manning requirements (or prohibited manning), based on assumptions used in the QRA studies.
- Study assumptions and data in risk and emergency preparedness analyses and RCM analyses shall be consistent.

8.6 Reliability/risk based testing

For dormant systems testing, intervals can be established on the basis of reliability/risk methodology, as described in NORSOK standard Z-016, 8.4.4.

From the safety acceptance criteria or the risk and EPA there may be requirements to on-demand availability for essential safety systems. Such systems, e.g RV, ESV or BDV, shall be tested at regular intervals and the test results recorded. The results shall be compared with the reliability requirements to see whether the requirements are met. Based on the results, the test intervals can be adjusted to achieve the required on-demand availability at minimum cost.

8.7 Risk based inspection (RBI)

RBI is a methodology which aims at establishing an inspection programme based on failure mechanisms which may be subject to inspection (corrosion, vibration, etc.). Interactions between RBI and other analysis functions are described in NORSOK standard Z-016, 8.4.5, from which the following text has been summarised.

The methodology combines availability and risk analysis work and is typically applied for static process equipment (e.g. piping, pressure vessels and valve bodies). The failure mode of concern is normally loss of containment. The input to a risk analysis is probability of leak and consequence to assets.

Interactions between RBI, RCM, regularity, availability and risk analyses are important to ensure consistency in relevant failure rates and associated downtime pattern for equipment covered in these analyses.

RBI in operations phase will provide information about failure mechanisms and frequencies, which may be included in risk analysis, especially in the analysis of causes for accidents.

Risk analysis will correspondingly give input to optimisation of inspection programs, in relation to which equipment and pipe systems that have the highest contribution to risk to life and assets.

8.8 Criticality ranking

Criticality analysis should be co-ordinated with RCM as described in NORSOK standard Z-016. The ranking of criticality should be based on the effect of errors/faults and on the time from the occurrence (of the error/fault) until the effect occurs on the installation. The main interfaces with risk analysis is to provide input to:

- Effects of failure of essential safety systems.
- Ranking of safety systems.
- Criticality classification of essential safety systems.

Reference is also made to NORSOK standard Z-008.

8.9 Risk and EPA for mobile units

Risk and EPA is required for mobile units (i.e. mobile drilling units and mobile accommodation units) according to statutory requirements, in relation to:

- Construction of new mobile units.
- Operation of mobile units.
- Major modifications of mobile units.
- Interfaces with fixed installations when connected by bridge, cantilevered, etc.

The planning and execution of risk and emergency preparedness analyses shall in principle meet the requirements of clause 1 to clause 6 of this NORSOK standard. The documentation may be based on accepted safety cases (UK legislation) or analyses according to NMD's risk analysis regulations.

8.10 Safety integrity level (SIL)

IEC 61508 shall provide a SIL for the electric, electronic and programmable part of a number of essential safety systems/functions such as ESD, F&G, shut down of ignition sources. It establishes an expression of required availability of the system.

To compare SIL against overall RAC is not relevant, as the RAC are too coarse. The SIL risk analysis is rather on a detailed level, which must be defined. As the SIL is an expression of availability figures for the system, it should be established and used as a 'barriers level' to be met. Hence, SILs might be relevant when applying SBSD, see annex F.

The availability of barriers is reflected in event trees and the SIL may provide an indirect input to the event tree. The risk analysis can be used for sensitivity studies related to the defined SILs, whether to maintain the level or relax this and still meet the performance standards.

Guidance on how to establish SILs is found in the OLF guidelines for the application of IEC 61508 and IEC 61511, see clause 2. See also NORSOK standard Z-016.

8.11 Health risk assessments (HRAs)

Occupational HRAs are not normally part of a risk analysis scope, but may be included as part of the analysis of occupational accidents.

There may be input from QRA to working environment analyses, in relation to what hazards that may lead to injuries. See NORSOK standard S-002.

