EXPERT JUDGEMENT AND RISK PERCEPTION

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ABSTRACT
***Risk assessments* are valuable for identifying, analysing and evaluating risks. However, there seem to be a general tendency to accept the analyses as objective measures of risks, when in reality a fair amount of subjectivity is involved. The primary reason for this subjectivity results from utilising expert judgement. Experts exhibit the same types of biases as lay people with respect to perception of risk, especially when forced to go beyond the limits of their observable expertise. Problems associated with using expert judgements stem from the lack of adequate understanding and treatment of biases. As risk analyses are rational procedures for evaluating risks, values and limitations should be taken into account in a realistic and well documented manner. The contributions from the risk analyses may then be combined with considerations of subjective perceptions of risk and value judgements in the decision making process.**

KEY WORDS: Risk Analysis, Risk Perception, Expert Judgement

INTRODUCTION

Risk assessments are structured methods for identifying, analysing and evaluating risks, which provide useful support in decision making and the regulatory processes. A risk assessment typically consists of hazard identification and ranking, risk analysis, evaluation and communication. Prior to the assessment phase, it is desirable that risk is handled as 'risk as is', while in the assessment and communication phases 'risk as perceived' and value judgements may be considered[1]. It is well documented that risk as perceived by the public in many cases deviates from the risk as is, based on objective documentation. However, it is less recognised that experts utilised in risk assessments may introduce subjectivity and biases into the assessment. Risk assessments are typically based on statistics and historical data, but in cases that statistical data do not exist, are not available, or are insufficient, an alternative is to obtain information from experts. An expert is defined as a person with background in the subject area and who is recognised by others as qualified as an expert in that subject area. The use of experts is a valuable approach; however, one has to be very aware of the limitations. Especially in the case that experts are asked about opinions and judgements that are not directly in their area of expertise, the experts will be influenced by biases in a similar manner as lay people.

In this paper, brief reviews and descriptions of perception of risk and the expert judgement process are given. Expert judgement is an informed opinion based on the experts training and experience. Experts may provide information, evidence, judgements and assessments. The terms are often used interchangeably, even though they suggest various degrees of value judgements. In the following discussions, the term expert judgement[2] will be used for the process of eliciting information from experts. Based on the reviews of the expert judgement process and risk perception, an attempt is made to link the two issues with respect to risk assessments, as well as decision and regulatory processes.

MOTIVATION

The use of experts in the Formal Safety Assessment (FSA) process has resulted in considerable controversies in the International Maritime Organisation (IMO). FSA is presented as objective, scientific, transparent, etc. However, if only expert judgements are presented without documentation of evidence, the FSA process is neither renewing nor improving the current IMO decision process.

The concern with respect to extensive use of expert judgement was further increased through an informal experiment in which 20 experts in maritime safety were presented with the following statement:

> *M/S MARION is a 19 year old bulk carrier owned by a Turkish ship owner, classed in Hellenic Ship Register. The ship flies the flag of Sc. Vincent, and is operated by a Cyprus based ship management company.*

The experts were asked which of the following statements about M/S Marion is most likely to be correct:

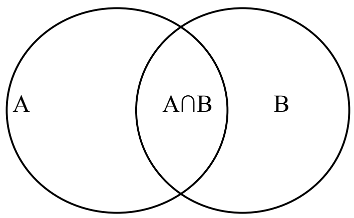
1. *M/S MARION is larger than 70.000 gross tonnes*
2. *M/S MARION is larger than 70.000 gross tonnes and has been detained twice in port state controls this year.*

Approximately 75% of the respondents concluded that the second statement was most likely to be correct. (One expert defined a third option as *M/S Marion disappeared a few months ago…*, which the expert found to be the statement most likely!) Compared to the first statement, the second statement is of course the statement least likely.

[1] Objective risk, actual risk and risk per se are other terms used for 'risk as is', while subjective risk is another term for 'risk as perceived'.

[2] Also called expert opinion, subjective judgement, expert forecast, best estimate, educated guess, and expert knowledge.

