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Does the 2024 version of the NORSOK Z-013 standard bridge the gap between risk assessment practice and contemporary risk science knowledge?

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Abstract

The relationship between theory and practice is thoroughly discussed in the scientific literature, including the field of risk. Research has revealed that a considerable gap exists between applied risk assessment and management and contemporary risk science knowledge. This paper examines the NORSOK Z-013 (2024), a recently updated standard primarily aimed at the Norwegian petroleum industry to meet the regulatory requirements for risk and emergency preparedness assessments. Since the previous version of the standard, a considerable shift has occurred in how the Norwegian petroleum authorities define and understand the risk concept, from a traditional probability-based perspective to a broader perspective highlighting uncertainty as a main component of risk. This conceptual change coincides with the uncertainty-based risk perspective described in the scientific literature. It is thus interesting to scrutinize and discuss new elements related to risk assessment in the revised NORSOK Z-013 standard compared to its previous version. The analysis aims to study how the new risk perspective is reflected in the changes and assess the alignment of the new version with fundamental risk science knowledge.

Keywords: NORSOK Z-013, risk science, risk assessment, theory-practice gap, Society for Risk Analysis, uncertainty-based risk perspective

1. Introduction

A mismatch often occurs between practice and theoretical development. This is often referred to as the "theory-practice gap" in the scientific literature. Many theories attempt to explain this gap, and previously discussed reasons for its existence include ignorance of new theories, cultural lag, and resistance to change (see, e.g., Arteaga et al. 2024; Roth et al. 2014; Greenway et al. 2019). A recent paper addresses this theory-practice gap in a risk analysis context, discussing why it is prevalent, the importance of closing it, and strategies for achieving this. It is argued that closing the gap will improve safety levels by enhancing the practical application of concepts, principles, and methodologies for understanding, assessing, communicating, and managing risk (Aven 2023). The present paper extends this work by examining current risk analysis practices in the Norwegian oil and gas industry more closely and discussing the extent to which they reflect contemporary risk science knowledge.

In discussing the theory-practice gap in this context, the present paper leans on work by the Society for Risk Analysis (SRA). The SRA is a global risk-researching community, and between 2013 and 2017, it conducted a project involving many senior risk scientists to clarify key risk analysis concepts and issues. The project resulted in different white papers, including (i) a glossary for risk-related terminology (SRA 2018A), (ii) core subjects of risk analysis (SRA 2018B), and (iii) fundamental principles of risk analysis (SRA 2018C). Later, SRA published a document covering various tests to evaluate the quality of risk analyses that support risk management decisions (SRA 2021).

In parallel with the development of the SRA white papers, the Norwegian Ocean Industry Authority (Havtil) started a process to adopt the conceptual ideas emerging from the scientific community in their regulatory requirements. In 2015, for instance, Havtil changed the definition of risk in the regulatory requirements from a traditional probability-based definition to a broader definition highlighting uncertainty as a main component of risk. The main reason for this change was to increase awareness of uncertainties and potential surprises not easily addressed and communicated by purely probabilistic risk assessment approaches (Røyksund and Engen 2020). However, it initially remained unclear how the petroleum industry should integrate an uncertainty-based risk perspective into practical risk management to align with regulatory expectations. Consequently, various joint industry projects emerged in the following years, such as “the Black Swan Project” in 2017 and “the Risk Informed Decision Support in Development Projects (RISP)” in 2019, to address the practical implications of the conceptual change. The authorities also published several memorandums and initiated various projects covering different risk-related topics that have influenced how regulated companies practice risk management (Røyksund and Engen 2020). These examples show how different actors in the petroleum industry incorporated a new risk understanding into practice following the updated regulations. However, the key risk analysis standard for facility design and operation, NORSOK Z-013:2010, was not revised until 2024. This standard is a cornerstone in the Norwegian petroleum context, making it highly relevant to examine when studying the theory-practice gap.