Annex A (informative) Risk acceptance criteria

A.1 Risk acceptance criteria for quantitative analyses

A.1.1 General

This type of RAC is most commonly used in relation to overall risk studies in the conceptual design, in engineering phases and in the operations phase. It will be required that relevant and quantifiable experience data are available for the analysis in order to enable comparison with quantitative RAC.

Requirements stipulated in standards, specifications, procedures, etc. which are necessary to achieve acceptable safety, should not be interpreted as RAC. However, such requirements will be important premises in relation to the risk analysis in order to achieve an acceptable level of risk.

The basis for the formulation of RAC should include:

- a) The regulations that control safety within the activities.
- b) Recognised norms for the activity.
- c) Requirements for risk reducing measures.
- d) Knowledge about accidents, incidents and consequences of these.
- e) Experience from own or similar activity.

Clause 4 in the normative text presents an overview of the high level expressions of risk to which RAC may be tied.

The decision context (in relation to phase, activity or system) and the need for decision support are aspects that need to be considered when choosing the RAC. In addition, the criteria have to reflect the approach to risk analysis, and finally be consistent with previous use within the company.

Some petroleum examples of decision support contexts into which risk analysis may play a role can illustrate the choice of RAC:

- a) In relation to decisions regarding the overall operations of an installation, the total risk potential has to be considered. The RAC that are relevant will usually be quantitative (for example FAR values) or semi-quantitative (such as risk matrix). These criteria enable the reflection of many different scenarios and the aggregation of these into one or a few characteristic values.
- b) One overall risk value is preferable for instance for the comparison of two alternative field development concepts, with respect to risk for personnel. PLL may in these circumstances be suitable, as this criterion also allows for different manning levels for the options being considered.
- c) Risk analysis or safety evaluation is often performed as one of the inputs for design development within an engineering project. Changes to the design will usually imply changes to the risk picture. The RAC should be formulated in such a way that these changes may be registered. Use of criteria related to impairment of safety functions will enable calculation of how the impairment frequency is changed according to design changes (e.g. in connection with relocation of equipment).

The RAC may be subdivided in categories according i.a. to the purpose and the level of detail of the analysis:

- Quantitative RAC for quantitative studies.
- Risk matrixes and the ALARP principle.
- Risk comparison criteria.

A.1.2 Risk acceptance criteria related to main safety functions

Example:

- The frequency 1×10^{-4} per year for each type of accidental load has been used frequently as the limit of acceptability for the impairment of each main safety function. Sometimes one prefers an overall frequency summing up all accidental load types. For these purposes an overall frequency of 5×10^{-4} per year has been used as the impairment frequency limit.

The main safety functions and their required functionality have to be defined separately for each installation. The exposed areas that are defined in relation to these criteria are often those separated by H-0 fire partitions. Sometimes such an area may be quite extensive and a further subdivision may be done. Such a subdivision within a fire area will be based on possible accidental effects and their extension. The exposed area may in these cases vary according to the type and the magnitude of the AEs.

The arrangement of accident probability and corresponding consequence in a matrix (see Figure A.1) may be a suitable expression of risk in cases where many AEs are involved or where single value calculation is difficult. The matrix is separated into three regions as follows:

- Unacceptable risk.
- Acceptable risk.

A region between acceptable and unacceptable risk, where evaluations have to be carried out in order to determine whether further risk reduction is required or whether more detailed studies should be done first of all

