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Application of Fuzzy Sets Theory in Qualitative and Quantitative Risk Assessment

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ABSTRACT

Risk analysis has become a powerful tool for identifying technical solutions and operations with high risk, and it is extensively used in the offshore industry. Risk analysis is also used to identify, assess and compare risk-reducing measures. For events where a database exists, the risk figures estimated in a quantitative risk analysis can be considered to represent the risk involved when carrying out said operations. For special operations where little previous experience exists, one has to rely on the experience of experts in order to establish probability figures. In a Bayesian risk-analysis approach, the values suggested by the experts represent the uncertainty in the expert's estimate. We will use the Fuzzy Sets Theory (Zadeh, 1965), a tool that is mathematically stringent in identifying, qualitatively or quantitatively, possibilities of accidental scenarios relying on the experts' assessments. This paper illustrates the use of the fuzzy sets method by assessing the risk during the lifting of an offshore module onto a live platform and the risk during an offshore tow operation.

INTRODUCTION

A risk assessment is concerned with measuring the risk of an operation towards the acceptance criteria set for this operation. The measurement of the risk can be qualitative or quantitative, depending on the availability of a suitable database for quantitative assessment. In certain operations/areas and industries, probability figures for unwanted/unsuccessful events have been collected over a long period. This applies to the nuclear industry, the operations of offshore platforms, and certain parts of the civil construction industry, such as crane lift operations.

The logics of risk assessment are well defined: Fault trees are used to define the probability for base events to happen, and event trees are used to follow the possible escalation of these events.

A risk assessment utilizing this methodology is well suited for the identification of activities that can contribute to high operational risks. The major weakness with a risk analysis relates to the identification of the probability for unwanted events to occur. In the case of a qualitative risk analysis, the *measurement* of the probability will highly subjectively be assessed as high, medium or low, although a finer mesh might be imposed.

In a quantitative risk assessment, a probability figure is introduced representing the likelihood for the unwanted event to happen. The probability figure could be found from relevant databases, such as the OREDA database (*Offshore Reliability Data*, 1992) referred to in offshore risk assessments. For special operations where no database exists, or for operations of the one-of-its-kind type, what results is a complete reliance on the analyst's subjective views. The analyst will in most cases, however, consult with technical experts and review the literature on the outcome of similar events in order to reduce the uncertainty in his/her quantitative assessment. In Bayesian theory, the judgment of the analyst is suggested to represent the uncertainty in the analyst's assessment.

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We will present an alternative way to qualify or quantify the probability that unwanted events occur: Use of the fuzzy sets theory, so that the analyst gives his/her assessment in the form of a range. In order to show the usefulness of the method, we will present examples of traditional qualitative and quantitative risk analyses. These examples are the towing of an offshore platform's deck, an example that is considered highly relevant in view of the large amount of marine operations presently conducted by the offshore industry (Gudmestad and Rettedal, 1999). Another example, illustrating a module being lifted onto a platform in operation, will be assessed through a qualitative analysis.

EXAMPLE 1: COMPARISON BETWEEN TRADITIONAL QUANTITATIVE RISK ANALYSIS AND RISK ANALYSIS BASED ON FUZZY SETS THEORY

The case we will consider is the towing of an offshore platform's deck (Nilsen et al., 1998) that weighs 22,500 *t* and was fabricated on 4 barges in dry dock (Fig. 1). The deck, as well as the 2 center barges, were transferred onto a heavy lift vessel/barge specifically designed for offshore tow from one Norwegian fjord to another (i.e. from Stord Island in Hordaland to Vatsfjord in Rogaland). The tow had to pass through open waters across Sletta north of Haugesund and along the western coast of Karmoy Island, prior to entering sheltered waters at the entrance of Boknafjorden. It was not considered feasible to transport the deck on multiple barges without the transfer onto the heavy lift vessel. Further, strict operational criteria were set for the tow (significant wave height less than 2.0 m), including the requirement of a forecast of "good weather." The results of an analysis of the uncertainty in weather prediction capability were implemented in the risk analysis of the towing operation (Brabazon, Hopkins and Gudmestad, 1996).

Traditional Quantitative Risk Analysis of Deck Tow Operation

A traditional quantitative risk analysis was conducted for the transport of the large deck of an offshore platform from the fabrication yard to the location where the deck would be transferred