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Review

Clarifying the concept of operational risk assessment in the oil and gas industry

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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

There is an increasing interest in risk and safety research to reflect risk fluctuations in operational phase to avoid major accidents from happening. A structured review that covers operational risk assessment, dynamic risk assessment and real-time risk assessment has been conducted to clarify the concept of operational risk that needs to be assessed under operational risk assessment. It is found that different terms are used in different ways, covering different purposes. The finding reveals a need to strengthen the link between risk assessment methodologies and supporting decisions by clarifying what needs to be measured for what purpose. Operational risk assessment, dynamic risk assessment, and real-time risk assessment have their key aspects to address, namely what information we need to make decisions, how the analysis is updated and how the data required for updating is gathered. The paper recommends using the terms in a consistent way to facilitate a common understanding.

1. Introduction

1.1. Background

In the Norwegian oil and gas industry, risk assessment has been focussed on design-related decisions to assist in developing safe facilities. After a facility is operational, the risk may fluctuate with changing system conditions, on-going activities and the operating environment. There are increasing demands and interests in applying risk assessment methodologies in the operational phase to capture such fluctuations (NORSOK, 2010; PSA, 2015a,b). Correspondingly, different terms have emerged to describe this. Operational risk assessment/analysis, dynamic risk assessment/analysis and real-time risk assessment/analysis are on top of the list. There are other terms, such as on-line risk assessment and point-in-time risk assessment, that are widely used in the nuclear industry but less frequently in the petroleum industry (e.g., see Wang et al. (2016) and Zubair et al. (2013)). Sometimes, instantaneous risk and point-in-time risk are used as substitutes for each other to express "the level of risk that arises from a specific plant configuration" of a nuclear power plant (OECD, 2004). Note that risk assessment and risk analysis are not strictly differentiated in some sources, as defined in ISO 31000. In this article, operational risk assessment is used and refers to the overall process of risk identification, risk analysis and risk evaluation during the operational phase. Then, risk analysis is the process used to comprehend the nature of risk and determine the level of risk. Risk analysis includes risk estimation.

There are many studies in the literature focusing on modelling and measuring risk, which may directly or indirectly be associated with the operational phase. However, it is not always clear exactly what is measured, and why this is measured. Furthermore, various terms create confusion among researchers and practitioners within the field.

On the other hand, experience has shown that decisions that are made in operational settings can significantly influence the risk of a major accident. For example, decisions that contributed to the Macondo blowout are as follows: using six centralizers instead of twenty-one, declaring the success of the integrity test, and offloading return mud from the well directly to a supply vessel instead of the mud return pit (Hopkins, 2012; NCBP, 2011). Decisions such as these are not addressed in the quantitative risk assessment (QRA).

During the operational phase, decisions can be classified in four types: strategic planning decisions, operational planning decisions, instantaneous decisions and emergency decisions (Yang and Haugen, 2015). *Strategic planning decisions* are characterized by a long planning horizon (with time to consider risks and benefits of alternatives carefully), low decision frequency, and long-term effects. Examples are approving of major modifications, choosing between alternative technologies, and deciding on a maintenance strategy. *Operational planning decisions* are related to actions that will be taken and implemented

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within a shorter period. The planning period is relatively short; however, it is long enough to carry out formal risk assessments. The offshore installation manager or operational manager typically makes these decisions. Examples can be the approval of initiating projects and approval of work permits on a daily basis. *Instantaneous decisions* are execution decisions that are made spontaneously by sharp-end operators (e.g., to follow or deviate from procedures; ignore or react to deviations from normal working conditions). *Emergency decisions* are the decisions taken by a team in emergencies to avoid or adapt to hazardous situations.

Input from risk assessment is an important dimension for these types of decisions, whereas various types of decisions need different risk information in different forms as input (Yang and Haugen, 2015). Accordingly, operational risk assessment is carried out to provide such risk information. This means prior to discussing operational risk assessment methodologies, one step back should be taken to specify what should be assessed and for what purpose first.

1.2. Objectives

The overarching objective of this paper is to clarify the concept of operational risk assessment in the oil and gas industry to better support decision making during the operational phase. The work is structured to answer two questions. The first question is how the related terms of operational risk assessment, dynamic risk assessment, and real-time risk assessment are used in the literature. Similarities and differences are explored by exploring what is measured under these terms, the purposes of the measurement, associated risk factors and how risk fluctuation is captured. The second research question is what key aspects are addressed by different approaches to support the choice of a method based on the assessment purpose.

