On Context, Issues, and Pitfalls of Expert Judgement Process in Risk Assessment of Arctic Offshore Installations and Operations

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Abstract - **Decisions to be made in the Arctic offshore operations rely extensively on risk assessment outputs, which require a great deal of historical data and information. However, at the current stage of operating in the Arctic offshore – compared to normal-climate regions – such data is scarce due to the limited industrial activities to date. Lack of data on the probability of the occurrence of an unwanted event and, given severe Arctic environmental conditions, the extent of potential severe consequences pose a great deal of challenges and issues for decision-makers. A widely acceptable alternative is the use of expert judgement process. However, this is faced with some issues and pitfalls, which may raise questions regarding the objectivity and level of uncertainty of risk assessment outputs. In this paper, we discuss such issues and pitfalls associated with expert judgement application in risk assessment of Arctic offshore operations**.

Keywords – **Risk assessment, expert judgement, decision-making, unwanted event probability of occurrence, unwanted event consequences**

I. INTRODUCTION

In the recent decade, the Arctic offshore has faced with an increasing trend of industrial activities, especially oil and gas (O&G) operations and their related activities such as offshore logistics support. Stakeholders involved in such activities often need to choose among several alternatives in accordance with their associated risks. Such a risk-based decision-making involved in the design and operation phases in a normal-climate area (e.g., the North Sea, Gulf of Mexico) is less challenging than that in cold-climate areas and the Arctic offshore, which is due to, for instance, notably different conditions under which an industrial activity takes place.

The Arctic offshore is usually characterised by sensitive environment and harsh meteorological and atmospheric conditions, including low air and sea surface temperature, low wind chill index, snow shower, atmospheric and spray icing, polar low pressure system (especially in the Norwegian Arctic waters), iceberg, and various types of sea ice [1-8]. Polar nights and reduced visibility due to summer fog are other issues faced with the industrial activities in the Arctic offshore. In addition, required infrastructure in normal-climate region, where industries have been operating for a considerably long period, is already in place. However, remoteness and lack of appropriate infrastructure remain as issues of the Arctic offshore linked to industrial activities in the Arctic [9-12]. The Arctic is environmentally sensitive to hydrocarbon pollution. Oil and gas compounds may take several decades to go under natural degradation, and hence they create long-term negative impact on the environment and food chain [13].

These characteristics of Arctic offshore impact risk-based decisions including choosing among different the design solutions, as well as operation and maintenance strategies. In order to make informed decisions, stakeholders and decision-makers usually rely on outputs of, often quantitative, risk analysis models. Such models require detailed data and information on failure probabilities of basic components, elements, and tasks involved in an activity or operation, in order to estimate the probability that an unwanted event can occur. Knowledge on potential consequences and their damage extent are other key inputs to any risk assessment model. In normal-climate areas, such information may be acquired from similar projects in the region, or be collected from field reports, handbooks, and databases [14]. This is mainly due to the invaluable experience gained in such regions over time.

Comparatively, the Arctic offshore industry does not have such experience and knowledge. On the other hand, employing the field or handbook data obtained in normal-climate areas and applying the same solutions and strategies to the Arctic offshore operations and activities are faced with a great deal of uncertainties due to the differences in notably underlying environmental conditions.

One of the main application areas of expert judgement process is where the data needed for performing an analysis is scarce [15, 16]. In the design and operation of Arctic offshore projects, one may use expert opinions as an alternative source of data required for risk assessment, and thus perform risk-based decisions. However, expert judgement process has its own pitfalls, issues, and challenges that analysts and decision-makers should be aware. Expert opinions are by definitions subjected to uncertainty and bias. Expert selection, elicitation and aggregation procedures add to such uncertainty and bias, which can potentially impinge the reliability of final risk-based decisions [17, 18].

The aim of this paper is to review the concept of expert judgements, and discuss its application in risk assessment of Arctic offshore operations and industrial activities, in addition to highlighting and discussing their associated issues, challenges, and pitfalls. The rest of this paper is organised as follows. Section 2 discusses risk assessment and risk-based decision-making in Arctic offshore projects, where expert judgements can be employed. A review and discussion on expert judgement process is presented in Section 3. Pitfalls and issues regarding the application of expert judgements in Arctic offshore projects and operations, from a risk assessment viewpoint are discussed and described in details in Section 4. Section 5 sums up the paper and presents the conclusions.

