JIP: Risk informed decision support in development projects (RISP)

Main report

Report for:
RISP Participants, att: Equinor Energy AS

Report no: LaC-P0647-R-0125 Rev: Final

Date: 13 December 2019

Summary

JIP: Risk informed decision support in development projects (RISP)		

Main report

Security classification of this report: Distribute only after client's acceptance

Report no:	**Revision:**	**Report date:**
LaC-P0647-R-0125	Final	13 December 2019
Prepared by:	**Reviewed by:**	**Approved by:**
Tore Sagvolden, Lilleaker Consulting	Unni Nord Samdal, Equinor	Unni Nord Samdal, Equinor

Tore Sagvolden   Unni Nord Samdal

This report presents the Joint Industry Project (JIP) called risk informed decision support in development projects (RISP). The project has been carried out in 2018 and 2019. The project is related to management of major accident hazards (MAH) in development projects on the Norwegian Continental Shelf (NCS).

The task for the project has been to further develop and concretise principles and ideas provided by a former NOROG project, into new methods and models. The methodology established is based on the risk-based decision-making framework given by ISO 17776, which differentiate the assessment technique dependent on the complexity of the development project.

The intention for the project has been to provide risk informed decision support needed in typical development projects. The information needed has been screened considering both the timing of when decisions are or should be made, and the available information for decision making.

Risk assessment methods and models have been established suited to the information available when the decisions are normally taken. The recommendations given by the models are considered robust as to avoid the need to reiterate the decision based on more detailed information available at a later stage provided premises for the decision are not changed.

The methods and models are established for proven design where prequalified solutions can be applied. Validity envelopes for the various models have been established.

As far as possible the methodology is based on design requirements given by standards. It is acknowledged that NORSOK S-001 is a key standard in this respect.

The methodology has been reviewed in relation to the present regulative regime to identify possible conflicts and need to update regulations and standards.

Document history

Revision	Date	Description/changes	Changes made by
Final	13 December 2019	Comments from RISP participants implemented	Tore Sagvolden
Draft	13 November 2019	Issued to RISP participants for comments	

Table of contents

Page

1. List of abbreviations and definitions

1.1 Abbreviations

AIS	Automatic Identification System
ALARP	As Low as Reasonably Practicable
ALS	Accidental Limit State
BAT	Best Available Technology
CAD	Computer-Aided Design
CAPEX	Capital Expenditure
CCR	Central Control Room
DDT	Deflagration to Detonation Transition
DeAE	Design Accidental Event(s)
DeAL	Design Accidental Load(s)
DiAL	Dimensioning Accidental Load(s)
DP	Dynamic Positioning
DP2	Dynamic Positioning – Redundancy Class 2
EERS	Escape Evacuation and Rescue Strategy
ESD	Emergency Shutdown
FEED	Front End Engineering and Design
FES	Fire and Explosion Strategy
FPSO	Floating, Production, Storage and Offloading
GBS	Gravity Based Structure
G-OMO	Guidelines for Offshore Marine Operations
HAZAN	Hazard Identification and Analysis
HAZID	Hazard Identification
HC	Hydrocarbon
HSE	Health, Safety and Environment
ISD	Inherent Safe Design
ITT	Invitation to Tender
JIP	Joint Industry Project (In this case the RISP project)
LD	Lethal Dose
LEL	Lower Explosion Limit
MAH	Major Accident Hazard
MEG	Mono Ethylene Glycol
MeOH	Methanol
NCS	Norwegian Continental Shelf
NOROG	Norwegian Oil and Gas
PDO	Plan for Development and Operation
PFP	Passive Fire Protection
PIO	Plan for Installation and Operation
PPE	Personal Protection Equipment
PRV	Pressure Relieve Valve
PSA	Petroleum Safety Authority
QRA	Quantitative Risk Analysis
RISP	Risk Informed Decision Support in Development Projects
SC	Steering Committee
SoW	Scope of Work

SPR	Sudden Pressure Relay
SSIV	Subsea Isolation Valve
TEG	Tri Ethylene Glycol
TRA	Total Risk Analysis
TSS	Traffic Separation Scheme
ULS	Ultimate Limit State
W2W	Walk to Work
WCPF	Worst Credible Process Fire
WG	Workgroup

1.2 Definitions

Terminology as used in the RISP project:

- Safety premises: Identified aspects presumed to be true and therefore used as a basis for the management of MAH. This can typically be presumptions (constraints and conditions) made in the HAZAN as a basis for concluding that the design is within the validity envelope of the RISP models. It can also cover other aspects such as operational restrictions. Safety premises typically needs to be verified at a later stage.
- Safety program: The safety program is a high-level plan describing the goals, means (resources), activities and analyses planned to manage MAH in a development project. Responsibilities, organisation and interaction arenas related to implementation of MAH design in the development project should be described. The safety program may also be called the HSE program or similar.
- Safety strategy: The safety strategy is a high-level plan giving the link between the safety program and the design development regarding MAH. The strategy describes how the end goals will be achieved. The safety strategy should also cover the needs related to fire and explosion strategy (FES) and escape, evacuation and rescue strategy (EERS). The safety strategy should outline applicable overall principles for design, layout, arrangements, philosophies and other high-level design and operational aspects related to barriers, e.g.:
    - Describing MAH relevant for the development (e.g. area by area) and describing key design measures and safety premises.
    - Describing how specific MAH are managed by the use of barrier functions, systems and elements. Typically, this should include a reference to standard requirements (e.g. NORSOK S-001) and whether there are special solutions required not covered by the standards.
- Proven design: Design or concepts that are considered prequalified through operational experience and/or previous engineering documentation and analyses to such a degree that the RISP methods and models can be applied.
- RISP methodology: The principles that have been used to establish methods and models in the JIP. The term is also applied as the totality of RISP methods and RISP models.
- RISP methods: The work steps and procedures proposed to be used for risk-based decision support in development projects.
- RISP models: The assessment tools proposed to be applied for risk-based decision support in development projects

2. Introduction

2.1 General

This is the main report from the Joint Industry Project (JIP) named "Risk informed decision support in development projects (RISP)". The project has been carried out in 2018 and 2019. The report summarises the work performed, results and conclusions obtained and recommendations for the way forward.