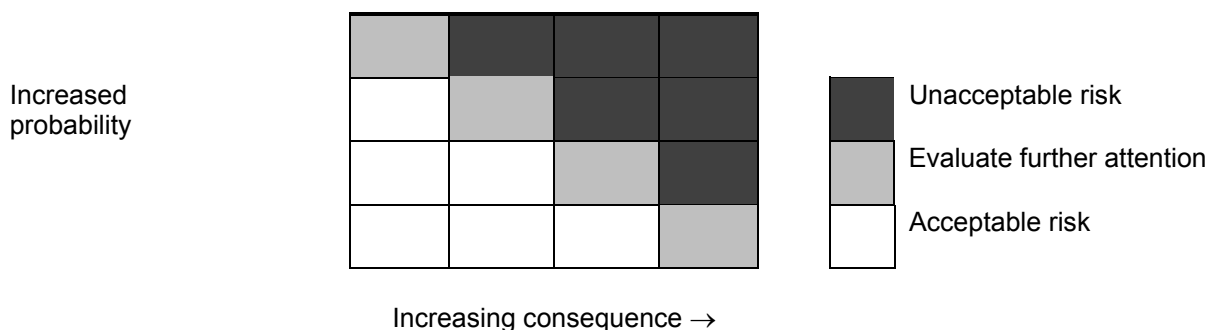


Figure A.1 – Risk matrix

The limit of acceptability is set by defining the regions in the matrix which represent unacceptable and acceptable risk. The risk matrix may be used for qualitative as well as quantitative studies. If probability is classified in broad categories such as 'rare' and 'frequent' and consequences in 'small', 'medium' and 'catastrophic', the results from a qualitative study may be shown in the risk matrix. The definition of the categories is particularly important in case of qualitative use.

The categories and the boxes in the risk matrix may be replaced by continues variables, implying a full quantification. An illustration of this is shown in Figure A.2.

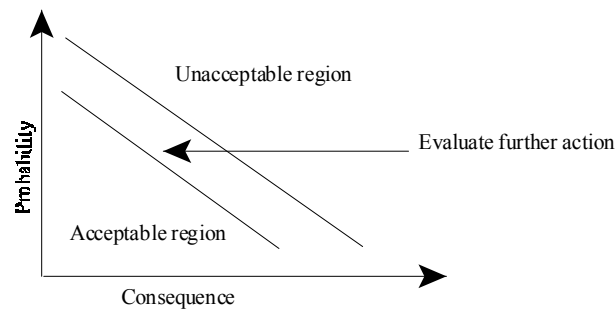


Figure A.2 – Risk matrix like presentation with continuous variables

The upper tolerability limit (Figures A.1 and A.2) is almost always defined, whereas the lower limit is individual to each individual risk reducing measure, depending on when the cost of implementing each measure becomes unreasonably disproportional to the risk reducing effect.

The following are examples of situations where the use of risk matrix is natural:

- Evaluation of personnel risk for different solutions such as integrated versus separate quarters platform.
- Evaluation of risk in relation to operations such as exploration drilling.
- Evaluation of risk in relation to a particular system such as mechanical pipe handling.
- Evaluation of environmental risk.

A.1.4 f-N Curves

The f-N curve (f = frequency, N = number, i.e. measurement of consequence) expresses the acceptable risk level according to a curve where the frequency is dependent on the extent of consequences (such as number of fatalities per accident). The acceptance limit may be adjusted according to the resource, which is exposed. The f-N curve used as an acceptance limit may reflect risk aversion to major accidents (with multiple fatalities), if the product of f and N is decreasing with increasing N. The calculation of values for the f-N curve is cumulative, i.e. a particular frequency relates to 'N or more' fatalities. Figure A.3 presents an illustration.

The f-N curve may be used in relation to risk acceptance for personnel, environment and assets.

