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Uncertainties in a risk management context in early phases of offshore petroleum field development

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A R T I C L E I N F O

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A B S T R A C T

The current risk management approach for the Norwegian offshore petroleum industry came into effect in 2001 and has been stable with minor changes for 15 years. Relatively few new installations were slated for development until quite recently, and several new projects have been started in the last few years. The paper considers the risk management approach in the pre-FEED phase and builds on two case studies selected from the most recent cases. These case studies have been evaluated with respect to how uncertainties are considered in the early phase, based on the submission of the Plan for Development and Operation, their evaluations by authorities and the supporting documents. Both case studies involve new concepts for which there is no experience from similar environments and/or water depths. In spite of what could have been expected, the case studies conclude that uncertainties have not been in focus at all during concept development. This appears to be definitely the case for the licensees, but also to be the case for the authorities. Some suggestions are presented for what could have been considered by the licensees and authorities.

1. Introduction

The Norwegian Health, Environment and Safety (HES) risk management approach for offshore installation concepts in the early (pre-FEED) project phases builds on the principles of Framework and Management regulations (PSA, 2014c, 2014d). This implies that risk levels shall be within the risk tolerance limits and that further risk reduction shall be sought for and implemented in an additional effort when the risk levels have been reduced to tolerable levels. In addition are some prescriptive requirements in the regulations, such as lifeboats to be of the freefall type (PSA, 2014b).

The definition of risk in petroleum regulations has focused on the uncertainty dimension of risk for some time, reflecting the (A, C, U) perspective as defined by Aven (2013b). In mid 2013, the Petroleum Safety Authority (PSA) (PSA, 2013b) published proposed changes to the regulations whereby the uncertainty dimension is given more emphasis. PSA argues in its proposal that it is important to focus on uncertainties in order to facilitate evaluations of uncertainty and that decisions about risk reducing measures can be made on as explicit a basis as possible. The intention with the revisions is to support this aim.

The current set of regulations came into effect from 2001, and changes since then have been cosmetic as far as offshore installations are concerned. One example of such changes is the proposal mentioned above, which, although it focus on an essential element, can be classified as 'cosmetic'. In the 10-year period from 2001, there were few new offshore installations slated for development and put into operation. At the same time, exploration activities on the Norwegian Continental Shelf (NCS) during the last few years have been highly successful, and several new fields and installations are currently being planned (pre-FEED phase) or have reached FEED or engineering phases. It is, therefore, a good opportunity to consider how the requirements from 2001 are being fulfilled in practice in the early phases.

It is often claimed, especially by authorities, that the early phases of field development give the best possibilities for cost-effective risk reduction. It is, therefore, particularly important that the ALARP (As Low As Reasonably Practicable) or risk reduction approach is effective and gives the lowest practical risk levels in the early phases. This is an important aspect but is considered outside

Abbreviations: ALARP, As Low As Reasonably Practicable; DNV GL, Det Norske Veritas – Germanischer Lloyd; EIA, Environmental Impact Assessment; EU, European Union; FAR, Fatal Accident Rate; FEED, Front End Engineering and Design; FPSO, Floating Production, Storage and Offloading [system]; HC, Hydrocarbon; HES, Health, Environment and Safety; HSE, Health and Safety Executive; NCS, Norwegian Continental Shelf; NOU, Norwegian Official Whitepaper; NPD, Norwegian Petroleum Directorate; PDO, Plan for Development and Operation; PRA, Probabilistic Risk Assessment; PSA, Petroleum Safety Authority [Norway]; QRA, Quantitative Risk Analysis.

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the scope of the present paper. A separate paper is focused on this aspect (Vinnem, in press).

One of the limitations of the discussions of pre-FEED risk management (Vinnem, in press) has been the lack of documentation available in the public domain, except for documents in relation to Environmental Impact Assessment (EIA). The present work has had access to documentation outside the public domain through cooperation with PSA in order to have insight into documentation and evaluations that cannot be revealed to the public due to commercial considerations. The obligation of the author is to not divulge aspects of any commercial sensitivity, and to discuss the relevant aspects in a generic sense. Case studies are, therefore, discussed anonymously.

The two case studies are fields in medium and ultra-deep water areas in the northern Norwegian Sea and in the southern part of the Barents Sea respectively. Both concepts are floating production installations of a type that has never been installed on the NCS, but there is significant experience with the relevant concepts in other offshore regions. Both structures are due to be installed in the Norwegian sector within the next few years.

