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Classification of risk to support decision-making in hazardous processes

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ABSTRACT

Application of risk assessments developed for the design phase to support decision-making in operational settings has exposed weaknesses in how risk is analysed and expressed in an operational context. The purpose of this paper is to clarify what we actually need to express when we use risk information to support various decision scenarios. We distinguish decision scenarios into strategic decisions, operational decisions, instantaneous decisions and emergency decisions. This forms a basis for discussing the different role risk and risk assessment plays in these decisions. Five categories of risk information (average risk, site-specific average risk, activity risk (activity performance risk and activity consequence risk), period risk and time-dependent action risk) are proposed and applications for different types of decisions are discussed. An example illustrates the use of the proposed risk types. The classification has novel aspects in providing a structure that should help in understanding how we need different aspects of risk and different ways of expressing risk in different situations. In addition, it improves communication among decision-makers by clarifying what aspects we are addressing when we use the term "risk".

1. Introduction

Risk assessment was first introduced to the Norwegian oil and gas industry when the Concept Safety Evaluation Guidelines were established by the Norwegian Petroleum Directorate in 1980. These guidelines required risk assessment to be performed for all new oil and gas installations to be installed on the Norwegian Continental Shelf.

In the first years after this, risk assessment was performed mainly to support high-level design decisions, typically issues such as layout of equipment and main areas, escape ways and evacuation means and also to establish performance criteria for safety systems.

Since then, the regulatory requirements have been revised several times and with them, the application area for risk assessment has widened continuously. Today, the situation is that risk assessment is being used to support a wide range of decisions, from the high-level decisions mentioned above to very detailed technical decisions. Similarly, the scope has also been widened to cover not just technical issues, but also operational and organizational issues. In addition, risk assessment is increasingly being used not just for design purposes, but also in an operational setting, to make detailed decisions about how to operate an installation, what activities to perform, whether operation can continue and so on.

This widening of the scope has led to the realization that the "risk" that is relevant to consider in one decision situation not necessarily is the same as we need in other situations. The risk that we consider when we are making a decision about some long-term *strategic decisions* will not be the same as the risk we consider when deciding to complete a short duration operation, even if a safety system has stopped functioning. This is the background for the present paper, where we are aiming at distinguishing between different decision scenarios and what we actually need to express when we use risk information to support the decision.

When preparing this paper, we have had mainly "technical" decisions in mind. Typical examples are decisions relating to maintenance/repair of equipment, how to operate the plant, how to perform a specific piece of work etc. Decisions that primarily are "organizational" in nature have not been specifically considered. One reason for this is that such decisions often are more of a *strategic* than *operational* type. This issue may require further exploration, but we have not gone into this.

The first part of the paper briefly reviews decision theory and describes types of decisions that need risk information as input. This is followed by a description of the types of risk information that is required in different situations and examples of how these can be applied in different scenarios and situations.

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In the oil and gas industry, it is common to consider three main types of consequences; consequence to personnel, which include fatalities and injuries, consequences to the environment, and consequences to assets (Vinnem, 2014). Personnel risk is the main concern in this paper, although the principles outlined would be relevant and could also be applied for environmental risk and asset risk. This work was further performed with major accidents in mind. This means that some of the descriptions may not be relevant for occupational accidents, but it is still considered that the overall principles are applicable also for occupational accidents.

2. Decision theory

Decision theory is a wide field in itself, and the paper does not attempt to go into details of the theoretical approaches. However, some basic descriptions of decision theory are provided, as a background to how risk information may play a role in the decision-making processes.

2.1. Rational choice and bounded rationality

In the rational choice theory, a decision (δ) is considered as a choice between two or more actions. To make a decision means to choose an action. The process starts by identifying the set of possible actions $A = \{a_1, a_2, \ldots a_n\}$, where A is called the action-space. Each action is evaluated against consequences, preferences and decision rules (March, 1994). The underlying assumption is that we can identify all possible actions in advance, and that we have "perfect" information about all actions.

