Safety Science 79 (2015) 206–212

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/ssci

Improving the risk assessments of critical operations to better reflect uncertainties and the unforeseen

Henning Veland, Terje Aven *

University of Stavanger, 4036 Stavanger, Norway

ARTICLE INFO

Article history:
Received 2 January 2015
Received in revised form 20 May 2015
Accepted 17 June 2015
Available online 30 June 2015

Keywords:
Risk
Uncertainties
Surprises
Risk assessment
Safe job analysis
Critical operations

ABSTRACT

In this paper we address risk assessments of critical operations and in particular the safe job analysis, the main aim being to improve these risk assessments by better reflecting uncertainties and the unforeseen. The work is based on the conviction that current practice does not adequately deal with potential surprises and the knowledge dimension of risk. An adjusted risk assessment approach is presented and illustrated using an example from the oil and gas industry. Several incidents in the oil and gas industry in recent years have shown a lack of proper understanding of risk, and the present paper is to be seen as a contribution to the work of improving the understanding of risk on the part of the personnel involved in critical operations.

1. Introduction

Several operations are carried out every day on offshore oil and gas installations (e.g. production platforms) with various levels of criticality with respect to safety. Some examples are maintenance work on equipment or pipes containing hydrocarbons, lifting of heavy equipment, and production and exploration drilling. Such operations often have the potential for severe consequences if a barrier (operational, technical or human) should fail. To deal with risk related to such operations, the industry has developed and applies several standardised operational risk assessments, including a system for work permits and Safe Job Analysis (SJA). The aim of these risk assessments is to ensure that the risk is adequately handled and is at a sufficiently low level when carrying out the operations. For some works presenting and discussing such operational assessments, see for example Vinnem (2014), Meyer and Reniers (2013) and Leistad and Bradley (2009).

The Petroleum Safety Authority Norway (PSA-N) conducts independent investigations following accidents and incidents in the oil and gas industry on the Norwegian continental shelf. According to the PSA-N, a common indirect cause of these unwanted events is related to a poor understanding of risk on the part of the personnel involved, at both the sharp end (operators) and/or the blunt end (planners/managers). This observation has recently been referred to in a publication from PSA-N, in which the status and signals of safety in the Norwegian oil and gas industry have been summarised (PSA-N, 2012):

> *"A number of technical, operational and organisational factors can individually or collectively cause an accident and influence its development. But the question is how the industry and the authorities work to prevent major mishaps and monitor risk in the Norwegian petroleum industry. This is first and foremost a matter of risk understanding and management in the companies, work to reduce uncertainty, and ensuring good emergency preparedness."*

Many of the investigations have uncovered that there are huge differences in the understanding of risk between the workers. Some may have the necessary insights, while others may have severe knowledge holes. The reason for this lack of knowledge is often poor communication. In other cases all the personnel involved have a poor understanding of risk, for example as a result of lack of information. A risk assessment constitutes an important tool for ensuring a proper understanding of risk. However, a risk assessment does not provide a guarantee that the relevant personnel have obtained a good understanding of risk. There may be several obstacles, including:

(1) The risk assessment itself may be poor, in the sense that it does not capture important risk issues.
(2) The follow-up of the insights uncovered during the risk assessment may be poor. Hazardous conditions may have

* Corresponding author. Tel.: +47 5183 2267; fax: +47 5183 1730.
E-mail address: terje.aven@uis.no (T. Aven).

http://dx.doi.org/10.1016/j.ssci.2015.06.012
0925-7535/

been identified in the risk assessment, but the safety culture or underlying matters or agendas may lead the personnel to not handle risk in an appropriate manner.

The latter item is as important as the former, but the present paper restricts attention to item 1. We will argue that there is a potential for considerable improvements to current risk assessment practice in the industry. The prevailing thinking pays too little attention to the knowledge dimension of risk and the potential for surprises. This issue has been thoroughly discussed in recent papers (e.g. Aven, 2013; Aven and Krohn, 2014). The main arguments can be summarised as follows:

(a) Common ways of summarising risk are based on assigned probabilities, for example by using risk matrices. This approach does usually not reflect the strength of knowledge that supports the assessment, and the produced probability-based risk description can seriously mislead decision makers. We may have two situations with identical assigned probabilities, but in one case the strength of knowledge is strong, and in the other it is weak. The assigned probability itself does not bring forward this aspect of risk. A risk event that is judged to be acceptable based on a probability assessment associated with a weak strength of knowledge should be given less weight when making a decision compared to a situation where the same assessment is associated with a strong strength of knowledge.
(b) Common risk assessment approaches do not pay sufficient attention to the fact that assumptions and prevailing explanations and beliefs may conceal important aspects of uncertainties and risk.