According to probability theory, increasing the specificity of an event will decrease its probability. That is, by considering the following:



x = *M/S Marion*
A = *Larger than 70,000 gross tonnes*
B = *Detained twice in port state controls this year*

It is easily seen that the probability of $x \in A$ is larger than $x \in (A \cap B)$. However, people tend to violate logic when asked to make probability estimates. The reason being that subjects tend to base their assessments on implicit similarity judgements. The tendency to judge probability on the basis of similarity, even though the two parameters are by no means equivalent, is a phenomenon called the conjunction fallacy.
The above experiment demonstrates that experts are subject to similar biases as lay people. Even though they may not be influenced in the same manner or to the same extent, it is evident that expert judgements should be utilised with great caution.

LAY PEOPLE AND RISK

The definition of risk utilised in risk assessments, i.e. probability times consequence, is not a universal definition. The word 'risk' is known to be ambiguous and many more or less specific definitions have been attributed to it. According to Sjöberg (1980), there are three broad classes of meaning:

1. Probability of negative events
2. Concern of the consequence of the negative events themselves
3. Joint function of probability and consequence of events

As the product of probability and consequence is the definition of risk associated with an event in typical risk assessments, it may not be surprising that numerous misunderstandings appear in communications of risk, as perceived risk may not be well represented by this product.

Background

The scientific investigation of risk perception was primarily a concern of the psychologist and sociologists. Early research, e.g. Green and Brown in the UK, Otway and colleagues in Austria, and the Decision Research group in Oregon, U.S., with Slovic, Fischhoff and Lichtenstein, appeared as a response to a paper by Starr in which he discussed the revealed preference approach and the emphasis on the dimensions of voluntarism and magnitudes of consequences, Starr (1969). Critics described research in which they were unable to replicate Starr's result using the same database, concluding that the method was not suitable to identify determinants of risk perception, Otway and Tomas (1982).

According to Pidgeon et al. (1992), four major trends are visible in recent risk perception literature. First, it is no longer believed that any risk assessments leads to an objective risk result. Analyses of risk, both with and without expert opinion, depends on human judgement, and it may therefore be argued that the analyses to a certain extent involve subjectivity. Second, the early psychological empirical studies of risk perceptions have evolved to a mature discipline. The approach is based on the traditions of cognitive psychology (study of human memory, sense perception, thought and reasoning) and human decision-making behaviour. Third, rather than only considering purely individual, psychological explanations, researchers attempt to include social, cultural, and political processes. Fourth, risk communication has become a major concern.
Risk perception research was further developed by Litai in his PhD thesis, in which he analysed risk utilising 25 factors, each having a dichotomous scale associated with it. The factors are found to be similar to factors addressed by Rowe (1977), Starr (1969), Kinchin (1978), Otway and Cohen (1975). Green et al. (1998) also list factors very similar (but not quantified) to the factors identified by Litai, even though no reference is made to the work of Litai or the references in the thesis, Litai (1980). The 25 Risk Conversion Factors (RCFs) identified were reduced to 9 factors by Litai, based on the realisation that some factors are similar. In the study, the only consequence considered was death, or the death to injury ratio was assumed to be the same for the activities or technologies considered.

Individual and Social Characteristics

Risk perception is at least in part dependent upon individual and group related variables. There is evidence that gender and age may influence the evaluation of risk, although the precise interpretation is uncertain. For example, several studies have found that women perceive more risk to the environment compared to men. One study found that students emphasise risks to the environment, while older people emphasise health and safety issues, Pidgeon et al. (1992).
In a US survey, only weak effects were found of socio-demographic variables. In contrast, a French study found a complex configuration of socio-demographic differences which appeared to relate predominantly to the social location of the respondents, Pidgeon et al. (1992).
Several cross-cultural studies of risk perceptions have been performed, which attempt to investigate differences as well as similarities in perceptions between different national, ethnic, racial and institutional groups. For example, U.S. citizens have been found to underestimate the risk related to sports, while Norwegians tend to underestimate health risks, Paoli (1996).
Some studies have been performed based on 'worldviews', with the aim of investigating whether constellations of attitudes and beliefs may be related to perception of risk and preferences with respect to risk acceptance. This cultural theory approach claims that attitudes towards risks vary systematically according to cultural biases. Cultural biases refer to attitudes and belief shared by a group, which cannot be explained by individual psychology or by natural science analysis. Four different worldviews are typically identified, namely hierarchists, sectarians or egalitarians, fatalists, and individualists. Sometimes a fifth category, autonomists, is added. The characteristics of the four major worldviews may be defined as follows, Pidgeon et al. (1992):

