

Risk and emergency preparedness assessment

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Standards Norway
Strandveien 18, P.O. Box 242
N-1326 Lysaker
NORWAY

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Telephone: + 47 67 83 86 00
Fax: + 47 67 83 86 01
Email: petroleum@standard.no
Website: www.standard.no/petroleum



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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 petroleum industry developments and operations. Furthermore, NORSOK standards are, as far as possible, intended to replace oil company specifications and serve as references in the authorities' regulations.

The NORSOK standards are normally based on recognised international standards, adding the provisions deemed necessary 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 Subject to development and publication of international standards, the relevant NORSOK standard will be withdrawn.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 A-001.

The NORSOK standards are prepared and published with support by The Norwegian Oil Industry Association (OLF), The Federation of Norwegian Industry, Norwegian Shipowners' Association and The Petroleum Safety Authority Norway.

NORSOK standards are administered and published by Standards Norway.

All annexes are informative.

Introduction

The purpose of this NORSOK standard is to establish requirements for effective planning and executive of risk and/or emergency preparedness assessment. This NORSOK standard has emphasis on requirements related to ensuring that the process of conducting such assessments are suitable for their intended purposes, rather than detailed requirements related to how the assessment and the various hazards typically included in such assessment should be analyzed.

This NORSOK standard is structured around the following main elements:

- use of risk and emergency preparedness assessment as a basis for decision-making. General requirements for planning and execution of risk and emergency preparedness assessments regardless of activity and life cycle phase;
- specific requirements for planning and execution of risk and emergency preparedness assessments for different activities and life cycle phases;
- the relation between the risk and emergency preparedness assessments, especially the integration of the two types of assessments into one overall assessment process.

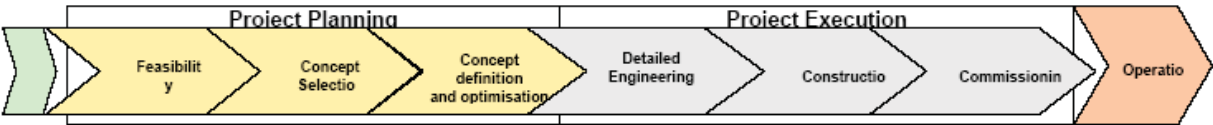
Clause 5 and Clause 9 describe the general requirements for risk assessments and emergency preparedness assessments, respectively.

Requirements for risk and emergency preparedness assessments for some defined life cycle phases are described in separate clauses. The phases included and the sections in which they are covered are:

	Risk assessment	EPA
Project planning:		
• Concept selection	(Clause 6)	(Clause 10)
• Concept definition and optimization	(Clause 7)	(Clause 11)
Project execution:	(Clause 7)	(Clause 11)
• Detailed engineering		
Operation (including small modifications)	(Clause 8)	(Clause 12)

For assessments in feasibility, construction and commissioning, cessation phases, as well as assessments of specific activities during the operational phases, the general requirements in Clause 5 and Clause 9 apply.

Project life cycle phases are illustrated in the figure below.



1 Scope

This NORSOK standard describes risk and emergency preparedness assessments for offshore and onshore facilities for production of oil and gas. Where applicable, this NORSOK standard may also be used for mobile offshore drilling units.

This NORSOK standard covers the process of planning and execution of risk and emergency preparedness assessments, including how to establish the risk picture and the assessment of potential risk reducing measures. Risk treatment, i.e. the process and decisions related to how to deal with identified risks (e.g. acceptance, the need for modifications and/or implementation of risk reducing measures) are, however, not covered by this standard. Nor is the establishment of risk acceptance criteria covered by this NORSOK standard.

This NORSOK standard covers risk for major accidents. Analysis of occupational fatalities and injuries are not covered in this NORSOK standard although this risk contribution from occupational fatalities often is included in risk calculations. Nor does the standard cover occupational health risk aspects, including physical and psychological working environment, working environment mapping and analysis.

This NORSOK standard covers requirements related to the risk assessment processes which include a quantitative risk analysis.

NOTE Requirements related to qualitative risk analysis are only briefly addressed.

This NORSOK standard does not cover security aspects, except from some implications for the emergency preparedness analyses.

2 Normative and informative references

The following standards include provisions and guidelines which, through reference in this text, constitute provisions and guidelines 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 the requirements of the referenced standards.

2.1 Normative references

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)
ISO 17776,	Petroleum and natural gas industries – Offshore production installations – Guidelines on tools and techniques for identification and assessment of hazards
ISO/IEC 31000,	Risk management, principles and guidelines on implementation
NORSOK N-001,	Structural design
NORSOK N-004,	Design of steel structures
NORSOK S-001,	Technical safety
OLF GL 070,	Guidelines for the application of IEC 61508 and IEC 61511 in the petroleum activities on the Norwegian continental shelf

2.2 Informative references

DNV report 2005-1221 rev 4 September 2006,	Anbefalte feildata for rørledninger
DNV report 2009-1115: rev HOLD, November 2010,	
ISO 13702,	Petroleum and natural gas industries - Offshore production installations - Control and Mitigation of Fires and Explosions - Requirements and guidelines
FABIG Technical note 8, 2005,	Protection of piping systems subject to fires and explosions

3 Terms, definitions and abbreviations

For the purposes of this NORSOK standard, the following terms, definitions and abbreviations apply.

3.1 Terms and definitions

3.1.1

accidental event

AE

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

NOTE The accidental events that are considered in risk and emergency preparedness analyses are acute, unwanted and unplanned. For instance; planned operational exposure that may be hazardous to health or to the environment, is usually not considered as an accidental event.

3.1.2

area exposed by the accidental event

AEAE

area(s) on the facility (or its surroundings) exposed by the accidental event

NOTE 1 An area (fire area or main area) shall be considered included as a part of the AEAE if the AE may cause loss of life or damage to health and/or assets in the area. The AEAE may be limited to a single fire area, or it may include several fire areas or several main areas.

NOTE 2 For some AE the AEAE may expand after a period of time due to the evolvement of the accidental event (e.g. due to impairment of a fire wall after a period of time).

3.1.3

area risk

risk personnel located in an area is exposed to during a defined period of time

3.1.4

as low as reasonably practicable

ALARP

ALARP expresses that the risk shall be reduced to a level that is as low as reasonably practicable

NOTE 1 ALARP expresses that the risk is reduced (through a documented and systematic process) so far that it is not justifiable to implement any additional risk reducing measures.

NOTE 2 The term reasonably practicable implies that risk reducing measures shall be implemented until the cost (in a wide sense, including time, capital costs or other resources/assets) of further risk reduction is grossly disproportional to the potential risk reducing effect achieved by implementing any additional measure.

3.1.5

average individual risk

AIR

risk an average individual is exposed to during a defined period of time

NOTE 1 The average individual risk may be established for defined groups of personnel and/or for all personnel on a facility.

NOTE 2 The average individual risk may be established by combining the fraction of time an individual, representing an average member of the relevant group of personnel, is located in various areas and the area risk in each of the areas.

3.1.6

barrier element

physical, technical or operational component in a barrier system

3.1.7

barrier function

function planned to prevent, control, or mitigate undesired or accidental events

3.1.8

barrier system

system designed and implemented to perform one or more barrier function

3.1.9**can**

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

3.1.10**defined situations of hazard and accident****DSHA**

selection of hazardous and accidental events 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 accidental events for the facilities and activities, and includes DAEs, hazardous and accidental situations associated with a temporary increase of risk and less extensive accidental events, 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.

3.1.11**design accidental load**

chosen accidental load that is to be used as the basis for design

NOTE 1 The applied/chosen design accidental load may sometimes be the same as the dimensioning accidental load (DAL), but it may also be more conservative based on other input and considerations such as ALARP. Hence, the design accidental load may be more severe than the DAL.

NOTE 2 The design accidental load should as a minimum be capable of resist the dimensioning accidental load (DAL).

3.1.12**dimensioning accidental event****DAE**

accidental events that serve as the basis for layout, dimensioning and use of installations and the activity at large

3.1.13**dimensioning accidental load****DAL**

most severe accidental load that the function or system shall be able to withstand during a required period of time, in order to meet the defined risk acceptance criteria

NOTE 1 DAL is normally defined based on DAE.

NOTE 2 The dimensioning accidental load (DAL) are typically generated as a part of a risk assessment, while the design accidental load may be based on additional assessments and considerations.

NOTE 3 The dimensioning accidental load (DAL) are typically established as the load that occurs with an annual probability of 1×10^{-4} .

3.1.14**emergency preparedness**

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

3.1.15**emergency preparedness analysis****EPA**

analysis which includes establishment of DSHA, including major DAEs, establishment of emergency response strategies and performance requirements for emergency preparedness and identification of emergency preparedness measures, including environmental emergency and response measures

3.1.16**emergency preparedness assessment**

overall process of performing a emergency preparedness assessment including: establishment of the context, performance of the EPA, identification and evaluation of measures and solutions and to recommend strategies and final performance requirements, and to assure that the communication and consultations and monitoring and review activities, performed prior to, during and after the analysis has been executed, are suitable and appropriate with respect to achieving the goals for the assessment

NOTE Emergency preparedness assessment does not include establishment of emergency preparedness.