The major part of the work is documented by separate reports produced by 5 work groups. The reports are attached to this main report and includes:

- Appendix A: WG 1 report – Risk management
- Appendix B: WG 2 report - Explosion
- Appendix C: WG 3 report - Fires
- Appendix D: WG 4 report – Other accidents
- Appendix E: WG 5 report – Risk management and regulatory framework including standards

Possible discrepancies or conflicts between the main report and the reports from the work groups, are due to maturing through the project execution. The content of the main report is prevailing in this respect.

2.2 Background

The project "Formålstjenlige risikoanalyser" ("Expedient Risk Analyses") was run until spring 2017 by Norwegian Oil and Gas, NOROG (Ref. /1/). The project (hereafter called the NOROG project) with results and proposals for further work was presented in the Operations Committee meeting in NOROG, and received full support. The authorities (Petroleum Safety Authority) have also expressed a strong wish to see the project being continued.

The NOROG project concluded:

> *Risk analyses have played an important role in the HSE work in the petroleum industry, and these have helped to give the industry detailed and comprehensive knowledge about risk conditions and design principles. Specific risk acceptance criteria have been used to a great extent in the industry and the advantage is that it provides clear answers on what is good enough and what is not. It is set a clear line.*
>
> *The models and tools, however, require input data at a very detailed level, and in many cases there is a mismatch between a) necessary input and the time it takes to set up and use the tools and b) the information and the time that is available at the time the key decisions are taken. Decision making support in many cases comes too late.*
>
> *Experiences and insights gained through years of risk analyses, has only marginally influenced the way the analyses are conducted. To a large extent, everything is analysed from scratch every time an analysis is required – the knowledge and experienced gained about potential accident scenarios and how an installation/module/system can best be designed, are not adequately exploited.*
>
> *Traditional quantitative risk analyses with emphasis on detailed calculations of total risk level and comparison against risk acceptance criteria (e.g. FAR and 1.0 x 10^{-4}) should be replaced by simplified risk analyses with the aim to provide the best possible decision support. Rather than trying to continue the quest for perfect descriptions of what the risk is, the goal should be to give better decision support at the right time.*
>
> *The recommended practice represents a significant simplification of the current risk analysis practice, especially when facing situations characterized by known technology, considerable experience and little uncertainty, i.e. what can be termed "standard solutions".*

The risk analyses will to a greater extent provide decision support at the right time, thereby contribute to the avoidance of late changes in development projects following results from risk analyses carried out at a late stage in the project. The analyses will also aid Operations in becoming familiar with the barriers' functions and ability to deal with potential events, both those that the facility is designed to handle and those that one cannot expect are handled. The new methodology will make it easier to demonstrate that a given development meets the minimum authority requirements, and the methodology also meets the intention of the authorities' recent definition of risk where uncertainty is a key aspect.

It is therefore recommended to continue the project with the following aim;

- To provide an overview of decisions in a project where risk analyses would provide improved decision support

- To establish risk- and consequence models to provide this improved decision support

- To establish guidelines for risk management in development projects

- To establish overview of where the proposed models and processes are not in accordance with the requirements and standards and propose regulatory changes

The RISP project described in this document is a continuation of the NOROG work and the recommendations it led to. The outcome of RISP is expected to form a significant part of the fundament for the upcoming update of NORSOK Z-013. RISP has focused on risk management in project development of topside facilities (in a broad meaning), including subsea accidents that may affect the facility.

2.3 Objectives and scope of work for RISP

The overall objective of the RISP project is to further develop the principles and ideas provided by the NOROG project into methods, models and guidelines, and establish a new common "industrial practice". This practice should describe how various decisions in a development project are to be based on general and specific knowledge about the incidents that the installation may be exposed to (such as leaks, fires and explosions).

Traditional quantitative risk analyses with considerable focus on detailed calculations of total risk and measurement against risk acceptance criteria such as FAR and frequencies of loss of main safety functions (1×10^{-4}) should, when technology and challenges are known, be replaced by input based on knowledge and experience acquired by past projects and analyses, providing a robust safety level. Instead of searching for detailed descriptions of what the risk level is, the objective should be to provide valid decision support at the right time.

The principles for risk-related decision support provided in ISO 17776, see Figure 1, shall be used as basis for the RISP project. The figure also illustrates the focus area for the work carried out as part of this JIP (RISP).

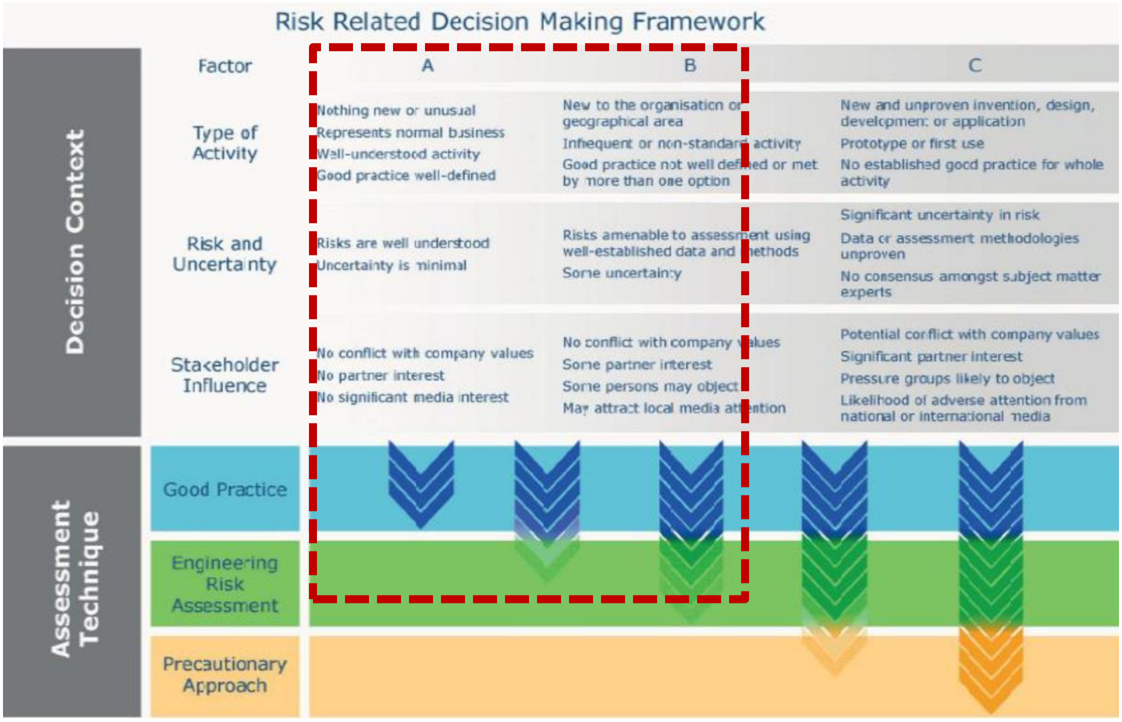

Figure 1 - Risk related decision-making framework from ISO17776 (Ref. /2/). The red doted box illustrates the focus area for the work carried out as part of this JIP (RISP).

