A method for developing and structuring risk activity indicators for major accidents

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Abstract

An activity indicator for work on offshore petroleum installations is developed, in order to reflect the risk of hydrocarbon leaks during planned activities in a medium long time scale. The indicators may be used proactively during planning, and are risk based, in the sense that the risk levels reflect the likelihood of loss of personnel, according to the severity of the leak, and expected performance of barriers. The approach is briefly compared to a more simplified scheme. Further work is outlined, including extended focus on concurrency of activities, and testing on a pilot installation.

1 Introduction

The 'Risk level report' for the Norwegian Continental Shelf [1] has documented that only about 30% of the hydrocarbon leaks are due to normal operation, implying that the majority of the leaks are due to some kind of manual activities, intervention and maintenance work. Hydrocarbon leaks are usually the main source of risk for major accidents for the offshore petroleum producing installations.

It is therefore important to address risk associated with manual activities. This is the topic of a research activity financed by Statoil and the Norwegian Research Council, called 'Activity indicators'. Statoil has been developing four different indicators for major hazard risk [2]:

- Basic barrier indicator
- Barrier performance indicator
- Incident indicator
- Activity indicator

Activity indicators are particularly important, as they are proactive indicators, whereas the other indicators are reactive. The main benefit of the proactive indicators is that they are forward looking, and may be used for optimization and planning purposes. Clearly it is useful to combine reactive and proactive indicators.

The paper presents the current work in the research project in order to develop activity indicators for Statoil, at present limited to activities that may cause hydrocarbon leaks, based on work in [3], [4], [5] and [6]. The basis for the development is to a large extent inspired by work in the nuclear sector, see for instance [7], [8] and [9].

2 Description of Approach

The approach described in this section is a brief summary of the approach. The full description is available in [10]. An activity indicator may be stated as

$$AI_i = n_i \cdot w_i \tag{1}$$

where

- AI_i is a risk based activity indicator for an activity i,
- n_i is the number of planned activities for activity i in a future period, and
- w_i is a risk weight factor for activity i, i.e. the expected risk per activity

The user of the activity indicator expresses the activity levels n_i according to the activity plans. We express the weight factor w_i as

$$w_i = \sum_s P(L_s \mid i) \cdot E(X \mid L_s) \tag{2}$$

where

- s is the size of the hydrocarbon leak
- L is the occurrence of a hydrocarbon leak
- i is a risk activity, and
- X is the number of fatalities.

Incident and exposure data for one Statoil operated field during a five-year period were examined. The distribution of leaks sizes are quantified as

$$P(L_s \mid i) = P(L \mid i) \cdot j_i \cdot f_s \tag{3}$$

where

- j_i expresses the observed proportion of significant hydrocarbon leaks related to activity i on the Statoil operated field.
- f_s expresses the observed proportion of significant activity related hydrocarbon leaks that fall in the categories on the Norwegian Continental Shelf in the period 2001-2002.

A sensitivity analysis was carried out to decide which of the analysed activities that have the greatest potential for risk reduction. The weight factor w_i serves as an expression of sensitivity. Based on the sensitivity analysis it was concluded that the activity indicators should be based on 'Work on pressurized equipment', 'Start-up of process equipment' and 'Changes in process conditions'.

2.1 Presentation of the activity indicators

A bubble diagram is well suited to present information in three dimensions. In the figure below each activity is represented by a different colored bubble. The y-axis represents a possible activity level associated with the activities, and the size of the bubble represents the activity indicator value associated with the activity level of each activity.

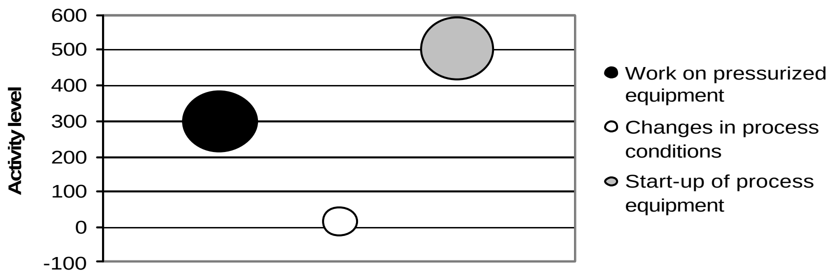

Figure 1 Activity indicators associated with a typical activity level during a year on a large offshore petroleum installation

This figure clearly shows how the activities contribute to the risk indicator picture. The activity planner will with such a tool have an opportunity to evaluate the plans. He/she can change the number of work orders related to each activity, and get a quick overview of how this will change the sizes of the activity indicator 'bubbles'. This could be a valuable tool to reduce risk at the installation.

The activity planner may also be interested in getting an overview of the activity indicators during a high activity period. To facilitate this, accumulated indicator values for each week could be presented. Another important feature of the activity indicator is that it could be used to choose how a project should be implemented, by comparing the activity indicator scores of different alternatives.