II. RISK ASSESSMENT OF ARCTIC OFFSHORE OPERATIONS

A. Risk assessment and decision-making

In a qualitative term, Society of Risk Analysis defines risk in a number of ways, such as the possibility of an unfortunate occurrence; consequences of an activity and the associated uncertainties; severity of the consequences of an activity and the its associated uncertainties with respect to something that human beings value [19]. The common principle in such definitions, is that for describing and characterising the risk, we often refer to a combination of the probability of the occurrence and severity of the consequences of an activity [19, 20]. In performing a risk assessment, the analyst is interested in quantifying the probability of failure, i.e., the probability of the occurrence of an unwanted event, as well as quantifying the extent of event's associated consequences. These will be further used to support decision-makers and stakeholders in making decisions and gaining view on different aspects of available alternatives and issues, acceptance of activities, etc. [19-21].

Risk assessment starts with identification of initiating events, often called "hazards". Further, a cause and consequence analysis is performed for the identified hazards. The cause analysis output determines the basic events that could, in various ways and combinations, lead to a hazard. Mathematical tools such as fault trees are available for estimating the probability of the occurrence of the hazard. By performing a consequence analysis, possible outcomes of the hazard are identified, and some tools such as event tree are used to quantify the probability of the occurrence of each possible consequence. The results are often represented using a risk matrix or a bow-tie diagram, which are further used by decision-makers. Estimation of the probability of failure of a system, or occurrence of basic events as well as performing barrier analysis to quantify the probability of occurrence of each possible consequence, as well as quantifying the extent and magnitude of each possible hazard consequence rely on various types of historical data and information including reliability data.

B. Risk of operations in the Arctic offshore

Type of historical data, suitable for Arctic offshore applications risk assessments and risk-informed decision-making might be the same as those in normal-climate regions. However, influence of Arctic operating conditions on activities and installations must be included and represented by the collected data [2, 14].

As depicted in Figure 1, harsh operating conditions of Arctic offshore can negatively influence the performance of technical systems, human performance, reliability of operations and activities, and, in general, the performance of active and passive safety barriers. This rises the uncertainties associated with the data collected in normal-climate regions and questions the validity of such data and their application to Arctic offshore industrial activities and installations. Harsh operating conditions also increase the probability of the occurrence of failures unwanted events. Additionally, harsh Arctic conditions may lead to failure modes and mechanisms that are not common in normal-climate areas. At the same time, from a risk analysis perspective, the performance of the measures in place for mitigating and limiting both the occurrence probability and the negative consequences of unwanted events (i.e., risk eliminating/reducing measures) may be threatened by harsh conditions of the Arctic offshore.

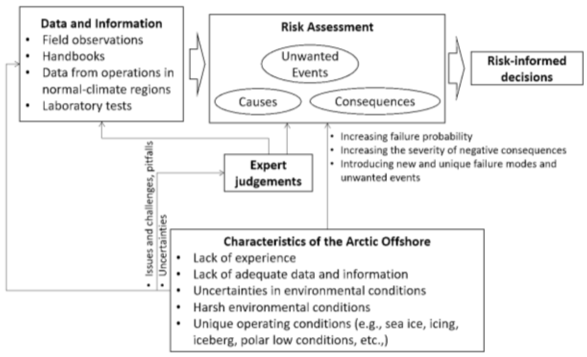

Fig. 1. Issues and challenges in Arctic offshore risk assessment from the viewpoint of harsh conditions and characteristics of the Arctic offshore

In order to evaluate the extent of the impact of Arctic offshore conditions on different elements of risks, not only should the key elements of operating conditions be identified, but also adequate knowledge on their spatial-temporal variations, and the uncertainties associated with such evaluation and estimation should be gained. At the next step, it is required to compute the extent of the negative impact of harsh conditions on the performance of systems, activities, and operations; for example, how cold weather could affect the performance of oil spill cleanup crew, or failures in gas pipelines due to potential gas hydrate formations.

In addition, some elements of Arctic offshore environment may give rise to the occurrence of unwanted events that could only be experienced in the Arctic offshore or cold climate areas. Sea spray icing on vessels and on-board critical equipment (e.g., lifeboats, firefighting equipment), platform haul damage due to sea-ice pile-up, vessel/installation-iceberg collision, are examples of such events [2].