The new «industrial practice» developed aims to clarify:

a) if a potential type of hazard/incident is sufficiently covered by using systems and solutions indicated by requirements in standards, established good practice and results of former analyses. Typically, left part of situation A in Figure 1. Or

b) if a potential type of hazard/incident can be sufficiently covered by simplified methods and models established based on knowledge and experience acquired by past projects and analyses. Typically, right part of situation A and major part of situation B in Figure 1 . Or

c) if there is a need for obtaining and using additional assessment techniques (compared to item b) for the hazard/incident. Typically, situation C in Figure 1.

When situation b) applies, the new "industrial practice" must specify the methods and models that should be applied and give guidance on how results (and the conditions/assumptions they are based on) can/should be used in the decision-making process. In this way the decision maker should also be made aware of the importance of the decision and the impacts of the various decision options.

The methods and models to be included in the new «industrial practice» will be adapted to the knowledge and information typically available at the time when the specific decisions of interest are normally made. The decision support provided shall be sufficiently robust, meaning that the recommendations given should not be subjected to scrutiny, reconsiderations or reassessment later in the project, provided that the basis for the decision support (the input used and the restrictions related to further design development) has not been changed throughout the project. This will minimise the need for late design changes, when e.g. more detailed information is available. An as-built total risks analysis/quantitative risk analysis (TRA/QRA) will thus not be required within the new "industrial practice", but verification activities need to be developed. Verification shall ensure compliance with the validity envelope of the new approach, and that any changes in assumptions made during the development project are considered.

Barrier management, in its wide context, should found the basis for risk management in operations. A balanced description of the risk comprehensive enough for the operational phase, should be established also within the new "industrial practice".

The RISP methodology includes decision gates related to whether the MAH hazard in question can be handled with use of the established RISP methods and models as decision support in development projects. The need for additional assessment techniques for the risk related decision-making process is identified. However, no details are established as part of this RISP project for these additional techniques except referring to ISO 17776, PSA regulations and present practices for management of MAH.

The RISP methods and models established are applicable for proven design where technology and challenges are known, and decision support can be based on experience and knowledge acquired by past projects and analyses. The intention has also been to identify the design standards which should be used as basis for the design.

2.4 Requirements to methods and models

Important requirements specified for the methods and models established include:

a) The methods shall ensure that at least the same level of safety is achieved as the level given by the current practice.

b) The methods and models shall be based on best available knowledge.

c) The theoretical and empirical basis for the methods and models established, including the assumptions made, shall be available for review. Possible differences in perceptions amongst experts (related to a subject) shall be stated, and an explanation for how this has been accounted for shall be given. Lack of general knowledge on a specific subject, and how this has been accounted for in the methods and models provided, shall also be described and be available for review.

d) The methods and models must be transparent, meaning that information on how the results have been produced and which factors are important for the results shall be available for review

e) The methods must be traceable, meaning that each assumption and parameter used in the model shall be available and documented.

f) The methods and models shall be openly available to the industry

In order to ensure that the methods and models established in the project remains updated over time (i.e. "at all time" are based on the latest/best available knowledge and experience), a process for when and how to update them needs to be established.

2.5 Project organisation

The RISP project is organised as a research project with 14 participants. The participants include sponsors, vendors and project owner.

Seven offshore operator companies have initiated and sponsored the RISP work; Equinor, ConocoPhillips, Total E&P, Vår Energi (ENI), Lundin, Wintershall and AkerBP.

The vendors are nominated by the sponsors. Different work packages are defined for the work to be carried out by the vendors organised as workgroups. The vendors are: Lilleaker Consulting, Gexcon, DNVGL, Lloyd's Register, Aker Solutions, Proactima and Safetec. The vendors have provided a considerable in-kind contribution.

The JIP consists of two subprojects. Subproject 1 has been carried out in 2018 and includes WG 1 and WG 2. Subproject 2 has been carried out in 2019 and includes WG 3, WG 4 and WG 5.

Aker Solutions was the project owner for Subproject 1, while Equinor has taken over the role as project owner from 2019. The ownership rights to the project results shall accrue to Equinor. All participants have a free right to access project results within their operations.

The PSA has been involved as observer in the RISP project.

The RISP project organisation for Subproject 2 is illustrated in Figure 2. Please note that communication with union representatives has been postponed and needs to be dealt with in a possible continuation of RISP work.

