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# An uncertain risk concept? Perceptions of uncertainty among risk professionals in Norwegian petroleum companies

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**Background:** In the petroleum industry, risk has traditionally been described as a combination of the probability of an event, and the consequences of the occurrence of the event. In 2015 the Petroleum Safety Authority of Norway changed the risk definition underlying its regulation, where risk is described as "the consequences of the activities, with associated uncertainties". With functional regulations the internal control systems of the companies are a fundamental element of safety. This means that how individuals understand risk will influence risk mitigation. The study aims to understand how uncertainty in risk is perceived and described by risk professionals working in the Norwegian petroleum industry. **Method**: Semi-structured interviews with 12 risk professionals in Norwegian oil and gas companies, analyzed with thematic analysis. **Results:** Descriptions of uncertainty in risk ranged on a scale ranging from more traditional risk definitions to uncertainty as the fundamental aspects of risk. Little practical impact of a changed risk definition was described beyond greater awareness and legitimacy to communicate uncertainty. **Conclusion:** There was no unified perception on how to view and describe uncertainty in risk among risk professionals. The present study indicates that, more often than not, uncertainty was perceived as an important and fundamental aspect of risk. Greater legitimacy to communicate uncertainties to decision makers may be a practical impact of the definition change.

*Keywords*: Uncertainty, perceptions, risk, regulation, probability.

## 1. Background

The concept of risk has many definitions, and different perspectives on risk are rooted in different fields (e.g., social science, mathematics, engineering, economics) (Aven & Kristensen, 2005). The terminology and communication of risk also varies within different disciplines and applications (Aven, 2009).

In safety science, risk has traditionally been described as a combination of the probability of an event, and the consequences of this event occurring (Røyksund & Engen, 2020). The definition is based on probabilities and the belief that risks can be calculated. However, the past decades have seen major discussions about the appropriateness of using a probability-based risk definition for risk analyses (Aven, 2012; Aven & Kristensen, 2005). As many high-consequence events are extremely rare, repetition that allows for frequency-based determination of the probability of the event will be difficult to justify (Aven, 2011). A key criticism against the traditional, probability-based definition of risk has been that it fails to take into account the

ultimately subjective nature of probabilities that underlie frequentist or probabilistic measurement (Aven et al., 2011). Resultingly, safety science has seen a movement from narrow, probability-based risk perspectives towards broader and non-probability-based definitions (Aven, 2012).

In Norway, this change can be viewed in regulation and in standardization work. In 2015, the Petroleum Safety Authority of Norway (PSA-N) introduced a new risk concept underlying their regulation, moving from a definition based on probabilities and consequences to describing risk as "the consequences of the activities, with associated uncertainties" (PSA-N, 2019). In broader risk assessment standards, such as NS5814 - Requirements for risk assessment, the risk definition has also been revised from "an expression of the combination of probability for and the consequences of an undesired event" (Standards Norway, 2008), to "uncertainty regarding whether an unwanted event will happen and its consequences" (Standards Norway, 2021). The standard describes the change as moving from expressing to defining risk. Authors of the standard also emphasize that even when risk is expressed or measured quantitatively through probabilities, the probabilities are always subjective perceptions and not an estimation of a true value (Standards Norway, 2021). This assessment is line with scholars' arguments (e.g., Aven et al., 2011).

The increased emphasis on uncertainty in legislation and risk assessment methods prompts a distinction between aleatory and epistemic uncertainties. Aleatory uncertainties represent natural or intrinsic variability in the components of the risk, while epistemic uncertainties stem from a lack of knowledge or data about the risk (Paté-Cornell, 1996). Thus, frequentist probabilities and probability models express aleatory uncertainty, while subjective knowledge- and judgment-based probabilities express epistemic uncertainties (Aven, 2013). In risk modelling, aleatory uncertainty is inherent and thus cannot be reduced, while epistemic uncertainty is reducible by collecting more data (Aven & Zio, 2011). Nonetheless, the risks associated with both types of uncertainty can be managed by strategic action (Packard & Clark, 2020). Uncertainty can also have multiple sources. The SRA-Risk Analysis Quality Test (SRA-RAQT) presents several sources of uncertainty, including uncertainty due to data, uncertainty due to expert judgement, uncertainty arising from limitations of data collection, uncertainty arising from disagreement among expert judgement, and uncertainty captured by scenarios and model uncertainty (Society of Risk Analysis, 2023).