As illustrated in the diagram in Figure 1, due to lack of adequate experience, the historical data for such unwanted events is scarce, which makes the related risk assessment very challenging. Laboratory and field tests and employing some statistical methods such as proportional hazard models and accelerated life models can provide the analysts with a foundation for estimation of the occurrence of unwanted events. However, reflecting upon an unwanted event's possible consequences, estimation of possible losses, and assessing the extent of negative consequences are faced with large uncertainties. To cope with lack of data and information, risk analysts often refer to experts to elicit their opinions. Such opinions may be collected and then combined with data and information available in normal-climate areas or collected and used directly (e.g., brainstorming ideas on possible consequences of an unwanted event; or on success probability of an oil spill cleanup strategy in ice-covered sea) [22, 23]. However, expert judgements are associated with some issues and pitfalls in the context of Arctic offshore risk assessments that should be avoided and tackled accordingly.

III. EXPERT JUDGEMENTS

Expert judgement has been extensively used in a variety of problems in various applications, especially where, no historical data is available, the problem of interest is new to some extent, and conducting laboratory tests and field observation is not feasible [24-26]. Thus, application of expert judgements in Arctic offshore can be justified due to the relatively different operating conditions (compared to normal-climate region) and potentially new technical problems, as well as lack of adequate historical data.

An expert judgement represents the state of expert's knowledge and information on a technical question at the time of response. The way such an opinion is formed in expert's mind, and the way it is presented are included in expert judgement processes as well [26].

In general, an expert judgement process has three main phases, namely, expert selection, expert opinion elicitation, and expert opinion aggregation, which cannot be planned without accounting for their inter-relations [15, 26, 27]. However, before selecting experts, one should clearly define the problem of interest and the level of details in which the information are acquired from experts.

A. Expert selection

Expert selection is the step, where the analyst selects an appropriate reliable number of experts. Irrespective of how an expert might be defined, he/she should have adequate background in the field of interest at a desired level of detail [15]. Experts might be chosen from a pool who are recognised or nominated by their peers. Selection of experts is usually a challenging task, where there is no universal agreement on expert selection criteria. Ambiguity in defining the term "expert", and the fact that there is no quantitative criteria for expert selection, add to the complexity of expert selection process. For instance, qualitative expressions such as "having a desired level of detailed background," "being recognised by their peers," and "being qualified" [16, 28].

The problem of interest may be complex in a way that it requires knowledge on a diverse range of fields, and thus a single person may not meet all the scientific requirements. Under these circumstances, such a person usually evaluates the problem mainly from his/her scientific background perspective. This, however, could have a positive impact on final answer for the technical problem, as it creates a foundation for evaluating the problem in hand from different angles.

B. Expert opinion elicitation

Expert opinion elicitation refers to a specifically designed process by which the opinions of experts on the technical problem are obtained [15, 16, 29]. Such a process may occur by means of a survey, interview, group meeting, or questionnaire. Obtained opinions may have a qualitative or quantitative nature. In quantitative expert opinion elicitation, experts present their ideas about a parameter in the form of a point-value, a distribution, parameters of a distribution, quantiles of a distribution, mean and standard deviation, ratio and interval scaling, etc. [30].

C. Expert opinion aggregation

Elicited expert opinions should be combined to form a single solution to the technical problem that can be used by the decision-maker [15, 16, 29]. Mathematical aggregation of expert opinions procedures may include Bayesian, axiom-based, method of moments, fuzzy set theory [27, 31-34]. In Bayesian approach, the analyst original opinion as the new information in the form of expert opinions are received. Axiom-based methods, which are very common, rely on weighted linear and logarithmic averaging rules [16, 24, 29, 35]. In these approaches, each expert receives a weighting factor representing his or her relative competence or importance of opinion with respect to other experts' opinions [29, 36].

IV. EXPERT JUDGEMENTS ISSUES AND PITFALLS

Although expert judgement process can be used as an alternative way of collecting required data for risk assessment of Arctic offshore operations and installations, it has its own issues and pitfalls that should be considered, managed, and dealt with. Not tackling such issues accordingly, faces the risk assessment results and thus risk-based decisions with a great deal of uncertainty. Some aspects of such issues and pitfalls are related to the expert judgement process itself, while some others are related to the technical problem concept, i.e., probability of the occurrence of unwanted events and their consequences in Arctic offshore applications.