In this paper we present and discuss an adjusted risk assessment method that meets these challenges (a) and (b), using the Safe Job Analysis (SJA) as an example. The main aim of the paper is to improve the current risk analyses of critical operations by better reflecting uncertainties and the unforeseen. To illustrate the analysis we will consider an application from the oil and gas industry. The general method is presented in Section 2, whereas Section 3 introduces a case study that will be used to demonstrate the key features of the adjusted risk assessment and practical implications for decision-making (Section 4). The final Section 5 provides a summary and conclusion. The case study and the generic SJA methodology is from the Norwegian oil and gas industry, but the method presented and the following discussion are also relevant for other areas of application.

2. An adjusted safe job analysis

The main objective of the adjusted SJA is to improve the risk understanding of personnel involved in the critical operation by:

- Highlighting the strength of knowledge supporting the assigned probability judgements.
- Providing new insights on the risk events assessed to have high consequences and low probabilities.
- Identifying and assessing any potential surprises.

The adjusted risk assessment process involves two analyst teams, referred to as teams I and II, see Fig. 1. Team II should have an unbiased focus in the sense that members of team II should not have been participating in any previous planning of the operation. The idea is that the second analysis team should see the critical operation with new eyes, thus better enabling them to identify any aspects of risk that team I did not identify.

The adjusted risk assessment process has four main stages. In **Stage 1**, analyst team I performs a standard risk assessment, analyses risk and describes risk according to (A_1', C_1', Q_1, K_1) (Aven, 2013). Here A_1' and C_1' are the specific events and consequences identified in the analysis, Q_1 a description/measurement of uncertainty (typically using probability) of A_1' and C_1', and K_1 is the background knowledge on which A_1', C_1' and Q_1 are based: data, information, justified beliefs (models, probability models, expert judgements, assumptions).

In **Stage 2**, analyst team I performs a self-evaluation of (A_1', C_1', Q_1, K_1), having a focus on the rationale for (A_1', C_1', Q_1, K_1) and highlighting the strength of knowledge of K_1. The updated risk description is denoted (A_2', C_2', Q_2, K_2). In many cases there would be no difference in A, C and Q, but the background knowledge K always changes after this review has been performed, adding a quality control of the various elements of the analysis process and a special judgement of the strength of knowledge of K_1.

In **Stage 3**, analyst team II challenges team I and their mental models (assumptions etc.), acting as a red team (the devil's advocate) and for example:

- Argues for the occurrence of events with assigned negligible probabilities,
- Searches for unknown knowns (events that are known by others but not team I),
- Checks how signals and warnings have been reflected.

A main purpose of the stage is to identify and assess potential surprises.

In the final **Stage 4**, the two analyst teams are to provide a joint risk description (A_3', C_3', Q_3, K_3), reflecting the input from both teams. The risk description provides a basis for understanding risk and supporting the decision-making.

SJA is a well established risk assessment method. The adjusted approach builds on the traditional one but adds some stages as described above. The methodology is framed in a general risk description, and expresses risk, using the generic risk set up of (A′, C′, Q, K). Expert elicitation knowledge may provide input to the uncertainty judgments Q and may form important aspects of the background knowledge K. The methodology specifically addresses the issue of surprises relative to current knowledge and beliefs, which is not commonly captured by existing approaches (such as standard SJA).

The analysis process could be rather resource demanding, but the full process should only be used in selected situations when the criticalities are considered high. In practice simplified schemes could be developed to make the process feasible.

3. Case study: offshore installation

In this section we will discuss how the adjusted risk assessment can be used for conducting an SJA on an offshore platform.

3.1. Background

In 2008 a serious oil leak incident occurred on a Norwegian offshore oil and gas installation (StatoilHydro, 2008). The oil leaked out inside a vertical passageway shaft located within one of the three 175-m tall concrete legs of the installation. See Fig. 2 for a similar neighbouring installation that has an additional fourth concrete leg.

The incident occurred during modification work inside the passageway shaft at 61 m above sea level. A special tool called a hot tap machine was used to contain the flow of hydrocarbon fluids while performing work on a pipe bend section that contained oil