The new risk concept of the PSA-N is formulated in a way that necessitates interpretation and can be difficult to implement in risk management practice (Røyksund & Engen, 2020). The PSA-N regulates the Norwegian petroleum sector through functional goal-based regulations where the companies' own internal control systems are a fundamental element of safety regulation (Kaasen, 2014). With goal-based functional regulation, it can be difficult to determine a path to achieve the goal of operating safely (Kaasen, 2014). Perceptions and understandings of risk by individuals working in the petroleum industry will influence internal control systems, risk analyses, and risk management efforts. Thus, how risk is defined, analyzed, and communicated by risk analysts will determine whether a decision is made to implement safeguards that can reduce the potential damage from the hazard (Aven & Zio, 2011). To make meaningful interpretations and decisions, it is important that decision makers are aware of the underlying subjective or objective components (e.g., uncertainties, probabilities) that make up the risk models (Aven & Zio, 2011). According to risk perception theory, an individual's knowledge and certainty about a risk influences their calculations of potential costs and benefits (Paek & Hove, 2017), and perceptions of risk will influence how different people make different estimates of the dangers of the risk (Wildavsky & Dake, 1990). Although perceptions of the conceptual contents of risk are distinguishable from perceptions of the particular risk itself, the conceptual risk perception will determine which and how inputs are used to assess risk, and will thus influence perception of the risk itself. This may be particularly the case for risk experts, who are assumed to rely on scientific information and objective assessment (Paek & Hove, 2017).

However, whether the academic conversation underpinning the definition change has had a practical impact on how uncertainty in risk is perceived is less known. Especially among the personnel working with risk analysis

and risk management. Responding to this research gap, this article examines, following the definition change, how uncertainty in risk is perceived and described by risk professionals working in the Norwegian petroleum industry.

## 2. Method

This is a cross-sectional qualitative study using individual semi-structured interviews. The study is part of the RISKY project (Consequences of fundamental changes in risk regulation), investigating the practical consequences of a change towards a risk definition based on uncertainty (Norwegian Research Council project number: 315302).

### *2.1 Recruitment and participants*

Eligible participants for this study were individuals in Norwegian oil and gas companies that were involved with risk analyses or risk management in the company. See Table 1 for descriptive information. Contact information for eligible participants were provided by the project contact in each company. Participants were then invited by e-mail to participate in a digital interview where they could talk about their thoughts and experiences relating to the new risk concept. Invitations for participation went through contact persons in four petroleum companies in Norway. Twelve participants from these four companies accepted our invitation for interviews. As a contact person forwarded our invitation we have no information on the response rate or characteristics of those declining to take part. No researcher in the present study had any prior relationship with the participants.

Table 1 - Participants descriptive information

| No | Area | Background | Years exp. |
|---|---|---|---|
| **1** | Risk analysis | Mathematics | 30+ |
| **2** | Risk analysis | Engineering | 20+ |
| **3** | Operations mgmt. | Engineering | 30+ |
| **4** | Risk analysis | Unknown | 20+ |
| **5** | Risk management | Engineering | 20+ |
| **6** | Safety strategy | Social science | 20+ |
| **7** | Technical safety | Engineering | 10+ |
| **8** | Technical safety | Engineering | 30+ |
| **9** | Risk management | Engineering | 10+ |
| **10** | Risk analysis | Chemistry | 20+ |
| **11** | Risk management | Engineering | 30+ |
| **12** | Technical safety | Engineering | 30+ |

### *2.2 Data collection*

Individual interviews are suitable for rich, in-depth descriptions from each individual, and were appropriate for the purpose of this article. Interviews were performed digitally by two of the researchers in the project. The interviews were conducted using a semi-structured interview guide focused around five question categories (the informants' work with risk analyses, the new risk concept, onboarding the new risk concept in the company, risk practice changes, and the risk definition when working with other actors) with several open-ended questions for each category. The interview guide was not followed top to bottom but provided potentially relevant questions in the topic categories. All interviews were audio recorded and transcribed verbatim.