- **Hierarchists:** Willingness to set acceptable risks at high levels as long as decisions are made by experts or in other socially approved ways
- **Egalitarians:** Accentuates the risks of technological development and economic growth so as to defend their own

way of life and attribute blame to those who hold to other cultural biases

- **Fatalists:** Unwillingness to knowingly take risks but accept what is in store for them
- **Individualists:** Realisation of risk and opportunity as going hand-in-hand

Heuristics

A theoretical framework, based on work of psychologists Tversky and Kahneman, has been developed in order to explain risk evaluations in terms of intuitive mental rules-of-thumb strategies that people use when judging the likelihood of everyday events. The strategies are easily applied in a variety of situations and often lead to reasonable decisions, Glass and Holyoak (1986). That is, heuristics may yield quick, intuitive insights, but may also result in dramatic lapses of logic. The heuristics are used by people in everyday life, but also by decision-makers and experts consulted when performing risk assessments. The different heuristics may be grouped in the following manner:

- **Structural biases**

Structural biases[3] involves the situation in which individuals are unduly influenced by the manner a problem has been structured before it is presented to them, Risk Analysis Workshop (1999). Even minor changes in the presentation may strongly influence the resulting answers. Probability judgements are especially vulnerable to the presentation and organisation of events in risk assessment, as individuals are relatively insensitive to omitted events and overly sensitive to events presented in great detail.

- **Motivational biases**

In cases in which an individual has a stake in the outcome of an analysis, motivational biases will most likely occur. For example, an individual involved in the design of a system, even though an expert with respect to that system, is likely to imply that the system is safer than it actually may be.

- **Representativeness**

Judgements related to categorisation often involve assessment of the similarity to the prototype of a category, Glass and Holyoak (1986). Probability is often evaluated based on degree of representativeness or similarity, which by no means is equivalent, e.g. an individual is judged to be a scientist if he/she fits the general impression of a scientist (e.g. curious, intelligent, etc.). Also, similarity is not always symmetrical; similarity of two items may be reduced if the more salient item is placed in the subject position, in which its distinctive features dominate. For example, Poland may be perceived to be more similar to Russia than Russia is to Poland, Glass and Holyoak (1986). Also, when individuals are given information about an individual case, they often ignore prior odds.

- **Availability**

Availability heuristics involves basing judgements on the ease with which relevant instances can be retrieved from memory, Glass and Holyoak (1986). Availability is based on the reversed rule stating that associations are strengthened by repetition. That is, if memory associations are strong, it is concluded that the events in question must be frequent. How perceptually available a parameter is may depend on the following factors:

- Distinctiveness
- Ease of visualisation
- Obviousness

In this manner, a recent disaster or a vivid movie easily distorts risk judgements. That is, frequencies of well-published causes are easily overestimated, while the frequencies of less notorious cases are underestimated.

- **Anchoring**

Anchoring is the phenomenon that subjects, when asked to estimate a probability, sometimes will fix on an initial value and then adjust this value, Cooke (1991). That is, an estimate is made by starting with an initial value, which may be suggested by the problem statement, and the initial value is adjusted to yield the resulting value. In cases in which anchoring heuristics occur, the resulting value is biased toward the initial value, i.e. the adjustment is insufficient.

- **Simulation**

In simulation heuristics, the perceptions or decisions are based on examples or scenarios that are constructed by the reasoner. Simulation heuristics may be demonstrated by the experience that defeats almost avoided and victories almost gained are the most difficult moments in life, Glass and Holyoak (1986).

The previously mentioned conjunction fallacy, which reveals that people tend to judge probability on the basis of similarity and violate the probability theory which implies that increasing the specificity of an event will decrease its probability, is an example of representativeness. Analogical reasoning incorporates elements of both representativeness and availability. In cases of being faced with a novel situation, individuals will recall a familiar situation that seems related, evaluate the similarity, and in that way use a known case to make predictions with respect to the novel situation. In most cases this approach is useful, but it is vital that the decision is based on functionally relevant attributes.