3.1.17

emergency preparedness philosophy

overall guidelines and principles for establishment of emergency response based on the operator vision, goals, values and principles

3.1.18

emergency response

action taken by personnel, on or off the installation, to control or mitigate a hazardous event or initiate and execute abandonment

3.1.19

emergency response strategy

specific description of emergency response actions for each DSHA

NOTE 1 Emergency response strategies shall be the basis for the establishment of the emergency response plan

NOTE 2 To illustrate the variability of each DSHA, more than one scenario description may be developed for each DSHA. The specific strategies may therefore be defined for each of the scenarios.

3.1.20

environment

surroundings in which an organization operates, including air, water, land, natural resources, flora, fauna, humans and their interrelation

3.1.21

environmental impact

any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's activities, products or services

3.1.22

escalation

escalation has occurred when the area exposed by the accidental event (AEAE) covers more than one fire area or more than one main area

NOTE 1 The definition of escalation covers both a) immediate escalation: Escalation due to the initial accidental event (e.g. an initial explosion causing impairment of a fire and/or explosion wall separation two neighbouring areas) and b) Delayed escalation: Escalation occurring at any time after the initial accidental event has occurred (e.g. a fire causing the impairment of a fire wall separation two neighbouring areas after a period of time).

NOTE 2 An escalation is either internal or external, see 3.1.29 and 3.1.40.

3.1.23

escape route

route from an intermittently manned or permanently manned area of a facility leading to safe area(s)

3.1.24

establishment of emergency preparedness

systematic process which involves selection and planning of suitable emergency preparedness measures on the basis of risk and emergency preparedness analysis

3.1.25

emergency preparedness organisation

organisation which is planned, established and trained 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.

3.1.26

essential safety system

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

3.1.27

evacuation

planned method of leaving the facility in an emergency

NOTE 1 For offshore facilities the methods are normally by bridge to neighbour facility not exposed to the accidental event or by helicopter, lifeboat etc.

NOTE 2 For onshore facilities the methods are normally by getting out of the plant area.

3.1.28

explosion load

time dependent pressure or drag forces generated by violent combustion of a flammable atmosphere

3.1.29

external escalation

when the area exposed by the accidental event (AEAE) covers more than one main area, external escalation has occurred

3.1.30

facility

offshore or onshore petroleum installation, facility or plant for production of oil and gas

3.1.31

fire area

area separated from other areas on the facility, either by physical barriers (fire/blast partition) or distance, which will prevent a dimensioning fire to escalate

3.1.32

group individual risk

GIR

average IR for a defined group

3.1.33

hazard

potential source of harm

NOTE In the context of this Standard, the potential harm may relate to loss of life, or damage to health, the environment or assets or a combination of these.

3.1.34

hazardous event

incident which occurs when a hazard is realized

3.1.35

immediate vicinity of the scene of accident

main area(s) where an accidental event (AE) has its origin

NOTE 1 In case of an AE occurring in one main area personnel located in other main areas are considered to be outside the immediate vicinity of the scene of accident.

NOTE 2 The main safety function: "preventing escalation of accident situations so that personnel outside the immediate vicinity of the scene of accident are not injured" shall be considered as impaired if and when external escalation has occurred in the period before.

3.1.36

individual risk

IR

risk an individual is exposed to during a defined period of time.

NOTE The individual risk may be established by combining the fraction of time an individual is located in various areas and the area risk in each of the areas.

3.1.37

informative reference

reference used informative in the application of NORSOK Standards.

3.1.38

inherently safer design

In inherently safer design, the following concepts are used to reduce risk:

- reduction, e.g. reducing the hazardous inventories or the frequency or duration of exposure;
- substitution, e.g. substituting hazardous materials with less hazardous ones (but recognizing that there could be some trade-offs here between plant safety and the wider product and lifecycle issues);
- attenuation, e.g. using the hazardous materials or processes in a way that limits their hazard potential, such as segregating the process plant into smaller sections using ESD valves, processing at lower temperature or pressure;
- simplifications, e.g. making the plant and process simpler to design, build and operate, hence less prone to equipment, control and human failure.

3.1.39

intermittently manned

work area or work place where inspection, maintenance or other work is planned to last between 2 h and 8 h a day for at least 50 % of the installation's operation time

3.1.40

internal escalation

when the area exposed by the accidental event (AEAE) covers more than one fire area within the same main area, internal escalation has occurred

3.1.41

main area

defined part of the facility with a specific functionality and/or level of risk

NOTE 1 A main area may consist of one or several fire areas.

NOTE 2 The defined main areas shall be separated by distance, by use of physical barriers as fire and blast divisions or by a combination of these to prevent external escalation.

NOTE 3 For an offshore installation the following main areas shall as a minimum be defined when relevant: a) accommodation (living quarter), b) utility, c) drilling d) wellhead, e) process and f) hydrocarbon storage.

NOTE 4 For a land-based facility the following main areas shall as a minimum be defined when relevant: a) administration building, b) central control room, c) process area, d) utility area, e) storage area, f) loading/unloading area and g) landfall.

3.1.42

main load bearing structures

structure, which when it loses its main load carrying capacity, may result in a collapse or loss of either the main structure of the installation or the main support frames for the deck

3.1.43

main safety function

most important safety functions that need to be intact in order to ensure the safety for personnel and/or to limit pollution

3.1.44

major accident

acute occurrence of an event such as a major emission, fire, or explosion, which immediately or delayed, leads to serious consequences to human health and/or fatalities and/or environmental damage and/or larger economical losses

NOTE This definition is not completely in accordance with the SEVESO2-directive:

'major accident' shall mean an occurrence such as a major emission, fire, or explosion resulting from uncontrolled developments in the course of the operation of any establishment covered by this Directive, and leading to serious danger to human health and/or the environment, immediate or delayed, inside or outside the establishment, and involving one or more dangerous substances'.

3.1.45

may

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

3.1.46

normally unmanned

work area or workplace that is not permanently or intermittently manned

3.1.47

normalisation

the normalisation phase starts when the development of a situation of hazard or accident has stopped.

NOTE Measures related to personnel safety in the normalization phase includes

- organizing transportation of injured or sick personnel,
- transportation of rescued personnel from safe area to the land-based health service,
- transportation of evacuated personnel from safe area to a land-based reception facility when needed,
- re-establish the normal operation of the facility.

3.1.48

performance requirements 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 regarding personnel, environment and assets and include availability, reliability, capacity, mobilisation time, functionality, vulnerability, personnel competence, expressed as far as possible in a verifiable manner.

3.1.49

permanently manned

work area or workplace manned at least 8 h a day for at least 50 % of the installation's operation time

3.1.50

recovery time

time from an accidental event causing environmental damage occurs until the biological features have recovered to a pre-spill state or to a new stable state taking into consideration natural ecological variations, and are providing ecosystem services comparable to the pre-spill services

NOTE Populations are considered to be recovered when the population is 99% of the pre-spill population.

3.1.51

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.

3.1.52

risk acceptance criteria

RAC

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

NOTE RAC are used in relation to risk analysis and express the level of risk 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.

3.1.53

risk analysis

structured use of available information to identify hazards and to describe risk

NOTE 1 The risk analysis term covers several types of analyses that will all assess causes for and consequences of accidental events, 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 accidental events, in a manner which allows comparison with quantitative RAC.

3.1.54

risk assessment

overall process of performing a risk assessment including: Establishment of the context, performance of the risk analysis, risk evaluation, and to assure that the communication and consultations, monitoring and review activities, performed prior to, during and after the analysis has been executed, are suitable and appropriate with respect to achieving the goals for the assessment

NOTE See Figure 3.

3.1.55

risk evaluation

judgement, on the basis of risk analysis and RAC, of whether a risk is tolerable or not

3.1.56

risk picture

synthesis of the risk assessment, with the intention to provide useful and understandable information to relevant decision makers

NOTE Establishing the risk picture includes reporting of the risk assessment process.

3.1.57

rooms of significance to combating accidental events

CCR and other equivalent room(s) that are essential for safe shutdown, blowdown and emergency response

NOTE E.g. the room/area where the BOP control panel is located if and when drilling or well operations are performed (offshore), or the part of substations incorporating ESD and F&G nodes and essential power supply (onshore).

3.1.58

safe area(s)

area(s) which, depending on each specific defined situation of hazard and accident (DSHA), are defined as safe until the personnel are evacuated or the situation is normalized.

NOTE E.g. mustering area(s), life boat stations, helicopter deck or bridge connected neighboring installation. As the safe area(s) are specific to each DSHA the area(s) may differ depending on the DSHA.