The NORSOK standards were established in 1994 to ensure compliance with regulatory safety requirements, value-adding in petroleum activities, and cost-effective development projects and operations. The standards are developed in tripartite cooperation between experts from employers’ organizations, employee unions, and the government. The NORSOK Z-013 standard, the subject of this paper, is referenced in the regulations as a viable means of meeting the regulatory requirements for risk and emergency preparedness assessment (*The Management Regulations* 2018). In 2024, this standard underwent a major revision from its 2010 version, including key concepts and methods for assessing and handling risk. An important motivation for the work was promoting flexibility in how risk is assessed and characterized, enhancing the value of the assessments as timely decision support in design and operations (Sandøy 2023).

This paper scrutinizes and discusses new elements in the revised NORSOK Z-013. The analysis aims to study how the uncertainty-based perspective of risk is reflected in the changes and to assess the alignment of these changes with fundamental risk science knowledge. As such, this study provides insight into the status of the theory-practice gap in risk analysis, as well as providing feedback to the scientific community about how generic risk science is understood and applied in practice. Two research questions have been formulated to guide the work:

(i) What are the key changes in risk-related concepts and methods in the NORSOK Z-013:2024 compared to NORSOK Z-013:2010?

(ii) To what extent do these changes reflect contemporary risk science knowledge?

Our analysis begins by systematically comparing the 2010 and 2024 versions of the NORSOK Z-013 standard. Due to the comprehensiveness of the standard, the analysis is not all-inclusive. Instead, we have aimed to highlight the most substantial developments from a generic risk science perspective, using the core subjects of risk analysis from the SRA (2018A) as our main themes. Of particular focus are the themes “fundamentals,” “risk assessment,” and “solving risk problems and issues.” We then compare the development identified based on these themes to the guidance provided by the SRA (2018A, B, 2020) and related scientific research.

The paper is structured as follows: Section 2 reviews the key changes from the 2010 to the 2024 version of the NORSOK Z-013 standard. Section 3 further discusses the identified changes based on contemporary risk science knowledge before concluding remarks are provided in Section 4.

2. Review of the Development in NORSOK Z-013 From 2010 to 2024

This chapter presents the key findings from the document review and is organized into three sections: 2.1 General development features, 2.2 Risk fundamentals, and 2.3 Risk assessment methods.

2.1 *General development features*

First, as mentioned in the introduction, the 2024 revision of the NORSOK Z-013 standard reflects an upgrade and alignment with recent developments in Norwegian petroleum regulations and industrial risk management practices. Compared with the 2010 version, this includes changes in the definitions of basic risk concepts and approaches and methods for assessing and describing risk.

A core change is the emphasis on ensuring that risk assessments and management practices during project development are efficient, timely, and expedient for decision-making support to warrant "safe and robust designs." Different strategies and methods for assessing risk are required to achieve this, depending on factors such as the project phase, the complexity of the risk problem, and the degree of available knowledge. This approach was adopted from the 2019 RISP report, a joint industry project in Norway from 2018–2019. Briefly, the RISP framework addresses the shortcomings of traditional quantitative risk analysis (QRA), which dominated the practices of the oil and gas industry. QRAs are often detailed, comprehensive, and time-consuming, requiring analyses to start from scratch even when solutions are well-known (JIP 2019). The new methods introduced in RISP aim to improve the analysis of major accident hazards (MAHs) using best practices and recommendations where proven designs and prequalified solutions can be applied. The RISP framework leverages knowledge and experience from past projects and analyses to ensure a robust safety level (JIP 2019).

Several methodological changes are suggested compared with the 2010 standard version. For instance, the recent revision now suggests predefined descriptions for assessing typical MAHs and introduces new methods for assessing the risk uncertainties. Moreover, the standard places less emphasis on risk acceptance criteria and has also departed from its previous use of the risk matrix to visualize the results from the risk assessments. The following two subsections elaborate on these changes.

2.2 *Risk fundamentals*

Consistent with the first research question, we have examined how the definitions and understanding of key risk-related concepts have evolved between the two versions of the NORSOK Z-013. As mentioned, the revised standard builds on an uncertainty-based risk perspective, representing a broader view of risk compared to the probabilistic risk approach of its predecessor. Consequently, a working hypothesis is that the term "risk," along with associated concepts, such as "uncertainty," "probability," and "knowledge," has been modified in the latest edition, as these are core concepts in the uncertainty-based risk perspective.

As shown in Table 1, the explanations of these four concepts have changed significantly.