An additional consideration is belief-biases, which are biases to accept arguments that result in conclusions believed to be true, and to reject arguments that result in conclusions believed to be false. The belief-bias effects may tend to make people's beliefs impervious to rational arguments.

Operational Experience

Experiencing an accident or a near-miss accident makes a person biased with respect to that risk. There exist different hypotheses with respect to risk exposure. Perceived risk caused by risk exposure may awake attention and cause safer behaviour, or it may cause stress reactions which reduces the ability to cope and therefore cause risk behaviour. Individuals that have not experienced any risk exposure or that perceive a risk to be negligible may reveal risk behaviours, Rundmo (1998). With respect to inspectors/surveyors, individuals may pay special attention to particular hazards, sometime at the expense of other hazards, based on accidents they have investigated. In addition, the cumulative effects of accident information may affect the individual's perception of risk, Short and Clarke (1992).

Risk Characteristics

In the work by Litai (1980), nine risk characteristics associated with risk perception were defined. For each of the nine risk characteristics, Risk Conversion Factors (RCFs) were identified, based on surveys and reviews, as presented in Table 1.

[3] Another term for 'structural bias' is 'framing'.

Table 1: Risk Characteristics and Risk Conversion Factors		
Characteristics	**Scale**	**RCF**
Volition	Voluntary-Involuntary	100
Severity	Ordinary-Catastrophic	30
Origin	Natural-Man-made	20
Effect Manifestation	Delayed-Immediate	30
Exposure Pattern	Regular-Occasional	1
Controllability	Controllable-Uncontrollable	5-10
Familiarity	Old-New	10
Benefit	Clear-Unclear	-
Necessity	Necessity-Luxurious	1

The RCFs may be utilised as a measure of risk acceptability, as well as an indication of the manner in which the risk perception may influence judgements about risk. By identifying the characteristics of the specific risk being evaluated with respect to the RCFs listed in Table 1, it is possible to calculate the RCF for the specific risk. For example, a risk characterised as man-made and immediate may be described as having a RCF of 600, i.e. 20x30, compared to natural and delayed.

In a more recent review described in Green et al. (1998), a different dichotomous/binary scale was used based on an UK-Department of Health document, HEA/IEH (1977). The RCFs were called risk perception fright factors, with the following definitions and examples:

- **Involuntary** (e.g. exposure to pollution) rather than voluntary (e.g. dangerous sport or smoking)
- **Inequitable distributed** (i.e. some individuals benefit while others suffer the consequences)
- **Inescapable** by taking personal precautions
- Arising from an **unfamiliar** or **novel** source
- Resulting from **man-made**, rather than natural sources
- Causing **hidden** and **irreversible** damage, e.g. though the onset of illness many years after exposure
- Posing particular danger to **small children** or **pregnant women** or more generally to **future generations**
- Threatening a form of death (or illness/injury) arousing particular **dread**
- Damaging **identifiable** rather than anonymous victims
- **Poorly understood** by science
- Subject to **contradictory** statements from responsible sources (or, even worse, from the same source)

EXPERTS AND RISK

Risk assessments are often criticised for relying too much on the judgement of experts. However, as the purpose of the risk analysis is to assist in decision making, it may be argued that risk assessments, even with the use of expert judgement, is at least better than the alternative of not having any assistance in the decision making process. Even though risk assessments with expert judgements are better than the alternative of no analysis, it is absolutely necessary to realise that expert information should be utilised with the proper caution.

Expert judgement, which by no means is an alternative to statistical data, is an important aspect of risk assessments in cases of insufficient or lack of data, i.e. it is a last resort. In some instances, it is the only solution to solving a problem or carrying out a risk assessment. This is especially true for new systems and rare events. Expert judgement is a more formal procedure compared to "engineering judgement", and there are major differences with respect to documentation, extent of information and completeness, as well as requirements with respect to objective evaluation of judgements. Various literatures exist on the methods of eliciting, analysing and utilising expert judgement. The literature typically covers the preparation phase, the elicitation phase, and the calculation phase, see Meyer and Booker (1991), SINTEF (1998).