### *2.3 Analysis*

Data was analyzed using thematic analysis inspired by Braun and Clarke (2006). This method is a flexible six-phased recursive process that allows researchers to move between phases, suitable for analyzing individual interview data. Each author was provided a minimum of three interviews to analyze, providing overlap and triangulation between researchers. The analysis had five steps: First, the authors read the interviews to familiarize themselves with the data, identifying initial ideas. Second, parts of each interview that were relevant for the study's aim was systematically coded into preliminary descriptive categories. Third, codes for each interview were then developed into potential themes. After these three steps, meetings between researchers were held where themes developed from each interview were presented and discussed. Through discussions these themes were combined into overarching findings that were relevant across participants. In the fourth step, these findings were checked against the initial codes by each author, to see whether they described the situation adequately or whether adjustments had to be made. In the fifth step, the themes were named to highlight the essence of their contents, i.e., what stories do the themes tell, what they are, and what they are not (Braun & Clarke, 2006). This step was finalized in discussions involving all authors. In the final step, all authors contributed to writing the analytic text, focusing on rich descriptions and quotes from the data that exemplify the contents of the theme, while also keeping in mind the nuances in the

themes that were present in their respective interviews.

An additional analysis was done based on predefined aspects of uncertainty. These were identified from the SRA-QRAT, which recommends aspects of uncertainty to be described in risk analysis. The focus of the interviews has however been uncertainty and risk in more general terms than presented in the SRA-QRAT, and hence not all sources of uncertainty presented in the SRA-QRAT are discussed in the interviews. However, by letting the respondents talk about uncertainty in general terms, the assumption is that the interviews brings forward what the participants consider important aspects of uncertainty in risk analysis, and that the answers relate to the predefined aspects of uncertainty. The result of this analysis is used to complement the findings from the more inductive thematic analysis.

## 3. Results

When participants in the present study describe uncertainty in risk, they often do so against the backdrop of PSA-N's new risk concept. This is natural as this definition change was described a central topic in the project description and was the reason for inviting informants to participate. Two major themes were developed from the analysis. The first theme contains participants' descriptions of uncertainty in risk and the second theme relates the practical implications of risk understanding.

### *3.1 Uncertainty in risk*

Participants differed in how they understood uncertainty in risk. While all participants described uncertainty as an important part of risk analyses, they had differing views on how to incorporate uncertainty in their understanding of risk. The descriptions of uncertainty in risk can be found on a scale ranging from perceiving the traditional risk concept of probability and consequences to sufficiently treat uncertainty, to uncertainty as a fundamental component of risk that needs to be considered separately.

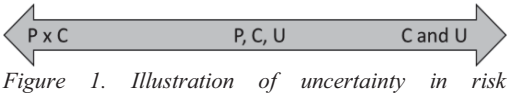


*Figure 1. Illustration of uncertainty in risk perceptions. PxC: Uncertainty is captured by probabilities times consequences. P,C,U: Uncertainty is separate and additional to probabilities and consequences. C and U: Uncertainty is the fundamental aspect that needs to be considered.*

#### *3.1.1 Uncertain probabilities and consequences*

Those at the former (left) end of the scale described that risk definitions based on probability and consequences already encompass uncertainty, and can be described through estimations of probabilities and uncertainty in which scenarios happen and how these scenarios play out. One example could be using statistical estimation based on historical frequencies and taking the uncertainty into account through confidence intervals.

*"Personally, I think it covers that uncertainty issue quite well in a good risk assessment where we discuss consequence and probability. […] it is really the uncertainty discussion you are doing throughout the risk assessment." Technical safety, 30+ years of experience*

This traditional thinking can be further illustrated by an interviewee describing that quantification is estimation, while uncertainty is guesswork. Focusing on uncertainty as a concept was also described as an "academic issue that doesn't concern me". However, most individuals that lean toward a more traditional risk concept recognize that they put more emphasis on the uncertainties in the analyses than before, even though it hasn't changed the risk analysis practice or methods they use.

*"I don't think it changes our work beyond being aware that we do not have exact answers in our risk analyses. […] The [answer] gives an indication of where you could be, and the uncertainty is included, but it has not changed practice or the tools we use." Technical safety, 10+ years*

Furthermore, those doing the analyses know that there are uncertainties behind their numbers, but also admit to not having succeeded in making these visible.

#### *3.1.2 Uncertainty as a third factor*

The difficulties of distinguishing between probabilities and consequences which already contain uncertainty, and a concept of risk with probabilities and consequences that include

uncertainty as something additional was a recurring topic.

*"In our risk matrix you are to select probability and consequence, and then you [choose] uncertainty as another factor. This may be to say something about how sure you are about how you placed the risk in the matrix." Technical safety, 10+ years*

This taps into the issue of multiple sources of uncertainty, and various sources' implications for risk assessment.