Table 1. A comparison of risk concepts in the 2010 and 2024 versions of NORSOK Z-013

NORSOK Z-013:2010	**NORSOK Z-013:2024**
RISK	
"a combination of the probability of occurrence of harm and the severity of that harm"	"consequences of the activities, with associated uncertainty"
PROBABILITY	
"May be expressed as a probability value (0–1 dimensionless), or as a frequency, with the inverse of time as dimension"	"Can be used as a measure for representing or expressing uncertainty, variations or beliefs, following the rules of probability calculus"
UNCERTAINTY	
No definition is provided, but the standard requires the effect and level of uncertainty to be discussed, given the risk perspective adopted.	"Not knowing the true value of a quantity or the future consequences of an activity, including imperfect or incomplete information or knowledge about a hypothesis, a quantity, or the occurrence of an event". Aleatoric and epistemic uncertainty are distinguished.

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Mentions several places without a clear definition, e.g., General requirements for establishing the risk picture (…) Occurrence of unexpected outcomes due to invalid assumptions and premises or insufficient knowledge.	Closely related to uncertainty. Strength of knowledge (SoK) is included and is important to account for when choosing solutions, barriers, and robustness of design. SoK assessment is related to how well hazards are understood.

Essentially, the definition of risk is modified in the revised version of the NORSOK standard, emphasizing uncertainty as one of the core components of risk instead of probability. Probability is considered a measure for expressing variations and beliefs, including both frequentist and subjective approaches. This is a broader understanding of the probability concept compared to the NORSOK Z-013: 2010 version.

Regarding "uncertainty," the new version adopts the SRA (2018C) definition, relating it to unknown future events and quantities. Conversely, the former version appears to view it more as a limiting feature of the assessment results and conclusions. Finally, the term "knowledge" represents something new. While this term is vaguely mentioned in NORSOK Z-013:2010, the newest standard document now highlights the importance of considering the knowledge basis by assessing the strength of knowledge supporting the probability assignments when developing the design and making decisions during the project. As is further discussed in Section 3, the focus on knowledge, or strength of knowledge evaluations as part of the risk description, is consistent with recent developments in risk science.

2.3 *Risk assessment methods*

2.3.1 *Standardization of methods*

A key methodological change in the revised version is the introduction of methods for assessing typical MAHs, including hydrocarbon fires and explosions, toxic leaks, falling loads, and vessel collisions. Relevant descriptions of obtaining event probabilities, accidental loads, and consequences are provided. These new sections on methods should not be considered prescriptive; it is emphasized that other methods can be used Nevertheless, increased standardization between analyses is highlighted as desirable (p. viii).

2.3.2 *Introduction of simplified methods*

In addition to traditional methods centered on probability and risk quantification, the risk assessment method section introduces a set of simplified methods for analyzing several MAH types. These risk assessment methods are based mainly on the JIP (2019) and represent new ideas for making these assessments more effective for the Norwegian oil and gas industry.

The basic idea of the simplified methods is to first consider whether the project is similar to other established and well-known design concepts when choosing the appropriate risk assessment method. This approach aims to make the risk assessment more efficient and useful according to the overall design and development process. As such, the focus is on making relative risk judgments based on "proven" designs rather than obtaining new and extensive quantitative risk descriptions in the early phase of a project. For example, the risk associated with a certain MAH, like a "hydrocarbon explosion", for a proposed design may be expressed as being at least as low as for similar facilities in operation. From such a conclusion follow a pre-described method (RispEx) to establish dimensioning loads for hydrocarbon explosions.

The use of these simplified methods depends on the extent to which the considered situation can be regarded as "normal," that is, to what extent knowledge exists about the combination of the hazard, design concept, and environmental conditions. The concept of a "validity envelope" is introduced to formalize these types of judgments, specifying constraints and conditions under which the simplified methods and models can be applied. For the previous example, which includes dimensioning loads for hydrocarbon explosion in line with the RispEx method, the validity envelope specifies the requirements related to the overall concept (e.g., naturally ventilated area, only natural gas), maximum area dimensions, openness in area boundaries, and module confinement level.

In addition to the validity envelope, an extended hazard identification (HAZID) process is introduced. The added steps are referred to as HAZAN and include initial judgments about whether the various hazards can be considered "normal" based on the considered design or whether special characteristics and uncertainties make the simplified methods inapplicable.