Judgement vs. Evidence

Typically, 'risk as is' is the term used for risk measures obtained by databases based on evidence, e.g. frequency of a specific event occurring. However, one should be very aware that databases might provide insufficient or false information. Also, actual vs. perceived risk may be a misnomer; a more accurate term may be 'risk as perceived and ranked by scientists within their field of expertise vs. perceived by anybody else', Fischhoff and Slovic (1983). Judgements are inherent in all risk assessments; however, it may be included in an informal manner. That is, the judgements are implicit, unstructured and undocumented. By making the judgements formal, the judgements become more explicit, structured and documented, Otway and von Winterfeldt (1992).

One approach that attempts to remove the judgmental aspects of expert judgement, is the 'expert information' approach. In comparison to the 'expert opinion' approach, the experts are asked for information and evidence, rather than for their opinions, Kaplan (1990). The approach puts emphasis on the experts' direct knowledge (i.e. experience and evidence) rather than on their ability to process this information into probability estimates.

Expert Judgement Process

In the following sections, some issues of concern related to the actual expert judgement process are discussed.

- **Selection of Experts**

The experts are individuals with knowledge and experience about a specific subject, system or field. The identification of experts is a critical part in the expert judgement process. The following evidence may be used as criteria for selecting individuals as experts:

- Experience in performing judgements and making decisions, based on evidence on expertise, e.g. degrees, research, publications, positions and experience, awards, etc.
- Reputation in community
- Availability and willingness to participate
- Impartiality and inherent qualities like self-confidence and adaptability

A more pragmatic view of an expert is that the selection is not dependent on specific criteria, but rather that the person has as much knowledge and experience with respect to the subject as possible, SINTEF (1998).

In selection of experts, a decision must be made whether to have a single expert or a group of experts. Consulting more than one expert will increase the sample size; however, one may introduce group polarisation. Group polarisation is a phenomenon in which responses individually favoured by the subject population are strengthened by group interaction, Myers and Lamm (1975). A number of theories attempting to explain the polarisation have been proposed, such as that of leadership dynamics, familiarisation with the issues and 'majority rule', have not found to explain the phenomenon sufficiently. According to Myers and Lamm (1975), one theory that has received support is the interpersonal comparison theory. In this theory, it is assumed that people desire to present themselves favourably in relation to others. Therefore, exposure to other's position may cause the subject to adjust his/her own position in order to be perceived more favourably. When a person discovers that the group opinion is more similar to his/her own opinion than expected or that someone else has a more extreme opinion, the person tends to shift in response. Another theory with some support is the informational influence theory. According to this theory, through discussions, arguments are generated which predominantly supports the initial view. Two types of experiments support this theory. The first type of experiment indicates that exchanging arguments produces group polarisation even if no mention is made with respect to initial views. The second type of experiment indicates that the amount of group shift will be determined by the direction of each argument (which side it favours), persuasiveness and novelty (degree to which the argument is not already known to group members before discussion). The theory explains why groups with quite extreme views before the discussion will not show as much polarisation after discussion. It also implies the conditions under which group polarisation is to be expected, namely when discussion generates persuasive information predominately in one direction. Each theory independently explains why such methods as the Delphi sessions produce consensus, although the agreed results could be biased.

When consulting a group of experts, the issue of dependence amongst the experts must also be addressed. Sources of dependence include similarities in education, training, experience, etc. In the case that the experts are dependent, the value of using many experts diminish. However, expert judgements are sure to be dependent to a certain extent. One may even argue that they should be, as independence may indicate that they do not qualify as experts due to lack of knowledge, Risk Analysis Workshop (1999). That is, different expert positions must be presented in order to provide a balanced set of opinions; however, one must be careful to distinguish between experts with novel ideas and experts with flawed ideas.