3.1.59

safety barrier

physical or non-physical means planned to prevent, control, or mitigate undesired events or accidents

3.1.60

safety function

measures which reduce the probability of a situation of hazard and accident occurring, or which limit the consequences of an accident

3.1.61

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.

3.1.62

shall

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

3.1.63**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

3.1.64**system**

common expression for installation(s), plant(s), system(s), activity/activities, operation(s) and/or phase(s) subjected to the risk and/or emergency preparedness assessment

3.1.65**system basis**

inputs (regarding the system subjected to assessment) used as basis for the assessment

3.1.66**system boundaries**

system boundaries defines what shall and what shall not be subjected to the assessment

3.2 Abbreviations

AE	accidental event
AEAE	area exposed by the accidental event
AIR	average individual risk
ALARP	as low as reasonably practicable
ALS	accidental collapse limit state
BLEVE	boiling liquid expanding vapour explosion
BOP	blowout preventer
CAD	computer aided design
CCR	central control room
CFD	computational fluid dynamics
CODAM	Corrosion DAMage
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
EnvRA	environmental risk analysis
EPA	emergency preparedness analysis
ER	emergency response
ERS	emergency response strategy
ESD	emergency shutdown
ESV	emergency shutdown valve
F&G	fire and gas
FAR	fatal accident rate
FMEA	failure mode and effect analysis
GIR	group individual risk
HAZID	hazard identification
HAZOP	hazard and operability study
HC	hydrocarbons
HSE	health and safety executive
IEC	International Electrotechnical Commission
IR	individual risk
IRPA	individual risk per annum
ISO	International Organization for Standardization
LEL	lower explosive limit
MSF	main safety function
NCS	Norwegian Continental Shelf
NOFO	Norwegian Clean Seas Association for Operating Companies
OGP	International Association of Oil & Gas Producers

OLF	The Norwegian Oil Industry Association
P&ID	piping and instrument diagram
PARLOC	Offshore North Sea Pipeline and Riser Loss of Containment Study
PFD	process flow diagram
PLL	potential loss of life
PSA	Petroleum Safety Authority
QRA	quantitative risk analysis
RAC	risk acceptance criteria
SIL	safety integrity level
SJA	safe job analysis
UEL	upper explosive limit
UKCS	United Kingdom Continental Shelf
UKOOA	United Kingdom Offshore Operators Association

4 The role and use of assessments in risk management

4.1 Risk assessment: A key element in risk management

The elements of a risk management process according to ISO/IEC 31000 are illustrated in Figure 1. Risk assessment, which include: risk identification, risk analysis and risk evaluation, is a key element in a risk management process.

ISO/IEC 31000 emphasises the importance of establishing the context prior to starting or executing any of the elements included in the process, and the importance of updating the context throughout the process. It also emphasises the importance of communication, consultation, monitoring and review throughout the entire process.

Although risk management in general is a subject beyond the scope of this NORSOK standard, the same structure, principles and model as the one used in ISO/IEC 31000 have been applied for the processes of performing a risk and emergency preparedness assessment covered by this NORSOK standard. The main difference is that the element "risk treatment" is not covered. The establishment of the context, communication and consultation, as well as monitoring and review, are included as a part of the assessment. Establishment of emergency preparedness is part of risk treatment and not part of an emergency preparedness assessment. Thus, the establishment of emergency preparedness is not covered by this NORSOK standard.

A complete risk reduction process (often referred to as ALARP process or evaluation) is part of risk treatment, and as such not part of this NORSOK standard, in accordance with the previous paragraph. However, in an ALARP demonstration process the risk analysis process may be used for the identification of potential risk reducing measures and evaluation of risk reducing measures.

An illustration of how the ISO/IEC 31000 principle has been used and modified in this NORSOK standard is illustrated in Figure 1.

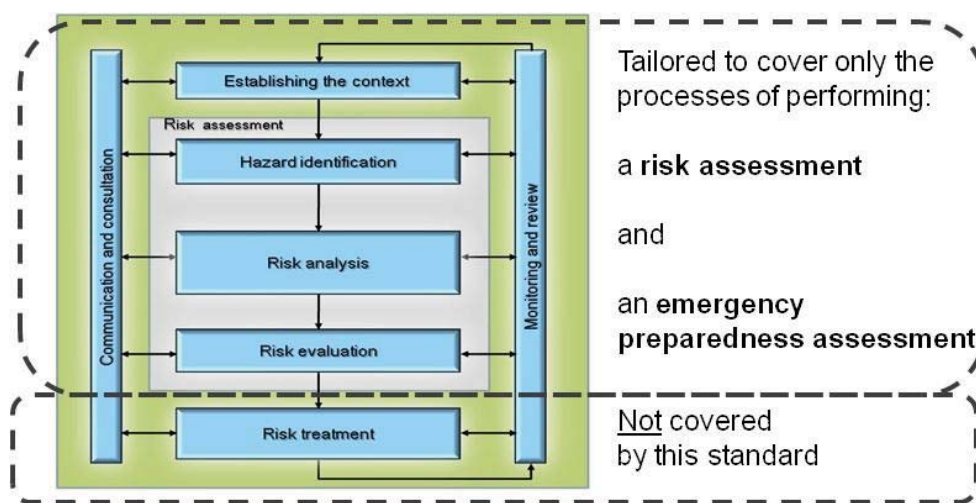


Figure 1 Use of ISO/IEC 31000 in this NORSOK standard

4.2 The process of performing a risk and emergency preparedness assessment

This NORSOK standard covers both a) the process of performing a risk assessment and b) the process of performing an emergency preparedness assessment. The standard is structured in a way that makes it easy to identify the requirements applicable for the two processes separately. Hence, the standard may be used when only one of the two processes is to be performed. However, if/when both processes are to be performed “simultaneously”, or during the same phase of a project, the two processes should as far as possible be integrated and/or coordinated. Input data used and results generated from one process will in many cases be used as input to the other process and vice versa. Thus, to some extent the two processes become one.

An illustration of the “common” or joint process of performing a risk assessment and an emergency preparedness analysis is presented in Figure 2. The figure illustrates the process of performing both processes “simultaneously” and thus illustrates what is common for the two processes and how they interact.

This common process and the elements included found the basis for the way the requirements related to risk and emergency preparedness assessments are structured in this NORSOK standard. The same process and the same elements are therefore used in each main section covering risk assessments or emergency preparedness assessments in general and/or for a specific phase (i.e. the concept selection phase), the concept definition and optimization phase, detailed engineering phase or the operational phase. The elements included in the processes are illustrated by the boxes in Figure 2.