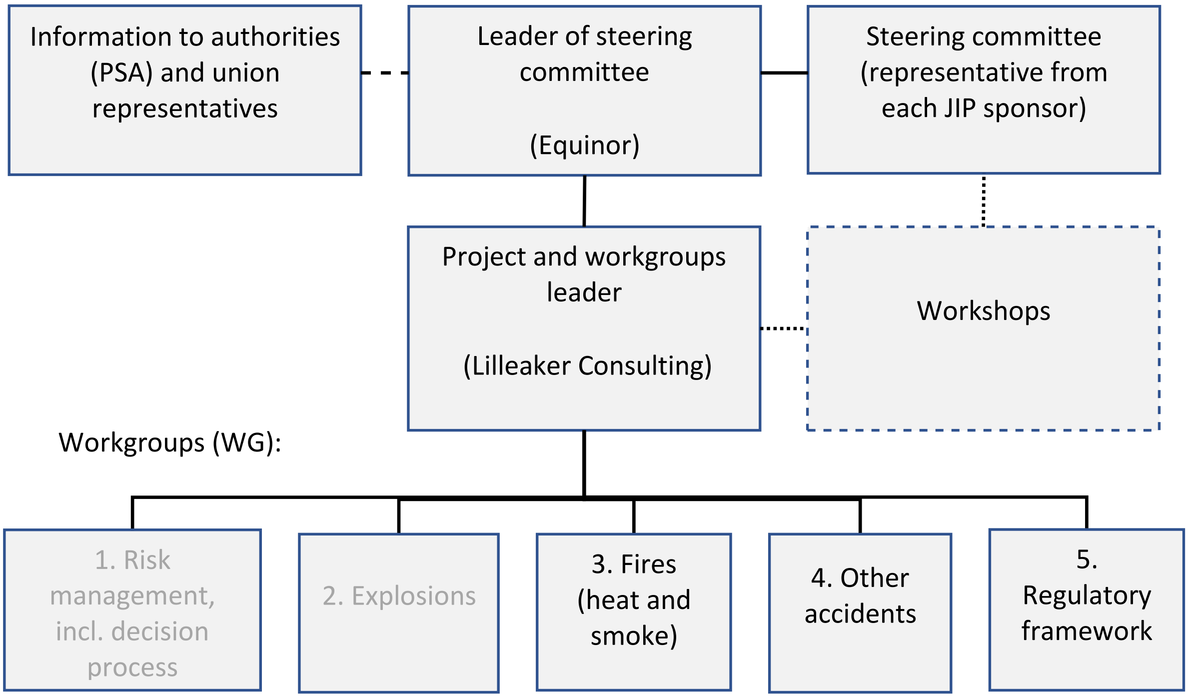

Figure 2 – The RISP project organisation overview (Subproject 2)

3. The RISP methodology

3.1 Framework for RISP

The RISP methodology has been developed with the main intention to improve the decision support provided related to MAH (major accident hazards) in the early design phases of offshore development projects on the NCS.

The framework for RISP includes the following boundaries:

- The RISP methodology includes decision gates related applicability for any development project. If the RISP methods and models are not applicable, the need for additional risk assessment techniques for the risk related decision-making framework is identified. However, no details are established as part of this RISP project for these additional techniques except referring to ISO 17776, PSA regulations and present practices for management of MAH.
- The RISP methods and models are applicable for proven design where technology and challenges are known, and decision support can be based on experience and knowledge acquired by past projects and analyses. The intention has also been to identify the design standards which should be used as basis for the design.
- The RISP methods and models are adapted to the decision support needed when the related design decisions are normally made. The models are tailored to the information typically available when the decisions are made, implying that the input often is coarse and with limited detailing.
- The recommendations given by RISP methods and models shall ensure at least the same level of safety is achieved as the level given by the present practice.
- The methods and models shall be based on best available knowledge, be transparent and traceable and openly available for the industry (see details in Chapter 2.4).
- The present probabilistic PSA requirement related to loss of main safety functions (annual likelihood of 1×10^{-4}) will not be documented quantitatively for each project. Instead the requirement will be indirectly complied with since the robustness of the new RISP designs will be based on experience from similar existing designs that comply with the requirement.
- The decision support given shall be sufficiently robust, meaning that the recommendations given should not be subjected to scrutiny, reconsiderations or reassessment later in the project, provided that the basis for the decision support (the assumptions used and the restrictions related to future decisions (e.g. detailed design), etc.) has not been changed throughout the project.
- The methods do not include requirements for an as-built TRA/QRA for verification. However, it is a prerequisite that the development project has a management of change system identifying and managing changes affecting the decisions made and that necessary verification activities to assure compliance to regulations and safety premises are identified, executed and followed-up.
- The present PSA regulations, including the standards referred to in the regulations, have been used as a basis for the RISP project. (Although referred to as the PSA regulations in this report, the sets of regulations fall within the jurisdiction of several regulatory authorities). Signals from the PSA is that the industry should propose the principles it believes provide the best solutions, and not be restricted by current regulations. The PSA pinpoints however, the ambitions to be world leading in HSE and the requirements for continuous improvement, robustness and risk reduction. If adjustments to regulations including referred standards and interpretations are proposed, it should be clear that it will lead to improved safety. Further the PSA pinpoints that when design is to be based on prequalified solutions described in standards, it is important that the solution described are robust.
- The RISP methodology can also provide relevant MAH information for the operational phase, e.g. as input to the risk picture, barrier management and emergency preparedness. However, elaboration of the risk informed decision support required for the operational phase, has not been part of the current work.

- The RISP models aims primarily to be used to define design accidental events, design accidental loads and corresponding survivability requirements. The models established cover to a lesser degree a complete input regarding risk drivers, probability reducing measures, input to robust and inherent safe design as well as recommended design standards. This needs to be considered as part of management of MAH.

3.2 Validity envelope

The RISP validity envelope describes constraints and conditions for using the RISP methods and models. The aim has been to describe the envelope as precisely as possible to simplify the application in use. The validity envelope is expected to be challenged as part of HAZAN in each development project. A topic for the HAZAN is to conclude if the RISP methods and models can be used or if there are special constraints and conditions for the use. Key elements in the validity envelope include:

- General aspects:
    - The (relevant part of) concept is considered proven for the current situation and conditions. This means that aspects considered potentially as novel or unproven, are evaluated specifically regarding the validity envelope. Examples of aspects that may be necessary to evaluate (in addition to technical aspects) includes operational philosophy, reservoir conditions, process conditions and environmental conditions.
    - The MAH causes and effects are well understood
    - Necessary resources and competence for a proper management of MAH are available for the development project. See e.g. the PSA Framework regulations section 10,11 and 12. Guidelines describing appropriate principles for management of MAH are described in e.g.:
        - ISO 17776: "Petroleum and natural gas industries – Offshore production installations – Major accident hazard ", Second edition dated 15.12.2016. See ref /2/
        - Petroleum Safety Authority Norway, "integrated and unified risk management in the petroleum industry", dated June 2018. See ref /3/.
- The intention has been to define the validity envelope for each RISP model as unambiguous as possible for each MAH as part of WG 2 – 4. It is emphasised that each model will define constraints and conditions applicable per hazard type and area. This means that within an area a RISP model for one type of MAH may be applicable while a model for another MAH is not applicable. Likewise, a RISP model may be applicable for one area of a concept while not applicable for another area.
- It is acknowledged that the NORSOK S-001, 2018 edition is a key document providing design premises related to MAH. The standard contains both prescriptive and functional based requirements to the performance required for safety barriers/-systems. It is concluded that application of this NORSOK standard as a basis for the design development, will be a valid and important premise for the RISP methods and models. Other standards giving design premises are identified as part of WG 2- 4.