2.3.3 *Introduction of methods for assessing uncertainty*

Apart from the assessment methods for typical MAHs, the new version introduces generic methods for assessing and characterizing uncertainties. Most notable is the method proposed for meeting the general requirement of a criticality assessment of the assessment assumptions. The proposed method is based on Flage and Berner (2018). It evaluates the criticality of the assumptions based on the sensitivity of the assessment results relative to deviations in the assumptions, the probability of such deviations, and the strength of knowledge (SoK) associated with the assumptions. The criteria for evaluating the SoK are defined with respect to aspects such as data reliability, expert agreement, accuracy of models, and the degree to which the assumptions represent simplifications.

Such SoK judgments are also included in the extended HAZID. The idea is that the judgments made during this process, linked to aspects such as hazard relevance, likelihood, potential development, and consequences, are supplemented with considerations regarding the associated SoK. The HAZID must be documented in a separate report and updated during the facility's lifetime. Updated knowledge may indicate that a hazard initially judged negligible in the design process is still relevant to include for further risk analysis.

The issue of uncertainty received minimal attention in the previous version of the standard (2010). However, a discussion on uncertainty was required, including the occurrence of unexpected outcomes due to insufficient knowledge or invalid assumptions. This version also included several requirements linked to the documentation and sensitivity analysis of assumptions.

3. A Risk Science Perspective on the 2024 Revision of NORSOK Z-013

This section examines the recent NORSOK Z-013 standard more closely in the context of contemporary risk science. Two main issues are discussed. The first is related to the extent to which the uncertainty-based risk understanding is incorporated throughout the standard. We then identify and discuss a few remaining potential gaps between theory and practice.

3.1 *Toward an uncertainty-based risk understanding*

No single, universally accepted definition of risk exists (Aven 2013). However, a noticeable trend among scientific communities is becoming apparent, as highlighted in the SRA glossary document (SRA 2018C). For instance, a growing consensus exists among risk scholars emphasizing a definition of risk incorporating uncertainty as a key aspect of the concept (Aven and Thekdi 2022).

As Section 2.2 outlines, the shift toward an uncertainty-based risk perspective is also evident in the revised NORSOK Z-013:2024 standard. In addition to the change in risk definition, we observe that the new risk understanding is largely integrated into all parts of the standard, including concepts, risk assessment methods, and risk management principles. Among the most prominent examples of a different approach is the introduction of SoK judgments and criticality evaluations of all assumptions as part of the risk assessments. According to Aven and Thekdi (2022), a main reason for including such additional evaluations is to improve risk understanding by revealing the basis of the probabilities, ensuring that decision-makers are better informed about the risks and uncertainties. For instance, if the risk assessment of event A is built on weak knowledge or the risk analyst has identified an assumption as critical, meaning that a change in a specific condition strongly influences the probability, this could have consequences for the design concept and should, therefore, be further considered.

A related concern emphasized in the updated standard is the importance of conducting risk assessments promptly to effectively support decisions in project development. The previous use of quantitative risk assessment methods in the petroleum industry has been criticized by the Norwegian supervisory authorities for being too "simplistic and mechanically executed," emphasizing the need to reflect on the use and appropriateness of these risk assessments (Røyksund and Engen 2020). The introduction of alternative and simplified methods for assessment, for example, MAHs, could thus be understood as an attempt to challenge current practices by promoting increased flexibility in the risk characterizations in a development project. The choice of method should follow from an evaluation of different factors, such as complexity and experience from similar projects. See Sections 2.3 and 3.2 for more details about the suggested risk assessment methods.

Compared to contemporary risk science, the SRA publications (2018B; 2018C) suggest similar flexibility in introducing various risk metrics/descriptions and risk assessment methods, indicating that no single risk metric/description and risk assessment method will best suit all types of risk problems. Moreover, the literature offers several examples of frameworks describing how various risk problems require different approaches for assessing and characterizing risks, as well as different strategies for managing them (see, e.g., Renn 2008 and Aven and Thekdi 2022). Although the flexibility element may not be directly linked to the modified definition of risk, it demonstrates how the practice field approaches risk science. The next subsection reflects more on these issues.