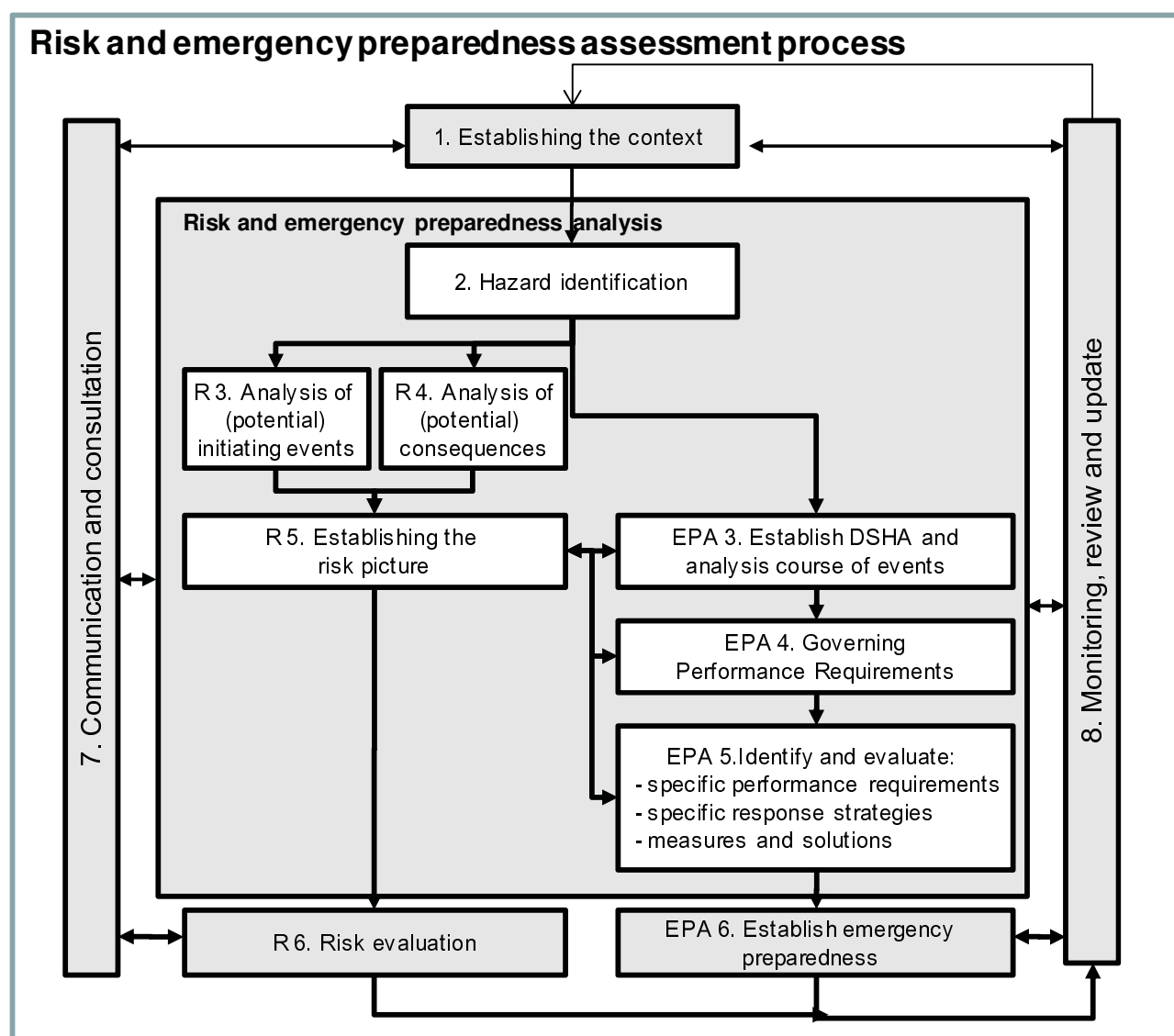


Figure 2 The process of performing a risk and emergency preparedness assessment

A description of the risk assessment process and the various elements included in the process is given in Clause 5. A description of the emergency preparedness assessment process and the various elements included in the process is given in Clause 9.

GENERAL REQUIREMENTS, i.e. requirements applicable for risk assessments and emergency preparedness assessments in all phases covered by this NORSOK standard, are also given in Clause 5 and Clause 9.

PHASE SPECIFIC REQUIREMENTS, i.e. requirements applicable for risk assessments and/or emergency preparedness assessments in one of the phases covered by this NORSOK standard (i.e. the concept selection phase, the concept definition and optimization phase, detailed engineering phase or the operational phase) are given in separate clauses. These requirements are to be considered as supplementary requirements to the general requirements.

Thus, in order to be in compliance with this Standard when conducting a risk assessment and/or an emergency preparedness assessment for a specific phase both the general requirements and the phase specific requirements for the specific phase shall be complied with.

5 General requirements for a risk assessment process

5.1 General

For the system subjected to the assessment, the risk assessment process shall always

- a) identify hazardous situations and potential accidental events,
- b) identify initiating events and describe their potential causes,
- c) analyse accidental sequences and their possible consequences,
- d) identify and assess risk reducing measures,
- e) provide a nuanced and overall picture of the risk, presented in a way suitable for the various target groups/users and their specific needs and use.

Figure 3 shows the main elements and the steps included in a risk assessment process. The general requirements to element 1 to element 8 as defined in Figure 3 are described in 5.2 to 5.9. Overall requirements to the entire risk assessment process are included in 5.2.

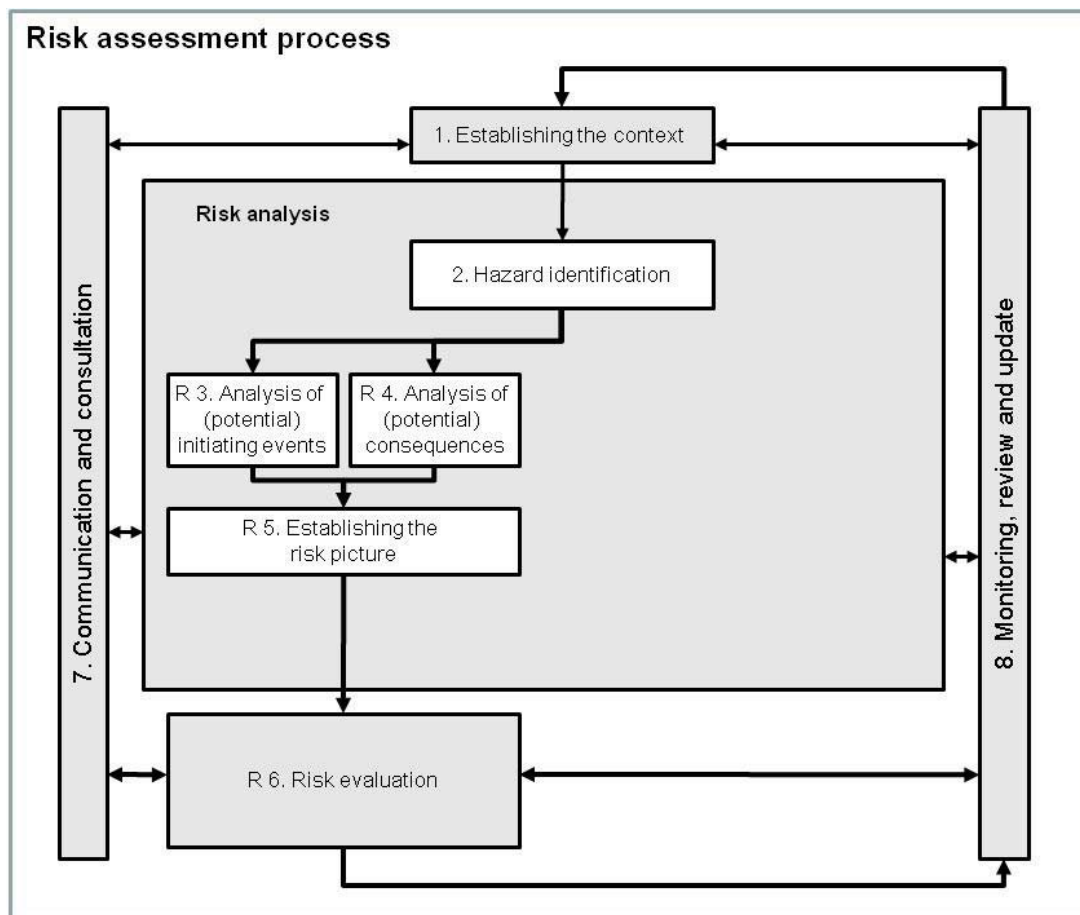


Figure 3 The process of performing a risk assessment

5.2 Establishing the context for a risk assessment process

5.2.1 Objective

The objective is to define the basic parameters for the risk assessment process, and to set the scope and criteria for the rest of the process. The context may include both parameters related to the internal context (anything within the organization that may influence the process) and the external context (anything outside the organization that may influence the process).

Establishing the context covers all activities carried out and all measures implemented prior to or as a part of the initiating phase of a risk assessment process, with the intention of ensuring that the risk assessment process to be performed is

- a) suitable with respect to its intended objectives and purpose,
- b) executed with a suitable scope and level of quality,
- c) tailored to the facility, system(s), operations, etc. of interest,
- d) tailored to the required and available level of detail.

5.2.2 Requirements

5.2.2.1 General

The establishment of the context for the risk assessment process shall involve, but not be limited to, the following:

- a) defining the objectives (for the process and for each of the elements 2 to 6 in Figure 3);
- b) defining the scope (of the process and for elements 2 to 6);
- c) defining responsibilities (for the process and for elements 2 to 6);
- d) defining the methods, models and tools to be used (in elements 2 to 6);

- e) defining the system boundaries and the system basis (for the system(s) that are to be analyzed and assessed);
- f) defining the risk acceptance criteria to be used;
- g) defining deliveries throughout, and at the end of the process;
- h) defining the execution plan (for the process and for elements 2 to 6).

The general requirements related to each of the above listed subjects are given in the following subclauses.

5.2.2.2 Defining the objectives

The following shall be considered, defining the objectives:

- a) for the system subjected to the assessment, the risk assessment process shall always be suitable for its purpose(s), particularly with respect to providing sufficient and appropriate input to the decision-basis at the right time, i.e. prior to decisions affecting/concerning the risk being assessed are made;
- b) the established objectives for each specific risk assessment process (and its included elements) shall be documented.

5.2.2.3 Defining the scope

The following shall be considered, defining the scope:

- a) depending on the system subjected to the assessment, the risk acceptance criteria and the objectives of the process, the risk assessment will normally include assessment of
 - 1) risk to people,
 - 2) risk to the environment,
 - 3) risk to assets,
 - 4) frequency of loosing (main) safety functions and impairment of barrier functions, systems and/or – elements.
- b) the scope may also include identification, assessment and/or the establishment of
 - 1) dimensioning accidental loads,
 - 2) requirements for barrier functions, systems and/or –elements,
 - 3) operational constraints and limitations,
 - 4) defined situations of hazards and accidents (DSHA),
 - 5) area, system and equipment classification.
- c) if the risk assessment is to include analyses of new concepts, solutions or technologies, or when analysing new approaches or solutions for performing specific operations or activities, emphasis shall be put on identifying and analysing hazards and risk specific for the new solution(s);
- d) the scope of the risk assessment process shall be documented.