3.3 HAZAN

HAZAN is a key element in the RISP methodology. It is based on and includes the present practice of performing a hazard identification (HAZID) as described in NORSOK Z-013. However, it contains further elements to assure a proper basis for applying the RISP methods and models as decision support. In addition, it contains an assessment (or analysis) part to obtain a deeper understanding of the MAH and the associated strength of knowledge for the specific concept/design. By describing and understanding the MAH involved including risk drivers, an important basis for risk reduction and communication with affected stakeholders and disciplines is obtained.

The HAZAN is considered a crucial and important basis for management of MAH in a development project and it needs to be comprehensive and well planned. The HAZAN typically includes one or more documented and structured workshops with stakeholders and subject matter experts involved.

By following the HAZAN process, the following is considered:

- It is evaluated whether there is something unique with the proposed design
- Relevant hazards are identified and classified (HAZID)
- It is evaluated whether hazards are different than normal for the areas on the facility. This includes evaluation of uncertainty, strength of knowledge and whether criteria for use of the simplified RISP methods are met per area and type of hazard.

The above provides decision support to conclude if the RISP methods and models can be used or if special studies or considerations are needed.

The HAZAN process may provide useful decision support at early stages of the project execution for any type of project. It can limit the need for changes to design caused by new or changed safety requirements at later stages.

The HAZAN process is carried out by performing the following steps:

1. Describe characteristics of the suggested development.
2. Identify and analyze initiating events including hazards and uncertainty factors. This includes:
    - Identify, evaluate and classify MAH
    - Identify key risk drivers
    - Identify and consider risk reduction issues
3. Evaluate and demonstrate strength of knowledge
4. Check predefined validity envelope for RISP methods and models and identify safety premises
5. Decide on use of RISP models and identify any need for additional information and special studies or considerations to be performed.

For an elaborative description of the HAZAN, reference is given to the WG1 report. See also the illustration of workflow using RISP methods and models in Figure 4.

3.4 Typical workflow using RISP models in development projects

The new RISP methodology compared to a more traditional approach is illustrated in Figure 3.

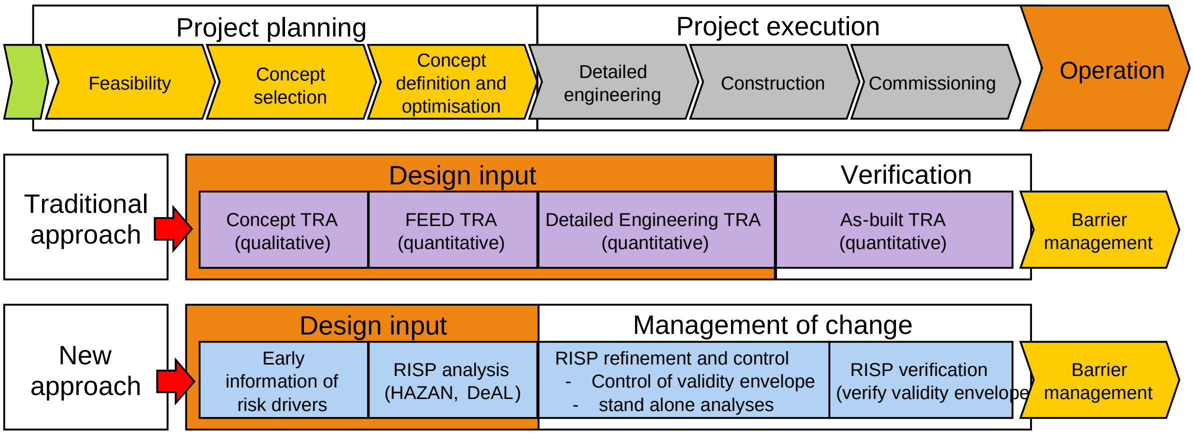

Figure 3 - Early design input delivered by RISP within the validity envelope

An illustration of a typical workflow using the RISP methods and models in development projects has been established. The workflow during Project Planning phase and Project Execution phase is illustrated in Figure 4.