3.2 *Reflections on the theory-practice gap*

As discussed above, many of the changes made in NORSOK Z-013:2024 can be regarded as operationalization of the uncertainty-based risk perspective in the offshore energy setting. As such, the new version represents a significant contribution to bridging the gap between risk science and practice. However, this section further emphasizes aspects of the standard that appear more disconnected from the scientific discourse on risk analysis. We hope these observations can contribute to stimulating further discussion on the relationship between theory and practice within the field of risk.

Probability remains a key concept in risk and uncertainty characterization, and the scientific community has devoted much effort to clarifying its meaning and use in the risk context (SRA 2018A). Notably, NORSOK Z-013 alludes to the generic probability definition provided in the SRA glossary (2018C), defining it as a measure for representing uncertainties, variations, and beliefs but provides no further interpretations or guidance regarding risk assessment and communication. Hence, key risk metrics, such as the probability of loss of main safety functions, remain with no clear and standardized meaning, although the methods for obtaining the probability are increasingly standardized. The reason behind this lack of clarity in the standard has not been investigated as part of this work. However, the issue cannot be explained by a lack of available guidance and resources from the scientific community (e.g., SRA 2018B; C). One might question whether practitioners often perceive such conceptual clarifications as academic quirks of minimal practical relevance to the work done. Additionally, the emphasis in risk science on probabilities as a measure of the risk assessor's degree of belief may meet resistance in a technical environment emphasizing objective instruments and measurements. Nevertheless, the lack of conceptual clarity and guidance on interpreting and communicating probabilities suggests further efforts are required to convince the field of practice about the importance of this type of scientific knowledge.

The MAH is also a concept used in the standard with no clear grounding in the scientific literature. The identified MAHs are central to the standard's prescribed risk assessment process in the sense that these are the starting points for risk analysis, characterization, and management. The MAHs are identified in the initial stage of the risk assessment using formal workshops and processes involving various disciplines and experts. Yet, clear explanations of what a MAH is and how it relates to similar concepts such as risk sources, initiating events, and major accidents are not provided in the standard. The SRA glossary (2018C) is an example of a resource that would clarify these issues and, hence, the process of identifying and defining MAHs for specific designs and facilities.

The absence of a reference to the resilience concept in the new version of the Z-013 standard is also notable. This concept has had major significance and importance in the scientific literature on risk and safety in complex systems since the last revision of the standard in 2010. Much work has been devoted to clarifying the link and synergies between risk assessment and resilience assessment in managing unexpected and surprising events, including the SRA glossary (2018C).

As a final point, we emphasize the simplified risk assessment methods introduced in the revised standard. These methods are centered on making relative risk judgments based on familiar projects and designs, using previous risk analyses and assessments. This thinking resembles the so-called comparative risk assessments used for assessing fire risk in buildings (see, e.g., Standard Norge 2014; ABCB 2020). In these assessments, relative risk judgments are made for a new design based on a pre-accepted reference design. Although requirements-based and risk-informed risk management strategies have been discussed thoroughly for settings with low uncertainty (e.g., SRA 2018B), to the present authors' best knowledge, minimal scientific guidance exists on principles and methods for conducting such relative risk assessments. As such, we consider this an area where the field of practice in the search for suitable approaches and methods has generated a theory-practice gap. The scientific community should aim to provide guidance and support on the development and use of such relative risk assessment methods.

4. Concluding Remarks

This paper explores developments and changes in the NORSOK Z-013 standard and its evolution within the context of contemporary risk science. It is concluded that the new version of the standard represents a significant contribution to bridging the gap between risk science and practice by operationalizing the uncertainty-based risk perspective in the Norwegian oil and gas industry. It achieves this mainly by redefining risk and related concepts, incorporating SoK evaluations at various stages, including a method for assessing the criticality of assumptions and enabling greater flexibility in risk assessment methods and characterization. Nonetheless, aspects of the standard that appear more disconnected from the scientific discourse on risk analysis have also been identified.

This paper uses NORSOK Z-013 (2024) as a proxy for current practice to discuss the theory-practice gap. However, it is notable that this standard may reflect actual practice to varying degrees. It would thus be interesting to conduct a future study on how this standard has shaped industry practices.

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