5.2.2.4 Defining responsibilities

Responsibilities related to planning and execution of the risk analysis process, the elements and the various tasks/activities included shall be defined. This is typically related to approval of assumptions, definition of objectives, providing of study basis, time schedule for required information and definition of acceptance criteria.

5.2.2.5 Defining the methods, models and tools to be used in the process

The following shall be considered, defining the methods, models and tools to be used in the process:

- a) methods, models and tools to be used in the process shall be suitable with respect to the decisions to be made and the defined objective(s) and scope for the assessment. The choice might need to be reconsidered based on results of the HAZID;
- b) the availability of relevant and/or required input data and models shall be considered when selecting the methods, models and tools to be used;
- c) it shall be documented which methods, models and tools that have been chosen in each specific risk assessment;
- d) in general only recognized and validated methods, models and tools shall be used. If new and/or none recognized and validated methods, models and tools have been used this shall be clearly stated. A description of the method, model or tool used, including a justification of its use in the analysis, shall be documented;

- e) an evaluation of the effect of human and organisational factors shall be performed. This may range from a qualitative discussion to a detailed analysis of human and organisational errors, depending on the criticality of such aspects for the risk picture;
- f) the use of alternative approaches (e.g. expert judgements, non-representative data, etc.) to compensate for lack of relevant and/or required input data and models, shall be clearly stated. The composition of the expert group should be documented;
- g) limitations in the validity of results due to lack of availability of relevant data and models, shall also be documented.

5.2.2.6 Defining the system boundaries and the system basis

The system that is to be subjected to the risk assessed shall be defined and described in a suitable manner.

The following apply:

- a) the system boundaries, i.e. what shall and what shall not be subjected to the assessment, shall as a minimum be defined for the following main aspects:
 - 1) the technical system(s): structures, buildings, layout, process system(s), utility system(s), safety systems(s), emergency preparedness system(s), pipelines, wells, storage, etc.;
 - 2) the organisation and the operational system;
 - 3) the period, phase(s) and/or activities.
- b) the inputs used as system basis in the risk assessment process, given the system boundaries, shall be documented. As a minimum the document/report/drawing name, revision number and date of issue shall be listed. This includes (if used)
 - 1) layout drawings, P&IDs, PFDs, etc.,
 - 2) descriptions of technical systems (fluid data reservoir, process, utility systems),
 - 3) descriptions of operational aspects (manning distributions, lifting activities, traffic, hot work etc),
 - 4) descriptions and/or data related to environmental loading,
 - 5) studies/analysis performed outside the scope of, or prior to, the risk assessment process,
 - 6) input data, e.g. equipment/system failure data, leak frequencies,
 - 7) description of neighbouring activities, environment and population, including vulnerable areas and objects,
 - 8) safety design basis, e.g. fire water strategies, gas detection strategies, blowdown strategies,
 - 9) SIL analysis according to IEC 61508/61511/OLF GL 070. This states specific requirements to safety barriers. The QRA assumptions and SIL analysis data basis/results should be harmonized as far as possible to ensure consistency and transparency between the two analyses.

5.2.2.7 Defining the risk acceptance criteria to be used

The following apply:

- a) RAC shall be established prior to the assessment as they constitute a reference for the evaluation of the results from the risk assessment;
- b) the process of establishing RAC is beyond the scope of this Standard. However, the need for establishing new RAC in order to fulfil the below mentioned requirements may be one of the outcomes of this activity. The RAC shall as far as possible reflect the safety and environmental objectives and
 - 1) be suitable for evaluation of the activity/activities and/or system(s) in question,
 - 2) be suitable for comparison with the results of the analysis to be performed,
 - 3) be suitable for decisions regarding risk reducing measures,
 - 4) be suitable for communication,
 - 5) be unambiguous in their formulation (such that they do not require extensive interpretation or adaptation for a specific application),
 - 6) not favour any particular concept solution explicitly nor implicitly through the way in which risk is expressed.

NOTE 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.

- c) the main safety functions, including their required functionality, is to be defined for each facility individually;

- d) the established RAC to be used in each specific risk assessment process shall be documented.

Measures/quantities that may be considered for the evaluation of the risk, together with interpretation of authority requirements related to acceptance criteria for main safety functions are presented in Annex A and Annex B.

5.2.2.8 Defining deliveries

As a risk assessment process may be conducted over a period of time, several deliveries from the assessment may be required during or throughout the process in order to provide decision support at the right time. Example of such deliveries may be input to decisions regarding the overall layout of the facility or input to the dimensioning accidental loads to be used. As the need for deliveries throughout a process will vary for each specific phase, the requirements related to such deliveries are given in Clause 6 to Clause 8. See also 5.2.2.9.

Required deliveries at the end of the process are also mainly phase specific. These requirements are therefore also given in Clause 6 to Clause 8. Deliveries at the end of the process include all deliveries not included as a part of the presentation of the risk picture and the risk evaluation covered in 5.6 and 5.7.

5.2.2.9 Defining the execution plan for the process

As the main purpose of performing a risk assessment is to provide decision relevant information, the risk analysis shall be carried out prior to decisions affecting/concerning the risk being analysed are made.

However, during the feasibility, concept and/or engineering phase of a project (e.g. a new facility), or during the planning of an operation, several decisions, which could have a minor or major effect on the risk, are typically made throughout the project. It is therefore important that the risk assessment contribute with decision-support throughout the development of the project, at the right time and with the appropriate level of detail, and not only at the end of the assessment process.

Typical decisions that are taken throughout the various phases in a project, which the risk assessment should provide decision-support to, are described for the recommended risk assessment process for each of the phases covered in Clause 6 to Clause 8.

A plan for the execution of the risk assessment process, which ensures that the objectives are met and that the deliveries are available at the right time, shall be established and documented.

5.3 Hazard identification (HAZID)

5.3.1 General

A comprehensive and thorough identification and recording of hazards is critical, as a hazard that is not identified at this stage will be excluded from further assessment. Well planned and comprehensive hazard identification (HAZID) is therefore a critical and important basis for the other elements of the risk assessment process.

5.3.2 Objectives

The objectives of the hazard identification are as follows:

- to identify hazards associated with the defined system(s), and to assess the sources of the hazards, events or sets of circumstances which may cause the hazards and their potential consequences;
- to generate a comprehensive list of hazards based on those events and circumstances that might lead to possible unwanted consequences within the scope for the risk and emergency preparedness assessment process;
- identification of possible risk reducing measures.

5.3.3 Requirements

The requirements to the hazard identification are as follows:

- identification of hazards should include hazards whether or not they are considered to be under control of the organization;

- b) tools and techniques which are suited to identify all relevant hazards associated with the system, and suitable with respect to the established context for the risk assessment process, shall be used. Possible basis for a HAZID may be
 - 1) use of check lists (typically ISO 17776) and accident statistics,
 - 2) experience from previous similar analyses/assessments, safety inspections and audits,
 - 3) internal/external incident reports,
 - 4) step-by-step methodologies such as HAZOP/FMEA.
- c) the system basis for the hazard identification (HAZID) shall be established upfront. Activities ensuring that the involved personnel know and understand the basis shall be performed;
- d) establish requirements related to which disciplines that shall participate in the HAZID, in order to assure that all relevant hazards are identified;
- e) the HAZID shall include
 - 1) a broad review of possible hazards and sources of accidents, with particular emphasis on ensuring that relevant hazards are not overlooked,
 - 2) a rough classification into critical hazards as opposed to non-critical,
 - 3) identification of measures to control hazards, e.g. by inherent safer design, possible design improvements, further evaluations or analysis etc.,
 - 4) classification of hazards relevant for the emergency preparedness analysis process if this is part of scope.
- f) the documentation of the HAZID shall as a minimum include
 - 1) personnel attending,
 - 2) method/guide words applied,
 - 3) statement of the criteria used in the screening of the hazards,
 - 4) documentation of the evaluations made for the classification of the non-critical hazards, i.e. hazards that are excluded from further assessment, and the basis for this evaluation,
 - 5) hazards identified with description of causes and consequences,
 - 6) description of implemented safety barriers,
 - 7) hazards that are to be subjected for further evaluation,
 - 8) a description of the system basis used in the HAZID, according to 5.2.2.6 b).

A list of potential hazards relevant for some facilities and operations is given in Annex C.

5.4 Analysis of initiating events

5.4.1 Objective

To analyze and identify potential causes of initiating events, and to assess the probability/frequency of initiating events occurring.