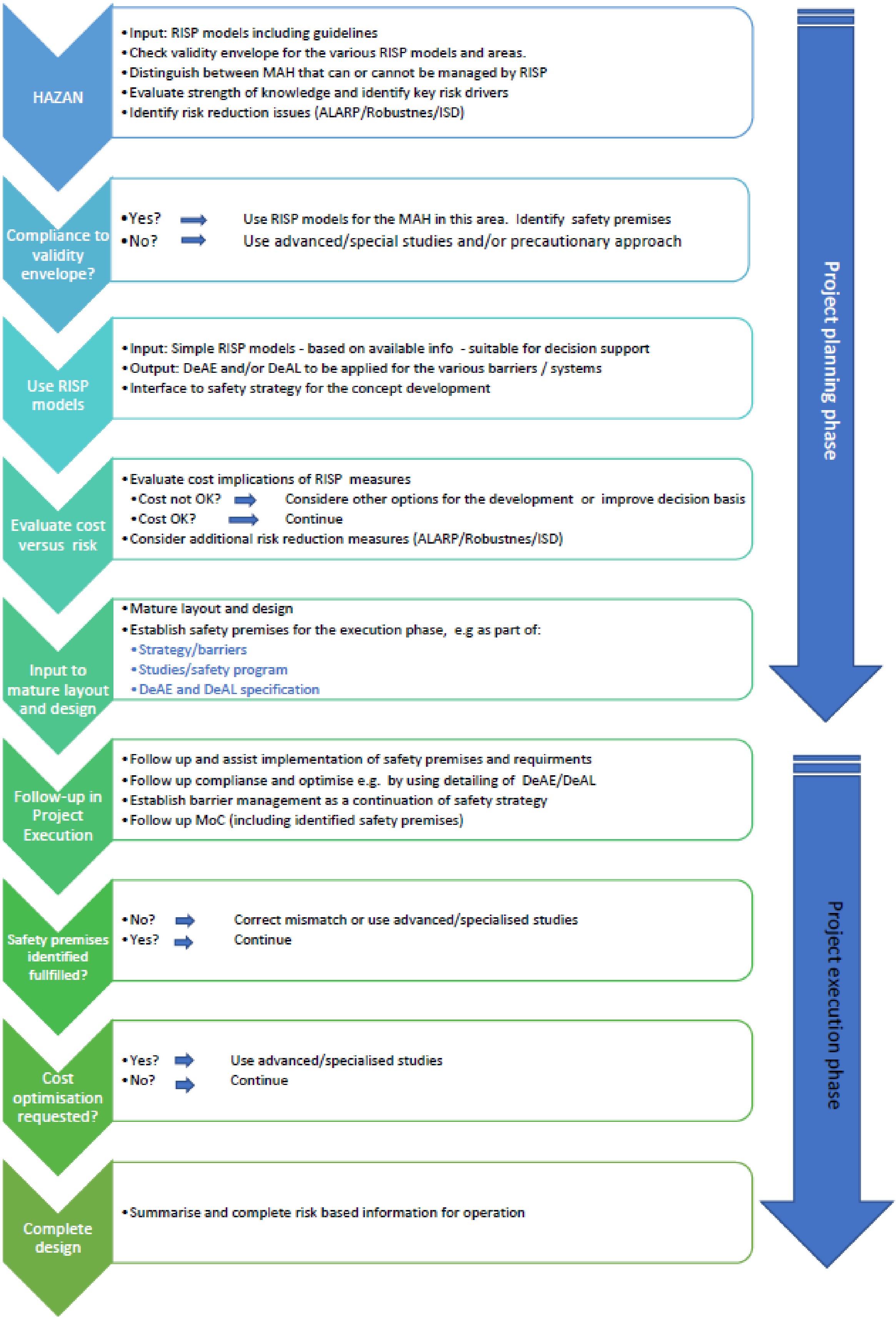

Figure 4 – Workflow using RISP methods and models - illustration

3.5 Type of decision support provided by RISP models

The need for decision support in development projects has been collected based on the experience of the RISP participants as well as by workshops and communication with engineering and oil companies.

It is found challenging to extract single decisions made at a specific time in the design process. The design process more typically implies a lot of dependencies and iterative work in decision making. A main task during Project Planning phase is to establish the technical basis for the subsequent Project Execution phase. The design premises (in addition to requirements given in regulations, standards and good practices) for handling of MAH should as far as possible be established in the Project Planning phase.

Decisions made in the Project Planning phase with respect to MAH will, have to include safety margins to avoid later changes unless a very strict management of change strategy is implemented. The extent and quality of the work in the Project Planning phase is hence crucial to obtain valid design premises that are not overly conservative. During Project Execution phase a main task is to detail the safety premises for implementation into design and to follow up effect of changes. It is expected that in many projects the design premises, detailing of the premises and way of implementation of the premises, will be challenged from a cost optimisation point of view. This may imply that the validity envelope of RISP is challenged and that other risk assessment techniques are applied for decision support. The focus for RISP is primarily to establish safety input and premises for handling MAH in a proper and efficient manner at the right time. As the concept, layout and technical basis for Project Execution phase are to be established in the Project Planning phase, the screening of decision support performed has focused on this phase.

The design accidental load specification normally plays a key role in design requirements related to MAH, especially related to survivability requirements. A main task for the RISP workgroups has hence been to establish models for recommending design accidental events and loads and the application of the loads.

It is acknowledged that the NORSOK S-001 2018 edition, is a key document providing design premises related to MAH. The standard contains both prescriptive and functional based requirements to the performance required for safety barriers/-systems. It is concluded that compliance to this NORSOK standard shall be a premise for the RISP methods and models.

The RISP methodology aims at contributing to accountability of decision makers for decisions affecting MAH. It is judged that that this can be achieved by providing simplified and transparent information that makes decision makers:

- understand importance of decisions being made,
- understand effect of decision on vulnerability and robustness and
- understand safety premises related to the decision.

The intention has been to provide the following results relevant for MAH by use of the RISP models:

- Recommended Design Accidental Events and Loads (DeAE and DeAL)
- Description of key/critical risk drivers and their:
  - importance for DeAE, DeAL and robustness
  - effect on layout and design solutions.
- Premises for use of standards, e.g. NORSOK S-001, rev 2018
- Input to extended HAZID i.e. the HAZAN including:
  - Check list for topics to be evaluated in the HAZAN
  - Description of validity envelope for the RISP models.
  - Design recommendations for handling of the MAH

3.6 Sample of RISP models

Table 1 presents some samples of RISP models established with key characteristics. The table is included to illustrate type of solutions for various models. This includes whether the hazard is a design event or not (DeAE/DeAL), how the scenario is specified and corresponding survivability requirements for key safety barriers. A complete presentation of the RISP models established are given in WG 2, 3 and 4 reports. For explosion there is an ongoing work to establish a RISP model (Ref. /4/).

Table 1: Samples of RISP models established.

Hazard	Key model	Comment
Ignited process fire	- Structural integrity (including secondary structure): DeAE = WCPF. Method to establish DeAL and potentially generic loads. - Escalation to process equipment: DeAL – 250 kw/m^2 for 2 minutes (no escalation) and 350 kw/m2 for 15 minutes (no escalation causing > 30 kg/s). - Global main safety functions (escape routes, evacuation means, muster area): DeAE 30 kg/s. Duration 15-60 minutes.	- Initial fire > 30 kg/s: Estimated annual frequency of 0.7 x 10^{-4} per year for a large process module. - Typical WCPF for structural integrity in a naturally ventilated module: 5-30 kg/s
Ignited riser fire	DeAE: Ignited leak in any of the riser segments that will give the worst fire exposure of the main load bearing structures, safe area and evacuation means.	- DeAE covers annual fire frequency levels between 1 x 10^{-5} and 1 x 10^{-3} - ESD valves and SSIVs can be credited as segregation for the riser segments. The closure time needs to be reflected regarding heat loads and duration. This presumes the valves are treated as safety systems with testing and performance requirement (typical reliability level of 98 % or higher). This implies that the valves have requirements for closing time and internal leak that are verified through testing. - The assessment of DeAE shall include possible escalations (to other risers, wells, and/or process equipment). - Main load bearing structure shall be intact to ensure escape to safe area and time for evacuation. Default time for evacuation is set to 60 minutes but should preferably be based on installation specific considerations. - Safe area/mustering area shall be intact and functional to allow time for evacuation. Default time for evacuation is set to 60 minutes but should preferably be based on installation specific evaluations. - Evacuation means for minimum 100 % of maximum manning onboard at any time shall be available for evacuation. Requirements for availability of an extra lifeboat for redundancy, shall also be included. The evacuation means shall be available from 15 minutes after onset of the DeAE until evacuation can be considered complete. For bridge connected installations the