*"… you have things you can call data-uncertainty, model-uncertainty, missing information in many ways. This is in addition and can have different impacts in different contexts. […] It is difficult, as the probability for the event is the main point, and the quality in your risk assessment depends on the information you have and whether you understand it and can put it to use." Risk manager, 20+ years*

This line of thinking can perhaps be placed in the middle of the scale between the traditional concept and the new PSA-N definition. Several of those who subscribe to this way of thinking explain that it involves more thorough descriptions of the uncertainties the in risk analyses, e.g., by focusing more on qualitative assessments of the risk, and not only on the quantification.

#### *3.1.3 Uncertainty as fundamental assumptions*

As we move further along the scale in Figure 1, uncertainty was perceived as 'the fundamental assumptions' that make up the risk analysis. Participants describe assumptions that influence the quantification of probabilities and consequences, but they also emphasized that uncertainty is about assumptions about the inputs for the analysis, and how these are interpreted regardless of quantification. Individuals that subscribe to the risk understanding at this end of the scale also described knowledge about the system, and the potential and consequences of various scenarios as components of uncertainty.

*"The biggest impact is that we have become more aware of the assumptions and accompanying uncertainty, in tools, methods, knowledge base, historical data. Essentially everything you build your analysis on has uncertainty attached." Risk manager, 30+ years*

One individual also summarized the findings in this chapter succinctly: Uncertainty is personalized, as people talk about different things, and what is uncertain depends upon who is in the room when risk is discussed.

There was a tendency that risk professionals in the present study lean towards the right side of our uncertainty in risk concept scale (Figure 1). A majority of participants describe uncertainty as an important and separate component of risk that goes beyond the statistical uncertainty in frequentist estimation of probabilities and consequences. This is illustrated by several individuals highlighting the importance of describing assumptions a core component of the uncertainty in an analysis.

### *3.2 Practical implications - a discourse change*

Participants differed somewhat in their view of the practical implication of focusing on uncertainty in risk. As stated above, several described that it has no practical significance, and that the methods they used had always incorporated uncertainty. The majority, however, describe that the new focus on uncertainty has enabled a broader discussion on the contents and expressions of risk and how to include uncertainty, even if the perceived practical changes for risk analysis are small. The main changes that were brought forward for quantitative risk analysis is an increased focus on a qualitative description of uncertainties in the analysis, often as a supplement or an add-on to the analysis describing assumptions.

*"I think this has improved in the recent years. That we are more open about our assumptions for the analysis. You used to have to search through the document to find them […] I'm not sure if it is because of the definition change from the PSA-N or because it has matured on its own, but the focus has changed from 10 years ago." Risk manager, 30+ years*

Thus, the risk analysis discourse has moved from being focused on risk acceptance criteria, towards having an increasing focus on describing uncertainties in the analysis, even where it cannot be quantified.

Participants also describe being able to justify qualitative and semi-quantitative descriptions of risk by pointing to requirements in legislation and guidance. With the definition change, the participants were able to use PSA-N's risk definition to legitimize more elaborate discussions of uncertainty in the risk analysis and when presenting risk to decision makers without being perceived as too vague or indecisive.

*"The perception has changed, both among us working with [risk] but also for decision makers and others. We are more aware that the risk analysis is no better than what we are able to predict." Risk manager, 30+ years*

This increased consciousness in the industry about there not being one single, clear answer, again made it easier for those performing risk analysis to communicate the uncertainties that do exist to decision makers. It is noted by some of the participant that the increased description of uncertainties, which should benefit the decision makers, is one of the most noticeable changes after the new risk definition.

*"I think this is the largest change. Changing the risk definition in this way, in order to emphasize communicating uncertainty more." Risk analyst, 20+ years*

## 4. Discussion

The present study has examined the perceptions of uncertainty in risk among risk analysis professionals in Norwegian oil and gas companies. The results demonstrate that uncertainty is incorporated into most risk analysts' perceptions of risk, albeit with varying perspectives on how uncertainty should be described. The results indicate that risk analysts in the Norwegian petroleum sector have an increased focus on epistemic uncertainty, which can be reduced by ensuring that the information that one has is accurate or by collecting more information (Dubois, 2010). Other risk management professionals in this study had more emphasis on describing inherent uncertainty in existing inputs, rather than on whether the inputs in themselves are appropriate. This could possibly lead them to implement risk mitigation strategies that reduce the consequences and probabilities of variability (i.e., aleatory uncertainty), rather than discussing whether the assumptions and knowledge about the inputs are valid (i.e., epistemic uncertainty), in which the risk reduction measures would likely be less accurate, or in the worst case, completely invalid.