5.4.2 Requirements to qualitative analysis

The initiating events to be analysed shall be determined by the hazard identification as specified in 5.3. The following requirements apply:

- a) the level of detail for analysis of causes of the initial event shall be suitable in relation to the context of the risk assessment;
- b) the analysis of causes shall reflect a broad experience basis, with respect to design, operation and maintenance;
- c) if coarse and subjective analysis is performed, it shall be ensured that the experience basis is adequate.

5.4.3 Requirements to quantitative analysis

The following requirements apply:

- a) the initiating events to be analysed shall be determined by the hazard identification as specified in 5.3.

Analysis of the following shall as a minimum be included if the hazard is relevant according to the objective:

- 1) process accidents;
- 2) risers/landfall and pipeline accidents;
- 3) storage accidents (liquid and gas);
- 4) loading/offloading accidents;
- 5) blowouts and well releases;

- 6) accidents in utility systems, e.g. leaks of chemicals, fires, explosion of transformers etc.;
- 7) accidents caused by external impact and environmental loads, e.g. collision, falling/ swinging loads, helicopter crash, earthquake, waves;
- 8) structural failure (including gross errors);
- 9) loss of stability and/or buoyancy (including failure of marine systems).

The frequency of the above listed initiating events shall be established. The following requirements apply (in addition to the requirements given in 5.2.2.5 concerning the methods, models and tools used):

- a) if failure data are used, the failure and accident data applied shall be suitable in relation to the context of the study and the method, model(s) and tool(s) used. Consideration shall be made with respect to how representative and suitable the available failure data (considered) used are. Factors for consideration may be (see also Annex C and ISO 14224)
 - 1) type of facility and the equipment used,
 - 2) process parameters, including substances involved,
 - 3) weather conditions on location at time,
 - 4) available safety barriers,
 - 5) working procedures, organisation and possible changes,
 - 6) reservoir conditions,
 - 7) design standards, margins,
 - 8) the quality and relevance of available historical data,
 - 9) technology development,
 - 10) maintenance programs,
 - 11) operational standards.
- b) explicit analysis of possible causes of initiating events should complement the assessment in lack of representative and suitable data;
- c) if trends in data are used, they shall be substantiated;
- d) the data applied shall be documented as well as a discussion of their relevance, see 5.2.2.5.

5.5 Analysis of potential consequences

5.5.1 General

The term “analysis of potential consequences” is here used in a wide sense, covering the entire accidental sequence or sequences that may be the outcome if an initiating event should occur, see 5.3 and 5.4.

As the objective and scope of a risk assessment may vary, the way to perform the analysis of potential consequences may range from detailed modelling (using extensive event-trees including a comprehensive assessment of the various branches) to coarse judgemental assessment (by e.g. extrapolation from experimental studies or from available data). Analysis of the potential consequences may therefore be qualitative, semi-quantitative or quantitative, depending on the context.

5.5.2 Objective

The following are the objectives of consequence analysis:

- a) to assess possible outcomes of identified and relevant initiating events that may contribute to the overall risk picture;
- b) to analyze potential event sequences that may develop following the occurrence of an initiating event, determine the influence of the performance of barriers, the magnitude of the physical effects and the extent of damage to personnel, environment and assets, according to what is relevant given the context of the assessment.

5.5.3 Requirements to qualitative analysis

The initiating events to be analysed shall be determined by the hazard identification as specified in 5.3. The following requirements apply:

- a) the level of detail for analysis of consequences shall be suitable in relation to the purpose and context of the analysis;
- b) the analysis of consequences shall reflect a broad experience basis, with respect to design, operation and maintenance;

- c) if coarse and subjective analysis of consequences is performed, it shall be ensured that the experience basis is adequate and extensive.

5.5.4 Requirements to quantitative analysis

The following requirements apply:

- a) the level of detail for analysis of consequences shall be suitable in relation to the purpose and context of the analysis;
- b) the initiating events to be analysed shall be determined by the hazard identification as specified in 5.3. The following separate event types shall as a minimum be included if the hazard is relevant:
 - 1) process accidents;
 - 2) risers/landfall and pipeline accidents;
 - 3) storage accidents (liquid and gas);
 - 4) loading/offloading accidents;
 - 5) blowouts and well releases;
 - 6) accidents in utility systems (leaks of chemicals, fires, explosion of transformers etc);
 - 7) accidents caused by external impact and environmental loads, e.g. collision, falling/ swinging loads, helicopter crash, earthquake, waves;
 - 8) structural failure (including gross errors);
 - 9) loss of stability and/or buoyancy (including failure of marine systems).

5.6 Establishing the risk picture

5.6.1 Objectives

To establish a useful and understandable synthesis of the risk assessment, with the intention to provide useful and understandable information to the relevant decision makers and users about the risk and the risk assessment performed. Establishing the risk picture includes reporting of the risk assessment process.

5.6.2 General requirements

The following requirements apply:

- a) the risk picture shall include
 - 1) a clear and balanced description of the objective and scope of the assessment, and of the system boundaries and system basis used,
 - 2) a clear description of the methodology, models and/or tools used, including a justification of their use,
 - 3) a presentation of the risk acceptance criteria and/or other decision criteria used, and the results compared with these criteria,
 - 4) a clear and balanced picture of the risk exposure and the main risk contributing factors,
 - 5) a discussion of uncertainty, including the following aspects:
 - i. the perspective on risk used in the assessment, e.g. classical, statistical, probability of frequency, combined classical and Bayesian, Bayesian, Predictive approach;
 - ii. the effect and level of uncertainty given the adopted perspective and the context for the assessment (including the 'system boundaries' and 'system basis') compared to the 'actual' or 'real' systems and/or activities of interest;
 - iii. possible implications for the main results;
 - iv. occurrence of unexpected outcomes, as a result of invalid assumptions and premises, or insufficient knowledge.
 - 6) if used, define and/or discuss the meaning of terms and quantities like: probability, frequency, mean value, expected values, conservative side, conservative approach, etc.,
 - 7) factors such as divergence of opinion amongst experts or limitations of the modelling should be stated and may need to be highlighted.
- b) the risk picture shall
 - 1) be suited for decision-making,
 - 2) be understandable to all relevant personnel, decision makers as well as engineering and/or operating personnel. This may be solved by the use of tailored documentation and presentations to different groups of internal and external stakeholders.
- c) the analysis itself should aim at presenting expected consequences. The expected level should be approached from the "slightly conservative side";
- d) within the limitations provided by the scope and methodology, the presentation and documentation of the risk picture shall be a comprehensive, balanced, many-faceted and holistic picture of the risk associated

with facilities and operations, including main contributions to risk from various areas, locations, phases, hazards, systems and operations. Focus areas for best possible risk reducing effect shall be part of the documentation;

- e) assumptions and presuppositions shall be clearly and explicitly documented and categorised in the following groups:
 - 1) analytical;
 - 2) technical;
 - 3) organisational/operational.
- f) assumptions and presuppositions which imply restrictions to the operation of the facility, the activities assessed or to modifications/changes in the system basis shall be described in a manner which is understandable and easy to use for the various users of the risk analysis. This includes a description of the implication of deviations from these assumptions and presuppositions. The need for sensitivity analysis in order to identify and to assess the implications of changes in the study basis shall be considered and performed when necessary. For quantitative risk analysis see also 5.6.3.4;
- g) results, premises and assumptions shall be documented in a manner which enables easy use as input to planning of operational activities, maintenance and modifications;
- h) an evaluation of the robustness of the conclusions given in the assessment with respect to changes in study basis shall be presented;
- i) background for the choice of assumptions/presumptions shall be given;
- j) for modification projects: a comparison of all risk metric before and after the proposed modifications shall be included.

5.6.3 Requirements to quantitative risk analysis

5.6.3.1 General

The requirements in this regard fall in two categories; concerned with the process of establishing the risk picture and the presentation of it.

5.6.3.2 Calculations needed to establish the risk picture

For the calculations needed to establish the risk picture, the following requirements apply (if included in scope):

- a) the following fatality risk contributions shall be considered and, when applicable, calculated and presented separately:
 - 1) immediate fatalities;
 - 2) offshore transportation fatalities including shuttling;
 - 3) escape fatalities;
 - 4) evacuation and rescue fatalities;
 - 5) off-site risk.
- b) the fatality risk contributions shall be split into areas or exposed employee groups and, if relevant, between 1st and 3rd party;
- c) when required, the probability of loss of main safety functions is established in accordance with guidelines given in Annex B;
- d) the environmental risk shall as a minimum be calculated for the environment in general, but it is recommended to calculate risk for identified environmental risk indicators or specific sensitive resource.