Hazard	Key model	Comment
		requirement can be fulfilled by availability of the bridge. - The applicable fire loads can be established by CFD tools or conservatively applying simpler methods (e.g. as described in NORSOK S-001). - The DeAL shall reflect/cover loads from at least 90 % of representative scenarios (DeAE) within each leak size category for each riser segment. The 90 % requirement is stated to cover variations in weather conditions, leak location, leak direction etc.
Ignited blowout	DeAE: Long lasting ignited blowout in all areas of topside except mud/module/shaker room (Subsea ignited blowouts not a DeAE). Fire rate to cover up to maximum blowout rate (Default value up to 100 kg/s).	- DeAE covers annual fire frequency levels between 1×10^{-5} and 1×10^{-4} - Main load carrying capacity to consider typically 5-30 kg/s - Other main safety functions to consider maximum rate (100 kg/s)
Collision from passing vessels	Not a DeAE	- Presumes compliance to traffic surveillance, alert and evacuation procedure (NORSOK S-001, section 25) - Presumes installation location away from traffic separation scheme (TSS), at least half of the width of TSS. - Important to do a Vessel traffic survey of AIS data and assess degree of operational barriers in place.
Collision from supply-vessel – Manoeuvring from standby position to operating position	DeAE: Head-on collision with larges vessel with impact speed of 4 m/s.	- Presumes compliance to G-OMO-procedure - Presumes waiting position for vessel to be downwind the facility
Collision from supply-vessel – Manoeuvring at operating position	DeAE: The corresponding speed in head-on collisions with largest vessel shall be 0.5 m/s and 3.0 m/s for ULS and ALS checks respectively.	- Presumes compliance to G-OMO-procedure - Presumes loading position to be downwind the facility
Crane boom fall	Not a DeAE	- Crane boom fall can be expected with a frequency of no more than 5×10^{-5} per platform year. - Crane boom fall should be considered as part of ALARP process. Guidance is given on protection energies and layout

Hazard	Key model	Comment
Dropped object impact on seabed arrangements	DeAE: Probabilistic model given a drop of the lifted load over sea. Pipelines must survive impact from 95% of all loads.	- A 95% survivability corresponds to an average annual fire on sea frequency in the order of 5 x 10^{-5}
Accidental heel	Accidental heel is a DeAE on floaters. Credible heel scenarios shall not cause a static heel exceeding 17 degrees. Static heel to be combined with 1-year weather condition giving dynamic roll and pitch as calculated for the installation.	- Presumes design according to regulations and standards. - Consequences of DeAE needs to be assessed and survivability requirements for safety systems to be defined.

4. Regulatory framework and standards

WG 5 has considered the outcome of WG 1, 2, 3 and 4 reports and evaluated where there may be a mismatch/conflict between the proposed methodology and the requirements given in the existing regulatory framework, including standards referred to in the regulations. The task has primarily been to identify needed changes, if any, to be able to implement the RISP methodology.

Since WG 5 is based on all previous work packages, also topics relevant for the overall scope for the RISP project is commented by WG 5 when found relevant and appropriate.

Key conclusions are summarised below:

- The regulative regime is ambitious and includes functional based requirements. The regulations have not explicitly expressed requirements for quantification of risk numbers. Hence, no direct conflict or mismatch has been found between the RISP methodology and the regulations. Although the regulations can be interpreted in different ways, the PSA underlines that it is a task for the responsible parties to establish practices that are compliant to the regulations and suitable for the industry.
- The regulations refer to several standards of good practice that relates to management of MAH and for proper safety design. These standards have included the concept of risk quantification to various levels. Alignment between the standards and the results provided by the RISP methodology may hence be beneficial to consider.
- The regulations refer especially to NORSOK Z-013 for the requirement that loads/actions with an annual likelihood greater than or equal to 1×10^{-4}, shall not result in loss of a main safety function. This has been interpreted as a quantitative requirement by the industry. Likewise, the practice related to probabilistic explosion analysis included as informative materiel in NORSOK Z-013, has been included as a best practice by operators. It is concluded that this standard should be updated to better stimulate good practices for use of risk assessment techniques and management of MAH for decision support. The RISP methodology as a way of documenting prequalified solutions should be a part of this update.
- The NORSOK S-001 2018 edition, is a key document providing design premises related to MAH. It is concluded that compliance to this standard shall be a premise for the RISP methods and models. The standard describes parts of management of MAH which is not well aligned with the RISP methodology. Also, the word should, is used a lot in the standard to describe “a suggested possible choice of action deemed to be particularly suitable without necessarily mentioning or excluding others”. This causes some uncertainty to what is required to be compliant to the standard and to the regulations. These challenges need to be considered when applying the RISP methodology in development projects.
- The regulations give ambitious requirements for continuous improvement and risk reduction. These requirements are challenging to fulfill. It is judged that both quality and efficiency in management of MAH may be improved by establishing suitable best practices.
- The RISP methodology can play a role and be part of a good practice for management of MAH. The methodology is judged suitable to provide valid decision support at the right time during development projects. Strong focus needs to be put on the HAZAN, both the methodology and involvement of stakeholders and subject matter experts in the work process.

5. Summary, conclusions and recommendations

5.1 Summary and conclusions

This report presents the Joint Industry Project (JIP) called risk informed decision support in development projects (RISP). The project has been carried out in 2018 and 2019. The project has further developed, and concretised principles and ideas provided by a former NOROG project into new methods and models. The project is related to management of major accident hazards (MAH) in development projects on the Norwegian Continental Shelf (NCS).

The project has screened the risk informed decision support needed in typical development projects. Risk assessment methods and models have been established suitable for decision support based on information available when the decisions are normally taken. The recommendations given by the models are considered robust as to avoid the need to reiterate the decision based on more detailed information available at a later stage provided premises for the decision are not changed.

The methodology established is based on the risk-based decision-making framework given by ISO 17776 which differentiate the assessment techniques dependent on the complexity of the development project. The methods and models established are valid for proven design where prequalified solutions can be applied.

As far as possible the methodology is based on design requirements given by standards. It is acknowledged that NORSOK S-001 is a key standard in this respect.

The methodology has been reviewed in relation to the present regulative regime to identify possible conflicts and need to update regulations and standards. The regulative regime is ambitious and includes functional based requirements. The regulations have not explicitly expressed requirements for quantification of risk numbers. Hence, no direct conflict or mismatch has been found between the RISP methodology and the regulations.