Selection of experts from a pool of candidates should be made in accordance with the content of the problem, as well as expert's related background. In this regard, selection criteria should account for expert knowledge on the operations and activities of interest, the operating and environmental conditions of the Arctic offshore, the impact of such conditions on the operations and activities as well as on the performance of the installations and equipment units. Given the industry's lack of extensive experience in the Arctic offshore, experts' knowledge on such problems is thus limited and has some uncertainties. The same argument holds for seeking expert opinions on the consequences of failures in Arctic offshore. For instance, remoteness, level of infrastructure, and harsh weather conditions coupled with lack of industry's experience make it even more difficult for experts to present their opinions on the probability of a successful oil spill clean-up operation, or search and rescue operations as passive safety barriers. This happens mainly because experts often form their judgements based on some implicit models considering various effects of environmental and operating conditions on different activities and operations, as well as on potential failure mechanisms of safety barriers in place. Such effects are usually complex, interrelated, and uncertain, which make the process of developing the implicit models a difficult and challenging task.

In addition, expert judgements are conditioned on their knowledge, data, information, and justified beliefs often formulated as assumptions, which are mainly gained from industry's experience in normal-climate regions. Tuning such knowledge and employing the impact of Arctic harsh environmental conditions is an issue that adds to the uncertainties associated with expert opinions.

Another issue is related to the formulation of the questions to be asked from experts and the way expert opinions are elicited, which may fail to cover the whole aspects of the problem of interest. For example, the final decisions made based on expert opinions on the probability of success of a specific oil spill clean-up strategy, may be different from that which is based on expert opinions about the potential impact of harsh Arctic conditions on various elements of clean-up strategy, such as equipment, human performance, available infrastructure, window-of-weather, etc. This is of special importance, once experts have diverse backgrounds and may suffer from lack of adequate knowledge on the whole concept.

Furthermore, expert opinions suffer from various sources of bias such as structural bias, motivational bias, and cognitive bias. While structural bias is related to the way the problem is formulated, motivational bias is hard to be reduced and controlled by the analyst [15, 17, 18]. For instance, while oil and gas operations are subjected to debates in societies, expert opinions on failure probabilities and failure consequences can be affected, unintentionally, by their overall view on the subject. Overconfidence, anchoring, and availability are different sources of cognitive bias that also impact expert opinions negatively. For instance, anchoring refers to the facts that the frequency of an event or the severity of a consequence is likely to be overestimated when experts recall an extreme and yet rare similar event in normal-climate areas. In such cases, it is difficult to objectively analyse the impact of Arctic harsh conditions on the problem of interest. At the same time, anchoring may lead to an underestimation of the probabilities, as experts may fail to capture the effects of Arctic harsh conditions on the problem of interest.

Expert opinions are often combined using averaging methods, where each expert receives a weighting factor. Although some approaches, such as performance-based weighting approach [29, 36] are developed to assign the factors based on expert's knowledge, the diversity of expert backgrounds, raises questions regarding the applicability of such an approach. Dependency among expert opinions is another issue, which is related to the same pool of information where experts use to form their opinions.

Regarding the context of the problems presented to the experts, a special concern is the occurrence of some events that are specific to the Arctic offshore. For example, while once is concerned with the analysis of escape, evacuation, and rescue (EER) in the Arctic offshore as a passive barrier, special failure mechanisms related to Arctic operating conditions may be missed. This may include the probability of not being able to use lifeboats or escape ways because they are blocked by sea spray ice. The impact of sea ice on reliability of lifeboats and thus its effects on EER reliability is also a case specific to Arctic offshore operations.

V. CONCLUSIONS

Due to the less industrial experience in the Arctic offshore, risk-based decision-making in industrial operations and activities in the Arctic offshore are often faced with the issue of scarce historical data for risk assessments. Differences among environmental conditions make it difficult for risk analysts and decision-makers to adopt the data collected and information gained in normal-climate regions and apply in Arctic offshore risk assessments.

Employing expert judgements, although seems to be an alternative approach, is faced with some issues and drawbacks potentially resulting in a large degree of uncertainty in the analyses and thus risk-based decisions to be made. Such issues and pitfalls can be related to the process of expert judgement itself, such as those involved with problem formulation, setting expert selection criteria, elicitation methods, and aggregation techniques. In addition, the nature of the Arctic offshore and its harsh and yet sensitive environment, can increase the uncertainties associated with expert judgements. Experts, analysts, and thus decision-makers should be aware of such issues and pitfalls. Different approaches of problem formulations, selection of a diverse expert panel in brainstorming tasks, and employing different elicitation and aggregation methods could be beneficial. Breaking down the problem into a number of sub-problems that are presented to the experts, and finally developing mathematical models to combine the outputs of different expert panels is an alternative that can be explored in Arctic offshore risk assessments.

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