5.6.3.3 Presentation of the risk picture

For the presentation of the risk picture, the following requirements apply (if included in scope):

- a) the main results and conclusions of any risk analysis shall be presented as risk for the activity in question, in accordance with the structure of the RAC and for the relevant risk elements. The risk picture shall include
 - 1) ranking of risk contributors,
 - 2) identification of potential risk reducing measures,
 - 3) important operational assumptions/measures in order to control risk.
- b) if required, the presentation of risk picture shall include dimensioning accidental loads;
- c) presentation of possible measures that may be used for reduction of risk and their risk reducing effect;
- d) the analysis shall present and describe accident scenarios relevant for the assessment of the emergency preparedness, see 9.4;

- e) presentation of the sensitivity in the results with respect to variations in input data and crucial premises. The basis for the chosen sensitivity analyses shall be presented;
- f) the results of the QRA shall be traceable through the analysis report. It shall be possible to identify any mechanism/equipment that causes large risk contribution;
- g) intermediate results shall be presented such that risk contributors can be traced through the report;
- h) assumptions and premises of importance to the risk assessment results, to decisions related to future project development or with implications to operations/maintenance shall be documented;
- i) assumptions, premises and results shall be presented in a way suitable as input for defining performance requirements for safety and emergency preparedness measures in later life cycle phases;
- j) assumptions, premises and results for environmental risk shall be presented in a way suitable as input for the environmental preparedness and response analysis;
- k) all recommendations made in the analysis shall be listed separately with references to calculations.

5.6.3.4 Sensitivity analysis

The following requirements apply:

- a) sensitivity analyses shall be carried out to include
 - 1) identification of the most important aspects and assumptions/parameters in the analysis,
 - 2) evaluation of effects of changes in the assumptions/parameters, including the effect of any excessively conservative assumptions,
 - 3) evaluation of effects of potential risk reducing measures.
- b) the input parameters to be considered for sensitivity analyses should, if relevant, include
 - 1) total manning and personnel distribution,
 - 2) leak frequencies,
 - 3) probability of ignition,
 - 4) performance (reliability, availability, functionality, etc.) of important barrier functions, systems and/or elements (technical, human and organisational) for personnel, environment and asset risk,
 - 5) operational parameters, such as the activity levels,
 - 6) environmental resources and their vulnerability,
 - 7) spreading of contaminant.

5.6.3.5 Establish input to design accidental loads

DALs are initially established in early project phases, based on quantitative risk analysis. The modelling may at that time be somewhat coarse and details concerning, layout, systems, equipment, etc., may not be available.

The following apply:

- a) the establishment of dimensioning accidental loads shall start with the completion of a risk analysis and the comparison of calculated risk with RAC;
- b) the risk analysis shall establish sets of accidental events and associated accidental loads, and possibly also associated probabilities. The dimensioning accidental loads are chosen from these sets, such that the RAC are complied with;
- c) it may be difficult to define the accidental load in relation to some types of accidental events, for instance in relation to filling of buoyancy compartments that may lead to instability of topside equipment, impact of escape routes, personnel panic, capsizing or loss of buoyancy. In these cases, the basis of dimensioning is given by the DAEs;
- d) the selection of dimensioning accidental loads shall take considerations described in c) into account, and provide sufficient margins in order to avoid inadequate dimensioning accidental loads at a later stage;
- e) tolerable damage or required functionality shall 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
 - 1) 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,
 - 2) 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 routes, main structural support system, etc.,
 - 3) the equipment has to be gas tight. This may be relevant for hydrocarbon containing equipment.

The final establishment of the design accidental loads will be decided based on a consideration of the DALs but also a consideration of other factors, e.g. risk reducing measures, design safety factor etc.

5.7 Risk evaluation

5.7.1 General

Assessments and decisions concerning whether or not risk is acceptable, whether or not additional risk reducing measures may be required, or if a measures should be implemented or not, is beyond the scope of this NORSOK standard. Hence, this subclause does only cover the part of the decision basis that may be used for such assessments and decisions which the risk assessment process can and should provide.

5.7.2 Objective

The objective is to establish a basis for decision-making, given the context of the analysis.

5.7.3 Requirements

If the consequences are expressed in categories in the quantitative analysis, the risk shall also be expressed as the cumulative frequency for all consequences.

Identification of possible risk reducing measures shall be performed throughout and as a part of any risk assessment process as follows:

- a) separate assessments with the purpose of identifying possible risk reducing measures and evaluating their effect shall be performed as a part of the risk assessment process;
- b) the assessment shall seek to identify measures with the following priority:
 - 1) measures that provide inherently safer design;
 - 2) measures that reduce the possibility of accidental events occurring;
 - 3) measures that reduce the consequences if accidental events should occur.
- c) evaluation of possible risk reducing measures should be based on
 - 1) qualitative assessments, i.e. reflecting inherent safety principles, best available technology, cautionary principles,
 - 2) quantitative or qualitative analysis of cost, benefit, and other effects of the relevant measures, i.e. reputation, robustness, effectiveness, maintenance and operational effects.
- d) the identification and evaluation of risk reducing measures shall be documented. It shall include a description of the risk reduction process that has been followed (see item e), as well as the results of the risk reduction process;
- e) documentation of the risk reduction assessment shall include
 - 1) overview of the elements in the risk reduction assessment,
 - 2) overview of the involved parties in the assessment,
 - 3) documentation of the identified measures and their effect on the risk, supporting analyses and evaluations.

5.8 Communication and consultation

5.8.1 Objective

The objective is to involve relevant internal and external stakeholders (relative to operator), at the right time and with the appropriate level of involvement throughout the entire process, as a measure to improve the quality of the risk assessment process and its ability to be tailored and suitable for its intended purpose(s).

Experience transfer from personnel with operational knowledge from practical utilisation of critical equipment and systems is of importance to establish high level of safety and predictability of risk assessment outcome.

Effective internal and external communication and consultation shall be done to ensure that those affected by the hazards and those accountable for managing the risk understand the established context on which the results are calculated and evaluations are made, the risk picture, and the reason why particular priorities may be needed in the risk treatment.

5.8.2 Requirements

The following requirements apply:

- a) a plan to communicate and consult with internal and external stakeholders shall be developed at an early stage of the process;
- b) the plan shall address communication and consultation related to (but not limited to)
 - 1) the establishment of the context for the risk assessment,
 - 2) the execution of the assessment,
 - 3) how the assessment and its results shall be communicated to various stake holders,
 - 4) involvement of personnel with operational knowledge.
- c) the plan shall include a brief description of how and when the communication shall be performed (written and/or oral communication) in general, and for subjects that requires a specific form of communication, including feed-back from the receiver to the sender. Assumptions and presuppositions that are to be used in the assessment are examples of information that requires communication between those performing the assessment and those responsible for the technical and operational solutions to be used;
- d) those responsible for the communication and consultation needed shall be identified and included in the plan.

5.9 Monitoring, review and updating the risk assessment

5.9.1 General

In several of the phases covered by this NORSOK standard (e.g. the concept selection phase and the engineering phase), several changes may be implemented (or decided implemented) to the plant, installation or operation(s) subjected to the assessment as the project evolves. The level of details will also in many cases increase throughout the process as a project develop.

5.9.2 Objective

The objectives of monitoring, review and updating the risk assessment are

- to monitor the established context, with respect to its validity due to decisions made, new knowledge (including the level of details available about the system or operation to be analyzed) or other factors which may jeopardize the validity of the context. Results from scoping or framing studies, performed after the context was updated, or results from studies or assessments performed as a part of the risk assessment process may also require the context to be updated,
- to update the context throughout the process, if and when required,
- to assure that the risk assessment process and its various elements is executed based on an updated context, if and when the context has been modified.

5.9.3 Monitoring and review of risk assessment process

Monitoring and review is related to

- analyzing and learning lessons from events, changes and trends,
- detecting deviations from assumptions and premises of the risk assessment,
- detecting changes in the external and internal context, including changes to the risk itself, that may required revision of risk assessment and evaluation.

The monitoring and review in all phases will be a mixture of qualitative and quantitative analyses. It will be essential to have a system to follow up results and recommendations from all types of studies.

Requirements to monitoring and review:

- a) monitoring and review can involve regular checking or surveillance of what is already present or can be periodic or ad hoc. Both aspects shall be planned. It is not sufficient to rely only on occasional reviews and audits;
- b) the results of monitoring and review shall be recorded and internally or externally reported as appropriate;
- c) responsibilities for monitoring and review shall be clearly defined;
- d) a plan for follow-up of the analysis shall be prepared, containing an assessment of the conclusions and recommendations as well as plans for implementation of risk reducing measures, including emergency preparedness measures.

5.9.4 Updating of risk analysis

A risk analysis is in general only valid as a basis for decision-making as long as the basis for the analysis (e.g. its methods, models, input data, assumptions, limitations, etc.) is assessed to be valid. Any deviation from the basis for analysis should therefore initiate an assessment of the deviation with respects to its effect on the risk and/or the validity of the analysis and its results, provided that the analysis is intended to be used as a basis for future decisions. When updating an analysis (or using an analysis as basis for sensitivity studies) all basis for the analysis should be reviewed. The review of the basis for QRA shall be documented.