- **Elicitation**

Elicitation is the process of obtaining expert judgement through specifically designed methods of communication, Meyer and Booker (1991). Elicitation also includes preparing and training the experts in the expert judgement process and methodology. Elicitation typically consists of the following steps:

1. Introduction to and preparation for the expert judgement process
2. Thorough explanation of the context of the problem
3. Questions with respect to evidence relevant to the various parameters
4. Possibly discussion in which the facilitator guides the expert in order to obtain all relevant information

Elicitees should as far as possible answer questions about observable quantities or issues with which the expert has 'hands on' experience. The reason for this is that experts' abilities to answer questions about unobservable quantities are often more subject to misunderstandings and biases, Risk Analysis Workshop (1999).

- **Aggregating Judgements of Multiple Experts**

According to Clemen and Winkler (1999), combination or aggregation procedures may be categorised as mathematical and behavioural approaches. Mathematical approaches consists of processes/models that combine/adjust the individual probability values or distributions into one single value or distribution. These approaches range from summary measures, e.g. arithmetic or geometric means, to procedures requiring inputs with respect to the quality and dependence of the experts' probabilities. Behavioural approaches attempt to generate agreement among the experts by various ways of interactions. The interaction may involve face-to-face interactions or anonymous exchange of information. These approaches consider the quality and dependence of the experts' probabilities implicitly. Behavioural approaches include the Delphi method, the Nominal Group Technique, and the recently proposed expert information method described by Kaplan (1990). According to Clemen and Winkler (1999), the mathematical and behavioural approaches have found to be similar in performance, with the mathematical rules having a slight edge.

EXPERTS VS LAY PEOPLE

There are a number of reasons for experts and lay people to disagree, including misinformation, miscommunication and misunderstandings. Additional reasons why disagreements between the public and experts need not be interpreted as clashes between actual and perceived risks are according to Fischhoff, Slovic and Lichtenstein (1981):

- Facts and problems are seen differently
- Debates over substance may disguise battles over form and vice versa
- Disagreements about feasibility

Lay people may have a different, and maybe better, overview of a scientific debate compared to the experts that actively participate. Lay people may see the full range of expert judgements and hesitations, and they may be more immune to the pressures of falling into one camp of beliefs, Fischhoff and Slovic (1983). Also, lay people may have noticed that a number of the indisputable scientific beliefs of yesterday are confidently rejected today, Franker (1974).

The early risk perception studies revealed differences and similarities between expert and lay judgements of risk; the differences receiving more attention than the similarities. In Slovic, Fischhoff and Lichtenstein (1979), an experiment is described in which four different groups of subjects were asked to rate different activities and technologies according to the risk of death. One of the groups consisted of persons selected for their professional involvement in risk assessment, while the other three groups consisted of lay people. The risk profiles were examined based on mean ratings for the characteristics of voluntarism, immediacy of effects, knowledge, control, newness, chronic/catastrophic, common/dread, and severity of consequence. It was found that the lay people's perceptions of risk were closely related to some of the characteristics, while the expert's judgements of risk were not related to any of the nine qualitative risk characteristics. However, this may be a result of the experts merely recalling data. Otway and Tomas found that, in studies performed by the Decision Research group, the experts were seemingly 'performing a test of their ability to recall the statistical tabulations that risk experts are supposed to know', Otway and Tomas (1982).

DISCUSSION

Expert Judgements

According to Hora (1992), specific biases prevalent among engineers and scientists have been discovered while working with experts in technical risk analysis. One example is judgement based on the results of a single computer model or experiment, in which other information is typically ignored and the model/experiment is treated as infallible. According to Slovic, Fischhoff and Lichtenstein (1979), typical problems associated with experts, when judging risk issues, are:

- Failure to consider all possibilities with respect to human error affecting technological systems
- Overconfidence in current scientific knowledge
- Insensitivity to how a technological system functions as a whole
- Failure to anticipate human response to safety measures.

Similarly, experts are found to be fairly negligent of sample sizes. Negligence of sample size involves poor intuitions about the size of samples needed to test research hypotheses adequately, Tversky and Kahneman (1971).