The rest of the paper is organized as follows: the scope of the literature review and review process is described in Section 2. The results are summarized in Section 3. The findings based on the results are further discussed in Section 4, which starts by looking at the confusion created by various terms used in operation and ends with recommendations for future usage. Section 5 concludes the work.

2. Risk associated with operations from the literature

Even though the focus of this paper is on the petroleum industry, the chemical and process industries are also included in the review due to their similar nature.

The journal and conference paper search results from Scopus utilized the following search criteria:

- “Operational risk” OR “dynamic risk” OR “real-time risk”, AND
- “oil and gas” OR “petroleum” OR “chemical”.

The search shows an increasing interest in recent years (the terms “assessment” and “industry” were omitted for the sake of brevity – Fig. 1). Khan et al. (2015) and Villa et al. (2016) also discussed this research trend in their review papers about methods and models in process safety and risk management. Note that some articles use operational risk assessment, while others use operational risk analysis when discussing the methodologies. This usage depends on to what extent the discussion covers risk management. To obtain a wide coverage of the review, “operational risk” is used as the search term instead of “operational risk assessment.” This applies also to dynamic risk assessment and real-time risk assessment.

Bearing in mind what is exactly being measured under different terms of risk during operation, a literature review has been conducted among relevant published articles. The review process is illustrated in Fig. 2. We narrowed down the scope of the review to 197 articles in the following representative scientific journals in the field.

- Journal of Loss Prevention in the Process Industry (53)
- Safety Science (30)
- Reliability Engineering & System Safety (30)
- Process Safety and Environmental Protection (23)
- Industrial and Engineering Chemistry Research (21)
- Process Safety Progress (10)
- Journal of Hazardous Materials (8)
- Risk Analysis (7)
- Chemical Engineering Transactions (9)
- Journal of Risk Research (6)

Among these articles, the searched terms are present in the main body of 81 articles, while in the other 116 articles, the terms only appear in the references. After the first round of screening, 32 articles from the 116 are considered relevant for the review. This is because the approaches that are discussed in the main text are still related to major accident prevention during the operational phase. Thus, altogether, 113 articles are covered in the literature review.

Initially, the following questions are set up to enable a structured review:

1. What is measured under the various methods of risk assessments that are applied in the operational phase (i.e., operational risk assessment, dynamic risk assessment, real-time risk assessment)?
2. What is the purpose of the risk assessment approach described in the article?
3. What risk factors are considered under the assessment?
4. How is risk fluctuation captured in the proposed method during the operational phase?

After this in-depth review, it is found that the risk factors are closely tied to the purpose of the assessment. The second and third question are therefore combined into one in Section 3.2. Question 1 is discussed in Section 3.1, and question 4 is answered in Section 3.3.

3. Results of the literature review

3.1. What is measured

3.1.1. Operational risk assessment

Operational risk is widely discussed in the context of finance and insurance as one of three main categories of risk in financial markets. Operational risk is defined in the Solvency II Directive (2009/138/EC), an EU Directive that codifies and harmonises the EU insurance regulation, as the “risk of a change in value caused by the fact that actual losses incurred for inadequate or failed internal processes, people, and systems, or from external events (including legal risk) differ from the expected losses” (CEA, 2007). The definition revealed the background to introduce operational risk to measure the actual losses due to imperfect people (e.g., errors in settlements of transactions), processes, and systems (e.g., IT failures).

Operational risk considered in safety engineering mainly has three interpretations. The first interpretation is the risk associated with human errors and organizational errors to emphasize the interactions among system components (i.e., human, technical system and organization) (Skogdalen, 2011; Verbano and Venturini, 2011). Casal and Olsen (2016) distinguished between fabric failures (i.e., failures due to mechanical degradation mechanisms) and operational failures (i.e., failures that are not mechanical failures). Thus, operational risk measures major accident risks that are caused by operational hazards. One example of such a hazard can be a drain valve left open after maintenance that leads to a leak, despite the fact that no mechanical failures occur. This interpretation is in line with how operational risk is considered in the context of finance and insurance.

In a broader sense, the second interpretation expresses the major accident risk involved during operations at the plant level (e.g., risk of