Update of a risk analysis or performance of a new analysis shall be based on consideration of

- the current phase in a project (changing from feasibility to the concept and/or engineering phase of a project, or from the detailed engineering phase to the operational phase),
- the period for future use of the current risk analysis (short-term or long-term use (operational phase),
- the types of decisions that the analysis is intended to support in the future,
- the extent of work and the time required to perform a new analysis versus the need for decision support at a given time.

6 Additional requirements to quantitative risk analysis (QRA) in concept selection phase

6.1 General

The requirements stated in this subclause are in addition to the general requirements given in Clause 5, and reflect an assessment performed in the concept selection phase.

The main purpose of the assessment is to compare different concepts and to identify any potential showstoppers for each concept. The available level of details related to the various concepts is assumed to be limited.

The risk assessment in this phase can be qualitative or quantitative or a combination of these. This would be dependant of the following aspects related to the various concepts listed below:

- complexity;
- applicable hazards;
- exposed systems;
- availability of information.

For combination of qualitative and quantitative analysis, the relevant parts of Clause 5 apply accordingly.

6.2 Establishing the context

6.2.1 Objective

The general objective of a QRA in the concept selection phase is to identify risk challenges for each concept, and to compare the concepts with respect to risk level and possibility of risk reduction. The more specific objectives are to

- identify potential showstoppers for concepts and risk challenges for any of the concepts under evaluation i.e. evaluate if it is likely that the authority and acceptance criteria for any of the concepts cannot be met,
- describe and characterise all risks that are significant for the facility, in order to assist the concept selection and optimisation process,
- identify possible significant risk reducing measures, so that safer, more environment friendly, more cost-effective design and/or inherently safe options can be adopted,
- provide a risk ranking of the proposed concepts. The risk may be expressed as risk to people, environment, assets and impairment of safety functions,
- evaluate the robustness and uncertainties of the proposed concepts with respect to possible changes during design development,
- identify need for any further risk assessments or detailed studies that should be performed,
- identify need and scope for further risk assessments during the next phase,
- establish preliminary DSHAs,

- i) evaluate the layout of main areas,
- j) establish preliminary dimensioning accidental loads and/or safety zones/separation requirements.

Other objectives shall be considered, see 5.2.2.2.

6.2.2 Requirements

No additional requirements, see 5.2.2.

6.3 Hazard identification (HAZID)

6.3.1 Objectives

Identify contributors to the major accident risk that will be dimensioning for separation between systems, systems safety zones or environmental risk level, main dimensioning loads etc, or which will be the most critical hazards for the concepts.

The HAZID approach shall also be used to identify construction and installation risks. The objective of this activity is to identify any such risks that may be of importance for development of the design solutions, costs, schedule or that might otherwise be of importance for concept selection. This is of particular importance for modifications on a facility in the operational phase. Construction related activities or significant increase in manning in construction period can be a significant risk for some of the concepts under evaluation and shall thus be identified.

6.3.2 Requirements

No additional requirements, see 5.3.3.

6.4 Analysis of initiating events

6.4.1 Objective

No additional objectives, see 5.4.1.

6.4.2 Requirements

The following requirements apply:

- a) hazards that represent a significant difference between concepts or represent a high risk shall be quantified. Normally limited information and time is available for a detailed analysis of initiating events. In a QRA in this phase it is therefore recommended to use data for comparable systems, or to use data from similar facilities;
- b) extra focus shall be on new unconventional concepts or concepts with limited operational experience;
- c) personnel transport risk, with respect to possible differences between the concepts or specific challenges, is an element that shall be considered in this phase;
- d) when ship collision risk is deemed to be significant, a detailed collision analysis shall be performed in this phase. This is in particular the case when collision risk will be dimensioning for the facility structure or determining for the location of the facility;
- e) possible concept challenges and differences regarding effects from and impact on neighbouring activities, environment and population (3rd party) shall be considered.

If the hazard identification process identifies hazards not critical for the decision making, either due to low risk potential, negligible difference in risk level between concepts or a combination of these, a qualitative analysis of these hazards may be appropriate.

6.5 Analysis of consequences

6.5.1 Objective

No additional objectives, see 5.5.2.

6.5.2 Requirements

The following requirements apply:

- a) all hazards that may contribute significantly to the overall risk picture for the facility shall be included in the consequence modelling in the concept selection phase. Analysis of consequences may often be performed by simplified (analytical/empirical) models. However, in situations where the results of such analyses are critical for concept selection or optimisation, more accurate modelling may be required;
- b) the valuation of robustness of the proposed concepts shall focus on impairment of main safety functions;
- c) the level of detail of the documentation of intermediate results shall be in line with the consequence modelling accuracy. For simplified modelling, the simplifications shall be documented. For more accurate modelling, the documentation of intermediate results shall be in accordance with needs for decision support.

6.6 Establishing the risk picture

6.6.1 Objective

No additional objectives, see 5.6.1.

6.6.2 Requirements

6.6.2.1 Presentation of the risk picture

The result shall be presented in such a way that

- a) it is clear if any of the concepts under evaluation cannot or will have difficulties to meet authority or company acceptance criteria,
- b) it is possible to rank between the concepts in a risk perspective,
- c) opportunities for inherently safe design, robustness and risk reducing measures are identified and the benefits from these can be clearly communicated,
- d) focus items for the next phase can be identified.

6.6.2.2 Estimation of dimensioning accidental load

In this phase a coarse evaluation of the dimensioning accidental loads should be performed. Aspects that should be evaluated are as follows:

- For land based facilities:
 - safety zones around the facility;
 - separation distances between main process functions such as administration building, tank farms, process areas, flare, utility area, landfall, burners etc.;
 - need for explosion protection on buildings, fire protection on major process equipment, or structures etc.;
 - earthquake, flooding and meteorological loads.
- For offshore facilities:
 - structural load actions due to ship collisions, earthquakes, anchor failures, ice and meteorological loads etc.;
 - fire and explosion loads for main barrier elements;
 - fire loads for risers and structure;
 - dropped object impact load, particularly for risers and structure.

For modification of existing facilities it is important to identify possible new dimensioning accidental loads. Equipment and structures shall be designed in accordance with the relevant DALs specification for the existing facility.

6.7 Risk evaluation

No additional objectives or requirements, see 5.7.

6.8 Communication and consultation

No additional objectives or requirements, see 5.8.

6.9 Monitoring, review and updating the risk assessment

No additional objectives or requirements, see 5.9.

7 Additional requirements to quantitative risk analysis (QRA) in concept definition, optimization and detailed engineering phases

7.1 General

The requirements stated in this clause are in addition to the general requirements given in Clause 5, and reflect an assessment performed late in the concept definition and optimisation phases.

Detailing of the analysis and the objective will typically differ during the various stages of these phases. It is assumed that the design is mature but it can still be modified. It is further assumed that layout drawings and P&IDs for process and essential safety systems are available at the time of the assessment.

Risk analysis of construction work and installation activities are not covered in this clause.

7.2 Establishing the context

7.2.1 Objective

The objective of the QRA in the concept definition and optimisation and detailed engineering phases is to provide input to decisions relating to

- a) compliance with acceptance criteria,
- b) ALARP evaluations,
- c) establishment of DSHAs,
- d) layout of main areas and equipment,
- e) site layout, including location of traffic routes and ignition sources (e.g. furnaces, flares, transformers etc),
- f) design of systems and equipment,
- g) DALs and/or safety zones,
- h) requirements to barriers,
- i) operational restrictions and conditions including restrictions applicable to simultaneous operations.

7.2.2 Requirements

The overall requirements to the QRA studies in the concept definition, and optimisation phases are as follows:

- a) the analysis shall consider the operational phase;
- b) different activity levels during the lifetime of the facility shall be considered;
- c) the need for revisions of the analysis during the concept definition and optimisation phases shall be considered;
- d) the risk assessment shall include evaluation of risk at the same format as given in the company and authority RAC;
- e) if risk to people is to be calculated, the risk in a quantitative study should be expressed in terms of: area risk for defined areas on the facility, group individual risk for defined groups of personnel and average Individual risk. Risk to 3rd parties shall be expressed, if relevant. Other additional measures of risk to personnel may be used in order to fulfil the objectives of the risk assessment process;
- f) a guidance for assessment of the main safety functions is given in Annex B;
- g) if risk to the environment is to be calculated, the risk shall be expressed in the same format as given in the company RAC. Further requirements and guidelines for the analysis methodology are given in 7.5.12 and Annex G respectively. Acceptance criteria for environmental risk are treated in Annex A.

7.3 Hazard identification

7.3.1 Objective

The objectives of the activity during these phases are

- a) to review and update the HAZID performed in the concept selection phase, given the available information (level of details) at the time of the assessment,
- b) to assess hazards related to systems and activities not covered in the concept selection phase, including hazards related to various utility systems,