Over and underconfidence are typical characteristics of the expert's confidence in own judgements. Overconfidence results in too narrow confidence intervals around his/her best estimate. Underconfidence results in too wide confidence intervals around the best estimate. Even the multi-million dollar Reactor Safety Study/Rasmussen Report has been criticised for using a procedure for setting confidence bounds that has been found in experiments to produce overconfidence, Slovic, Fischhoff and Lichtenstein (1979) and U.S. Nuclear Regulatory Commission (1978).

Another issue of great concern is that of operational experience. As previously mentioned, experiencing an accident or a near-miss accident makes a person biased with respect to that risk. In most cases, when evaluating or judging risks, the experience will cause the person to overestimate the risk. As individuals with operational experience are likely to be used as experts, especially in HAZID[4] teams, one has to be very aware of this type of bias.

In addition to the above specifically mentioned biases, experts are subject to the same biases as lay people. Even though the experts may not be influenced in the same manner, caution should be utilised when acquiring and utilising expert judgement. In addition to being aware of and attempting to adjust for the above discussed biases, expert judgements may be improved by considering and emphasising the following issues:

- **Observable/'Hands On' Parameters**

Experts should only be asked for information/judgement with respect to issues of which they have direct or 'hands on' experience. In addition, the experts should be asked about what experience and information they have relevant to the value of the parameter. Even though the experts have much knowledge in their particular domains, they may not be trained or experienced in the use of probability as a language.

[4]Hazard identification

- **Decomposition**

Decomposition refers to the process of dividing complex issues into smaller parts, and in this way it is possible to quantify each part of the problem individually, Chhibber, Apostolakis and Okrent (1992). Decomposition, when carefully utilised, improves judgmental predictions, allows self-documentation, and makes the thought process more explicit. (However, it is necessary to be aware of structural biases which makes people overly sensitive to events presented in great detail, e.g. the size of a fault tree may influence whether or not the issue is seen as risky or not.)

- **Calibration**

Calibration describes the extent to which the estimated probability agrees with the observed relative probability/frequency, SINTEF (1998). The estimates of an expert that shows systematic deviations should be corrected or calibrated by the use of limited historic data. Large amounts of research address calibration, see Cook, Mendel and Thijs (1982).

- **Documentation**

The entire expert judgement process should be well documented. In this manner, as new evidence becomes available, understanding the rationale for the probability values or distributions will allow the judgements to be reinterpreted instead of being discarded.

An additional consideration is that of the risk analysis team. The individuals performing the risk analysis may in reality be acting as experts. That is, the risk analysts may decide which assumptions to make as well as the overall structure of the analysis. Similarly, the analysts are selecting the experts and in most cases designing the expert judgement process. The subjectivity that may be introduced by the risk analysis team was demonstrated in a European benchmark study, presented and discussed in Center for Chemical Process Safety of the American Institute of Chemical Engineers (1989), Arendt et al. (1989), Amendola (1986) and Risk Analysis Workshop (1999). The European benchmark study showed that experts in Chemical Process Quantitative Risk Analyses had difficulty in reproducing risk analysis estimates, as well as the dependency of these estimates on the very basic but different assumptions made by various teams of analysts. The teams were given identical systems to analyse, the techniques to use, and a common database. In the first phase, the teams independently constructed their own models, i.e. the teams were given complete freedom with respect to making assumptions, deciding which incidents to study, choosing failure data, etc. The resulting estimates ranged over several orders of magnitude, well beyond the range of uncertainty calculated by some of the teams. Subsequently, the teams were directed to make similar assumptions, which resulted in estimates converging to a more acceptable range, i.e. within a factor of 5. The study illustrates the importance of recognising that the accuracy and corresponding uncertainty of risk estimates also heavily depend on the expertise and judgement of the risk analysis team.

Value Judgements

The risk analysis, including expert judgements, should be as objective as achievable, while subjectivity is introduced in the assessment and decision-making phase. That is, the consideration of what is acceptable or desirable in social decision making should be included in the last phases of the risk assessment. By reducing the amount of subjectivity from the actual analysis, or at least providing documentation and transparency, the level of risk associated with a certain activity or technology will be better understood. At the time of cost-benefit or the decision-making phase, subjectivity and risk perception may be considered. That is, in the assessment phase, acceptance criteria, willingness to pay, and utility theory, i.e. the distribution of utility and risk, should be taken into account.