2.2 Use of the Activity Indicators

Statoil could be interested in making the activity indicators a standard procedure for key personnel at the installations. Many activities are usually planned on a weekly basis, and then more in detail on a daily basis. When the activities are planned, these plans will be registered electronically in the control room, so this is a natural time to use the activity indicators.

The activity indicators could be made available for the management. The managers may then test their activity plans and combinations, before plans are finalized. This may help avoiding unwanted high-risk periods, and could also serve as a tool to boost involvement in and understanding of important safety issues. A spreadsheet has been created to facilitate the use of the activity indicators.

2.3 Data Basis

Incident and exposure data for ten activities and conditions were gathered, and were used to express the leak probabilities that the activity indicators are based on. The chosen approach takes into account that the distribution of leaks related to 'Changes in process conditions' is quite different from the two other activities.

3 Decision Support and Challenges

A proactive use of the indicator makes it possible to include risk impact in activity planning, in particular when deciding where to implement risk reducing measures. Indicator values for different sets of planned activities can be compared. They can be plotted as a function of activity type, time or different project options, giving the decision maker the possibility to put safety related focus where risk is highest (see example in Figure 1)

The indicator model presented in [3] focuses primarily on risk related to independent activities. Sets of activities can be evaluated and compared with regard to hydrocarbon leak risk, with a basis in the local risk analysis. However, the activity 'Hot work', and the condition 'Backlog of planned maintenance', represent risk only in concurrency with another event; a leak. Hence, the relevant weight factors for 'Hot work' and 'Backlog of planned maintenance' refer to the combination of such activities and hydrocarbon leaks.

A more complicated aspect of simultaneousness is presently not included in the activity indicator model: How will a number of parallel activities influence risk? Intuitively, 'Work on pressurized equipment' simultaneously with 'Construction work' is considered to have a higher risk than the same activities performed in sequence. Expressing the risk related to high activity levels (a high number of parallel activities) is difficult, and there are little data available for establishing weight factors.

The issue of parallel activities should be further explored, as it would give decision support to risk evaluations performed daily by operations personnel: How to coordinate activities in a way that minimizes risk?

4 Alternative Approach

In the oil and gas industry also other approaches for using activity based indicators have been considered. An example is the approach by Norsk Hydro, in which activity indicators are defined and used as a part of a larger group of indicators related to major hazards. From an initial set of activities that influence risk: corrective maintenance, hot work, crane lift, backlog of preventive maintenance, 'outstanding corrective maintenance, 'outstanding' measures, alarms, shutdowns, electric power failures and inhibits (inhibits of e.g., gas detectors), three were chosen to be the basis of Norsk Hydro's activity indicators: 'Backlog of preventive maintenance', 'Outstanding corrective maintenance' and 'Inhibits'. The choice was made based on the activities' significance for safety and the access of data.

An overall key performance indicator related to activities, KPI_A, summarises the information from the various indicators. This overall indicator is defined by

$$KPI_A = \frac{k_1 \cdot N_{PM} + k_2 \cdot N_{CM} + k_3 \cdot N_{BP}}{n} = \sum_{i=1}^{3} \frac{k_i \cdot N_i}{n} \quad (4)$$

where

- k_i is a risk weight factor for each activity, where $\sum_{i=1}^{3} k_i = 1$
- N_{PM} is the number of work orders related to preventive maintenance
- N_{CM} is the number of work orders related to corrective maintenance
- N_{BP} is the number of inhibits and by-passes in the last three months, and
- n is the number of tags.

The goal of the indicators is to improve the safety management by monitoring the technical conditions. The indicators are used by all sectors of Norsk Hydro, and are based on existing reporting systems, i.e. by counting equipment and reviewing databases. The indicators are used by the managers and safety inspectors, and give a focus on safety, identify needs for changes and improvements. They are also used for budget prioritization.

It has recently been decided to remove N_{CM} and N_{PM} from the original activity indicator as expressed by KPI_A above. This implies that only 'inhibits' remain as the basis for the indicator.

5 Conclusions and Recommendations

Activity indicators may be used to optimize activity plans and avoid high-risk periods. The approach presented in this paper is relatively detailed and requires quite extensive input data. This is nevertheless the recommended approach due to the opportunity to influence planning in a proactive manner.

A pilot project is being planned in order to test the approach on a specific installation. This will provide more insight into whether and how the activity indicators should be implemented on a permanent basis , including:

- For which planning horizons would the activity indicators be most useful? (Long-term planning; 1-3 months; 1-7 days?)
- How can concurrency between activities best be included?
- Should 'Hot work' or other activities be included?
- How has the pilot installation benefited from the use of activity indicators?

It is also the intention to test the simple, reactive indicator, based on the number of inhibits retrospectively, in order to learn what this approach can offer as a supplement to the proactive indicator.

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