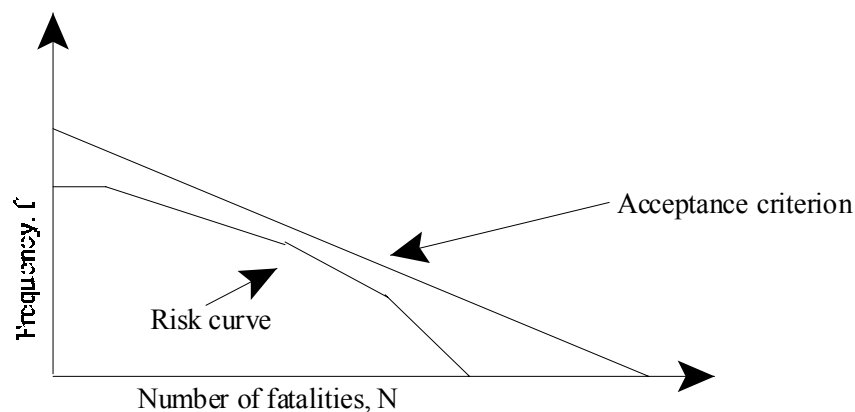


Figure A.3 – f-N curve

A.1.5 ALARP – principle

The ALARP (see Figure A.4) principle is sometimes in the industry used as the only acceptance principle and sometimes in addition to other RAC.

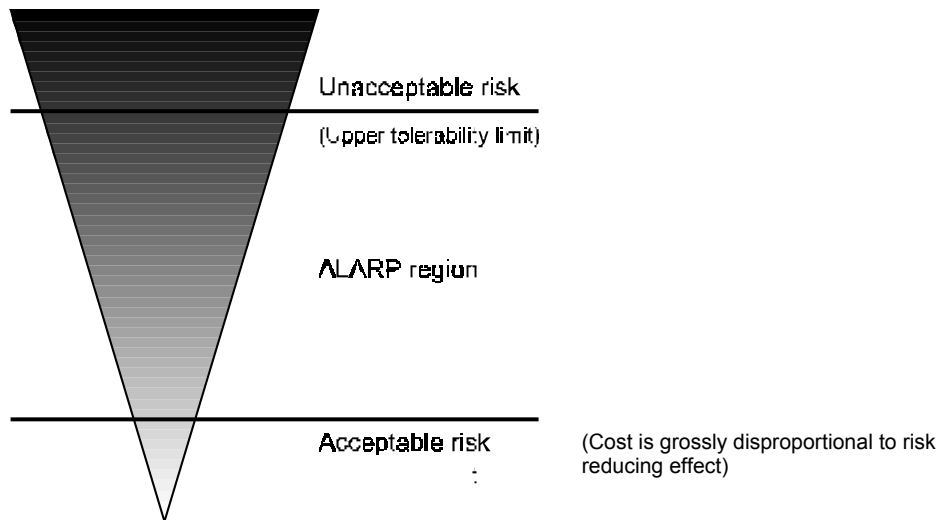


Figure A.4 – The ALARP – principle

The use of the ALARP principle may be interpreted as satisfying a requirement to keep the risk level 'as low as possible', provided that the ALARP evaluations are extensively documented.

The risk level should be reduced as far as possible in the interval between acceptable and unacceptable risk. The common way to determine what is possible is to use cost-benefit evaluations as basis for decision on whether to implement certain risk reducing measures.

The upper tolerability limit (see Figure A.4) is almost always defined, whereas the lower tolerability limit is sometimes defined and is in other cases left undefined. The lower limit is individual to each individual risk reducing measure, depending on when the cost of implementing each measure becomes unreasonably disproportional to the risk reducing effect.

The ALARP principle used for risk acceptance is applicable to risk to personnel, environment and assets.

A.1.6 Comparison criteria

This type of criteria is suitable in more limited studies which aim at comparing certain concepts or solutions for a particular purpose with established or accepted practice. Often our risk studies for such purposes are relatively limited, implying that this type of RAC will be the most suitable. The criteria are suitable in relation to operations which are often repeated such as drilling and well interventions, heavy lift operations, diving, etc. The use of the comparison criteria requires that the basis of the comparison is expressed relatively precisely.

The formulation of the acceptance criterion in this context may be that the new solution should not represent any increase in risk in relation to current practice.

Examples of comparison criteria are:

- Alternative design (or use of new technology) for fire water system should be at least as safe as conventional technology.
- The risk level for the environment should not be higher compared to existing solution.
- Alternative solution should be at least as cost effective as the established practice.

This type of RAC is also suitable for risk to personnel, environment and assets.