It should be noted that using the word 'rationality' about 'risk as is' may be considered extremely narrow-minded. From a societal perspective, it may be rational to say that a fatality is equally severe irrespectively of who, where, when, how, and how many. The nine RCFs identified by Litai are interesting parameters with respect to rationality, and the factors may be considered in the decision making process, when assessing risk and communicating decisions.

The RCF of volition (voluntary vs. involuntary) is not 'irrational' from an individual perspective. That is, from an individual perspective, it is not 'irrational' to take voluntary risks that are higher than involuntary risks that are not accepted. Individuals may take risks, knowing that they are high, in order to obtain personal benefit or experience pleasure.

The severity issue (ordinary vs. catastrophic) is generally accepted as a societal concern. Most risk assessment standards accept that it is more severe for society that N fatalities occur all at once compared to fatalities happening individually. Most FN-curves have a slope of –1 on the logarithmic FN-diagram, which is an aversion to large accidents. However, some national regulators use a slope of –2, e.g. Switzerland and the Netherlands, VROM (1989), which is extremely risk averse.

The aspect of origin (natural vs. man-made) is maybe more difficult to understand. However, the perceptions related to origin are not surprising, as natural hazards were traditionally accepted as ‘acts of God’. Compared to natural hazards, man-made hazards may be easier to control.

The effect manifestation (delayed vs. immediate) is easily rationalised. Most people would probably prefer a farewell to family and friends to an immediate death. Additionally, from a societal point of view, it would seem rational to change from a measure of consequence based on fatalities to life-years lost. This is the basis for risk acceptance based on societal indicators, Skjong and Ronold (1997) and Lind (1996). Risk acceptance is converted from life-years lost to fatalities by assuming that work related accident happens at midlife. The United Nations Development Programme (UNDP) social indicators are based on life-expectancy and therefore implicitly value life-years.

The risk characteristic of exposure pattern (regular vs. occasional) is associated with a RCF of 1, i.e. no change, which seems rational.

The risk characteristic of control (controllable vs. uncontrollable) may be difficult to see as rational, but is understandable. A sense of being in control implies an ability to do something to prevent a fatal outcome. Still this is irrational, as the situation is presented as one with fatal result, i.e. probability of 1, independent of control.

The characteristic of familiarity (old vs. new) could also be regarded as irrational, but clearly understandable. For new unfamiliar risks there will be a sense of uncertainty, and a suspicion that the risks are not yet known. There are numerous examples of unfamiliar risks that have a tendency to increase with time.

For the characteristic of benefit (clear vs. unclear), no RCF is identified, as it is little evidence that anyone takes risks without any benefits.

The risk characteristic of necessity (necessity vs. luxurious) is associated with a RCF of 1, i.e. no change, which is rational.

By taking the above discussed issues into consideration in the decision making process, and maybe even more importantly in the communication processes, the public's reactions may be better understood and conflicts may in this manner be avoided. It should also be noted that cost effectiveness criteria on risk control options may be found by 'willingness to pay' studies. Subjectivity of the public may be directly introduced by such studies, as the public may support highly cost-ineffective risk reducing measures to control risks perceived to be great. For instance, in a survey combining contingent valuation and risk perception, it was found that the same factors providing a nomenclature for risk perception are central in explaining and estimating willingness-to-pay, McDaniels et al. (1992).

CONCLUSION

Risk assessments are rational procedures for evaluating risks, which contribute significantly to decision making if values and limitations are taken into account in a realistic manner. It is evident that experts are vulnerable to many of the same biases as lay people, especially if providing opinions about parameters somewhat outside their area of expertise. That is, when experts are forced to go beyond the limits of their observable expertise or to convert incomplete knowledge into judgement to be utilised in risk assessments, the experts may fall back on intuitive processes, just like lay people. Therefore, expert judgements in risk assessments should be elicited and utilised with care. Subjectivity and risk perception should rather be considered in the decision making and communication phases of the risk assessment process. That is, acceptance criteria, willingness to pay, and utility theory, i.e. the distribution of utility and risk, should be taken into account when assessing the risk analysis results in the decision making process.

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