Rational choice theory is criticized by organizational decision-making (Cyert and March, 1963; March and Simon, 1958; Simon, 1976), pointing out that most decision-making in real-life is better described as outcomes of bounded rationality. This means that not all alternatives are known, not all preferences are taken into consideration, and not all consequences are considered. The decision (i.e., choice) is actually based on the available knowledge K which results in the action a_i. As a consequence, only a few of all possible alternatives are considered and the choice is a "good enough" solution, not necessarily the "best" (Almklov et al., 2014). It is worth noting that under bounded rationality, the current available knowledge K may change over time, so the decision made today may be different from a decision made tomorrow.

2.2. Naturalistic decision-making

Naturalistic decision-making (NDM) goes one step further compared to bounded rationality theory. It claims that rational decision-making promotes better decisions only when time is available to make a choice, the problem is clear, essential information is distributed, and uncertainty around details is low. More typical, situations that we are facing are characterized by ill-defined goals and ill-structured tasks; uncertainty, ambiguity, and missing data; shifting and competing goals, dynamic and continually changing conditions, action-feedback loops (real-time reactions to changed conditions), time stress, high stakes, multiple players, organizational goals and norms, and experienced decision makers (Klein and Klinger, 1991).

The goal of NDM is to understand the cognitive work of decision-making, especially when performed in complex sociotechnical contexts (Schraagen et al., 2008). Lipshitz (1993) reviewed nine models of naturalistic decision-making and identified six common themes: diversity of form; situation assessment; use of mental imagery (i.e. construction of scenarios); dynamics processes; context dependence; and description-based prescription. The key concepts can be summarized as follows:

(1) Recognition-Primed Decision (RPD) model highlights pattern matching which combines intuition with analysis (Klein, 2009); that the pattern recognition from the cues that sharp-end personnel recognize from the situation, suggests an effective course of action, and then people use a mental simulation to make sure it would work (Fig. 1).
(2) NDM shifts focus from selection of alternatives to initial stages of observing phenomena and developing descriptive accounts. This is elaborated under the concept of *situation awareness* proposed by Endsley and Jones (2012) into three levels: "*perception of the elements in the environment; comprehension of the current situation; and projection of future status*".
(3) NDM adhere to empirical-based prescription, based on how experts describe and assess the situation. (Almklov et al., 2014).

Rational choice theory and NDM give two quite different descriptions of decision processes that require different information. The information includes risk, which is one of the important dimensions for decision-making to avoid major accidents. It is important to recognize the role of risk in different decision scenarios with these two schools of decision theory as basis, to develop different ways of presenting/providing information and corresponding risk assessment methods to help with searching for risk reduction measures and effective risk control measure. In the next section, categories of decision types that are faced by different levels of decision-makers are looked into to see the expected role of risk in decision-making and further explore types of risk information that are needed.

3. Classification of decisions from a risk assessment perspective

In this paper, we have chosen to classify decisions into four categories (Fig. 2). First, we differentiate between *planning decisions* and *execution decisions*. *Planning decisions* are characterized by a (relatively long) time lag between the decision and action. The time lag is long enough to systematically identify and evaluate different alternatives. *Execution decisions* are made by sharp-end personnel (personnel who monitor or control on-going operation and/or emergency response teams) with much less time lag between action and decision and will be characterized by minimal or no planning (although decisions may be taken based on "generic planning", such as emergency response plans). Examples of decisions are execution of an intervention and reacting upon deviations.

Planning decisions are further divided into two categories: *strategic decisions* and *operational decisions*.

- *Strategic decisions* are characterized by a long planning horizon (with time to consider risks and benefits of choices carefully), low decision frequency, and long-term effects. The disadvantage is that few details often are available, limiting the available information or making it uncertain. Blunt-end decision-makers make these decisions. Examples are approval of major projects, choosing from alternative designs/technology, and deciding on maintenance strategy before operation starts.
- *Operational decisions* are related to actions that will be taken and implemented within a shorter period. The planning period is relatively short, however, long enough to carry out formal risk assessments. Middle-level decision makers, such as operational managers, typically make these decisions. Approval of medium term operational plans, e.g. for a 1–3 month period, approval for initiating projects, and approval of shorter term operational plans (1–2 weeks) are examples of *operational decisions* which require risk assessment to understand both short term and long term effects on risk. Another type of *operational decisions* is made on a daily basis, such as approving work permits and daily plans.