Reflections based on the performed work includes:

- Although management of MAH in the Norwegian oil industry has been successful, there is an obvious potential to improve both quality and efficiency in application of risk assessment techniques as decision support in development projects.
- A considerable maturation of views on the RISP principles and ideas has taken place among the participants during the execution of the RISP project. Clearly it has been different views on the degree of the challenges with the present practice, the causes of the challenges and on the best solutions.
- The ambitions of the RIP project have been large and the complexity of the tasks and project organisation considerable in comparison to the resources available for execution of the project. As must have been expected, the ambitions of the project are not fully completed, and thus for some of the methods and models further work is needed.
- Methods and models for risk-based decision support in development projects have been established. A workflow for use of the RISP methods and models has been established to support management of MAH. The extended HAZID called the HAZAN is an important part of the workflow. The models established covers a number of hazards, both those which can be managed primarily by following design standards and those requiring simplified assessments models. The assessment models established focus on establishing design accidental scenarios and loads (DeAE and DeAL) and corresponding requirements for survivability of safety barriers.
- A set of requirements has been defined for the RISP methods and models (see Chapter 2.4). The requirements are fulfilled to various degrees for the different models. A review of the models from subject matter experts as well as by potential users of the models would be beneficial to identify improvement areas. During the work performed, different perceptions amongst experts have not been documented. Further, the basis for the models are only partly documented and available for review. How to assure that models remain updated over time has not been answered. However, in order to comply with the expectations in the

regulations, the RISP models must be placed in a context of continuous improvement, and this context should be owned by the operators (as the responsible party) in terms of overseeing the use of models and identify an initiate improvement actions when deemed necessary.

- The ambition to assure at least the same safety level as present practice is considered achieved within the validity envelope of the models. This is obtained by a conservative approach regarding the scenarios, loads and survivability requirements included.
- The decision support provided by the methods and models are considered to give the essential input needed during development projects – especially during planning phase for proven design.
- The PSA is positive to and support the initiative taken by the industry in this project. They pinpoint the ambition to be world leading related to HSE and the requirements for continuous improvement, robustness and risk reduction. The regulation includes functional requirements, it is a task for the industry to establish good practices for compliance.
- Topics covered to less degree in the present RISP project includes:
  - Measures to reduce the likelihood for an incident to occur
  - Methods and models to use outside the validity envelope of RISP
  - Best practices for management of MAH within development projects
  - Risk based decision support in operations

5.2 Recommendations

A new methodology replacing traditional quantitative risk analysis with simplified experience-based methods for improved decision support in development projects has been outlined and substantiated in this report. In order to qualify the new RISP methodology and improve its ability for risk-based decision support in development projects, the following recommendations are given for the SC members to consider:

1. Through the JIP execution, considerable maturation and consolidation has been achieved among the RISP participants. The common understanding of context and basic ideas for the RISP methods and models has been improved along the way of the project execution. For a successful implementation and use of the RISP methodology, it is recommended to continue and extend the effort on anchoring the methodology with important stakeholders, including authorities, union representatives, operators, engineering, consultants and subject matter experts.
2. Although a considerable effort has been made to establish the RISP methods and models, it is recommended to evaluate the need for additional work to make them qualified and ready for use. Topics to consider include:
   a. Establish a precise description of the validity envelope for the methods and models
   b. Assure that the RISP methods and models are based on best available knowledge, documented to show compliance to the 10^{-4} criteria and fulfilling risk reduction requirements (such as ALARP/ISD/BAT/Robustness).
   c. Assure that required input to topics for the HAZAN is established and identified
   d. Assure that valuable design recommendations are captured and provided where relevant for the different hazards.
3. The regulations are ambitious regarding management of MAH and requirements for continuous improvement, robustness and risk reduction. The requirements are generally functional based, and it is a task for the industry to establish good practices for compliance. In the same way as it is a potential for better methods and models for risk-based decision support, it is judged valid to stimulate improved management of MAH within the development projects This includes work

practices within the project organisation, scoping of risk assessment work and anchoring of relevant decisions. Although the requirements are functional based and complex, it should be an ambition to establish simple practices that are compliant with regulations. Hence, it is recommended to establish best practices for management of MAH. The PSA document "Integrated and unified risk management in the petroleum industry" as well as present various procedures applied by operators and contractors are considered to give valuable input to the context for such practices. The practices could include:

  - Practices for risk reduction. A key aspect will be how to assure efficient integration into the normal design development.
  - Practices for how to include robustness into design
  - Practices for barrier management in development projects. The practice may reflect the need to assure that required barriers are included in the technical basis for the design during Project Planning phase (e.g. as part of safety strategy) while more detailed performance requirements are established in the Project Execution phase.

4. Based on experience from performed projects, it has been expressed that requirements for verification activities at the as-built stage are important to assure high focus and commitment on HSE aspects during project execution. As the practice of as-built QRA/TRA is not part of the RISP methodology, it is recommended instead to consider implementing verification at the as-built stage that all identified safety premises for the design are fulfilled.
5. The focus of the JIP has been on decision support needed in development projects. The need for decision support in the operational phase has not been considered as part of this JIP. The idea for the RISP methodology is that barrier management should be governing for the risk management in the operational phase. Traditionally, the QRA/TRA with comprehensive and detailed risk assessment, has been used as a basis for the barrier management. It is recommended to perform further work to evaluate how the needed and required risk picture should be established as a basis for management of MAH and barrier management in the operational phase.
6. It is recommended to update the NORSOK Z-013 standard to reflect the RISP methodology and establish best practices for use of the RISP methods and models. The updated standard should reflect the risk related decision-making framework in ISO 17776 and the PSA definition of risk and risk reduction. The standard should be more open for different approaches to risk assessments including required risk assessments for prequalified solutions.

6. References

/1/ Norsk Olje & Gass (NOROG): Prosjekt «Formålstjenlige risikoanalyser» Resultater og forslag til videreføring, Versjon: 6. februar 2017

/2/ ISO 17776: "Petroleum and natural gas industries – Offshore production installations – Major accident hazard ", Second edition dated 15.12.2016.

/3/ Petroleum Safety Authority Norway, "integrated and unified management in the petroleum industry", dated June 2018.

/4/ DNVGL and Aker Solutions: "RispEx – decision support for explosion design loads", DNVGL report no 2019-1329. Not yet issued.