The somewhat differing views of uncertainty in the present study also highlight the need for the recognition in newer standards, such as NS5814 , that all risk estimation is inherently subjective, regardless of whether it is expressed quantitatively or qualitatively (Standard Norway, 2021). The Society of Risk Analysts also describes uncertainty as a subjective probability, and probabilities as subjective based on judgements and knowledge in their glossary (Aven et al., 2018). As one of our interviewees illustratively expressed; the risk description and analysis is determined by which individuals that are in the room.

In a previous study, Røyksund and Engen (2020) found that the PSA-N supported the introduction of an uncertainty-based risk perspective, with the intention to challenge current risk management practices. The present study shows that many risk analysts have adopted the uncertainty-based risk perspective, but the results also suggest little actual change in risk analyses. While this may be contradictory, it could indicate that risk analysts can have changed their perceptions of risk, but the risk analysis methods used may not entirely reflect this as several participants described that the methods have always incorporated uncertainty. Another explanation suggested by Røyksund and Engen (2020) could be that the new risk definition was an adjustment more aligned with actual practice, and as such would induce little change from what was previously expected.

The increased awareness of, and discussion of, uncertainties in risk analyses runs as a red thread through our informants' descriptions of the consequences of PSA-N's risk definition despite the perceived lack of practical changes. We should keep in mind that this paper to a degree presents the perspective of risk professionals in organizations with substantial specialization, where each work on their delimited risk object, which reflects a limited scope of responsibility.

The largest impact of the definition change may, however, be for the decision maker receiving the analyses. The definition change has

allowed a greater emphasis on uncertainty when communicating risk. This may provide decision makers with broader insight into what underlies the analysis, thus improving the decision basis. As decision making higher up in the organization is informed by several information sources and parameters, amongst which a specific risk analysis is only one. Decisions will typically depend on evaluating potential combinations of uncertainties from different sources. Uncertainty considerations that are used as inputs of a particular risk analysis may conflict with other aspects, and this information might still be important for a decision upstream in the organization. This means that a thorough description of the uncertainties and assumptions for each delimited risk object will further highlight the limitations and assumptions of the consolidated risk picture. Without providing adequate information on uncertainties for the decision makers, one can argue that the decisions have already been made earlier in the risk analysis process, by the risk analysts.

Rasmussen (1997) illustrates the relation between singular functions and processes in the larger organization, when he models the drift towards danger that may take place if variability of delimited functions or processes are not considered with respect to the effect on other functions and processes. With his model, Rasmussen shows the need to oversee interdependencies at a system level, and thus points to aggregated uncertainties and combination effects that the individual process owner or risk analyst cannot oversee. This points towards the importance of rendering uncertainties visible to decision makers upstream, who are in position to make informed, holistic decisions. As such, by increasing legitimacy of communicating uncertainty descriptions, the PSA-N has at least partially succeeded in challenging the status quo.

Whether decision makers appreciate being presented with more uncertainty is however, also uncertain. Thus, more research is needed on how these decision makers utilize uncertainty-descriptions in their decisions.

The findings in this paper largely support Aven's (2016) argument about decision-making and risk management being affected by how risk is defined, understood, analyzed, and communicated.

## 5. Conclusion

This paper reports from a study investigating how risk analysts describe uncertainty, and how uncertainty relates to their risk analysis practices, following a regulatory definition change in 2015. Although no unified understanding of uncertainty in risk could be identified, risk professionals in the Norwegian petroleum industry to a large degree subscribed to an understanding of uncertainty in risk that is in line with the new risk definition by the PSA-N.

The definition change has contributed to greater awareness of uncertainty in risk, and a strengthened insight that risk analyses should always be critically considered with respect to uncertainty both of input parameters and results. However, while accounting for uncertainty is considered an important task for risk analysts with responsibility for specific functions or processes, it seems to have small impact on their practical work. To find the impact of the strengthened focus on uncertainty in risk, one could look towards decision makers higher up in the organization, where different sources of uncertainty are subject to potential interaction. The definition change provided risk professionals with the legitimacy to communicate uncertainties to decision makers. These may have a more systemic overview than individual risk analysts and could benefit from a greater focus on thorough descriptions of uncertainties in risk analyses. Thus, the PSA-N has likely moved the field forward, by providing legitimacy and discourse change in allowing uncertainties to be communicated to a larger degree than previously. We suggest that the main users of the uncertainty information may be decision makers higher up in the organization, where uncertainties associated with different sub-processes meet and interact.

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