It should be observed that one of the characteristics of the pre-FEED phase is that some of the decisions may relate to a choice of unconventional concepts or solutions. Typically, this could include the choice of unconventional structural concepts, for instance a concept, which has not been installed in the same geographical area before but which may be ‘proven’ in other geographical areas, often less hostile environments. Uncertainties will thus exist about whether unknown mechanisms may apply in new geographical areas, or whether unknown responses may occur based on environmental loads, which are outside what there is experience with from other areas. These could be classified as ‘unknown unknowns’.

All structural concepts are subjected to extensive model testing before being sanctioned for development. The purpose of such model tests is to establish what structural loads and responses will be expected for the concepts. Such model tests are usually carried out in relatively small scales, say typically 1:100 and sometimes up to 1:50 or down to 1:200. It is well known that scaling laws of model tests may be a potential source of some uncertainty for new concepts where there are no operational data available for calibration of the parameters of scaling laws.

It is also well known (Moan, 2009) that the use of large diameter offshore structures has led to surprises due to a new phenomenon (called ‘ringing’) that was not observed in model tests (or at least was not interpreted from the model tests) and is caused by nonlinear mechanisms of wave action and response. At least in one case, this phenomenon was not observed until the structure had been in operation for a few years. Thereafter, it could be confirmed by model tests. Parameters for scaling laws can only be determined through comparison of full scale and model scales in such cases.

With these findings as a background, it should not be ruled out that new structural concepts may experience some unknown mechanisms and responses that could not be determined from model tests, especially with the present two case studies, which involve considerably larger diameters than those of any other structures installed so far in these hostile environments.

There are also several other novel aspects in these two cases, including engineering contractors that have never performed detailed engineering work for the NCS. This is addressed in more depth in relation to the case studies.

The importance of such uncertainties is related to cost as well as to major accident risk. If unknown phenomena are revealed after a structure is installed and put in operation, there may arise a need for significant modifications or reinforcements, which may have significant cost effects. There could also be severe operational restrictions that could have significant cost effects. Modifications implemented in the offshore location are often very costly. If the phenomena are not revealed proactively they could, in extreme cases, be the source a structural collapse with very severe consequences. The capsizing of the flotel Alexander Kielland (Vinnem, 2013) in 1980 is, to some extent, an illustration of such a mechanism, although it may be argued that the failure mechanism was not unknown in the Kielland case. Rather, the existence of construction defects was the unknown factor.

1.1. Regulatory context

Norwegian regulatory requirements, compliance with the requirements and the authorities' response are the main topics of focus in the present context. The relevant regulatory requirements are the following:

- Need to formulate risk tolerance criteria, including overall criteria for personnel on the installation and for personnel groups, according to Section 9 in the management regulations (PSA, 2014d).
- Carry out risk analysis studies in order to demonstrate that the concepts and solutions give risk results that are in accordance with the risk tolerance criteria, according to Section 17 in the management regulations (PSA, 2014d). Section 17 also has a requirement to consider sensitivities and uncertainties.
- Implementation of risk reduction processes (‘ALARP processes’), according to Section 11 of the framework regulations (PSA, 2014c).
- Need to work for continuous improvement in all operations, according to Section 23 of the HES management regulations (PSA, 2014b).

These requirements present a somewhat extended regulatory framework for the case studies. The strict regulatory reference is the requirement to implement risk reduction processes according to Section 11 of the framework regulations. The requirements mentioned above have all been virtually unchanged since 2001, whereas the two first requirements, in essence, have been applicable since 1992. Finally, the proposed added focus on uncertainty is planned to be adopted as a regulation from 2015, according to present knowledge.[1]

It should, nevertheless, be considered that the requirement to consider uncertainty is not a new regulatory requirement; it has been a requirement in the regulations for several years. Thus, the industry and authorities have had a requirement to consider uncertainties in relation to the management of major hazard risk for a long time, but this obligation has not been particularly focused on. The new wording implies an increased focus. The industry is presently querying how this should be implemented. The authorities issued a guideline document for preparation of the Plan for Development and Operation (PDO, PSA, 2010) over 10 years ago; it has not been updated recently. This document mentions uncertainty in relation to cost and resource estimations but not in the context of risk management as discussed in the paper.

There may be several sources of uncertainty, particularly in an early development phase. New phenomena (often referred to as ‘unknown unknowns’, see Aven, 2013b) are definitively one source of uncertainty about what may occur that may threaten the safety of an installation. But information may be available scientifically but still not be considered in a risk assessment due to inadequate hazard identification or other faults. Some mechanisms may even be known by a risk assessment team but neglected. There is some debate about whether such should be considered ‘black swans’ or

[1] To be updated before publishing.