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The Probability Is High That You Can Improve Your Risk Assessment Performance

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Background

Well-performed risk assessment provides important business benefits. Fundamentally, risk assessment that follows through with risk reduction enables companies to cut costs arising from occupational accidents and illness. Proper risk assessment helps to reduce rates of sick leave, and insurance costs come down with fewer claims. More highly motivated workers are more productive and efficient, and staff turnover rates fall. This all helps businesses gain a competitive advantage. As more and more risk-complex systems are implemented in the workplace, with their accompanying new dangers and ill-defined hazards, well-performed risk assessment allows safety professionals to foresee and thus avoid OSHA penalties for serious and willful violations.

Many safety experts agree that one reason that injury rates are high is that protective measures that are only appropriate for low-level risks are being applied in situations where the risk involves frequent exposures to fatal or serious traumatic injury hazards. How to actually make acceptable risk decisions? Fischhoff (1981) contends that they can be arrived at operationally through fair compromise among reasonable individuals, including those at risk, using the best available estimates of a technology's consequences. Risk assessment can be done quickly, flexibly and conveniently when the process proceeds, only as needed, from initial screening to closer observation to further analysis. Human reliability estimates can be used to help set qualitative ratings of probability of occurrence (e.g., high, medium, low, or negligible).

This paper will include exercises in efficient probability evaluation and risk assessment that participants can take home to use in their own on-the-job training activities. These exercises rely on an understanding that mindfulness of risk must be treated as a culture that is a product of individual and group values, attitudes, competencies, and patterns of behavior that determine the commitment to an organization's health and safety programs.

Introduction

Risk assessment is a generally accepted tool for preventing injuries and illness in the workplace. Many good references already exist for risk assessment (Main, 2004; MILSTD 882D, 2000; ISO 14121, 2006; Etherton, 2007). Risk assessment is generally described as a procedure for evaluating the probability of occurrence and the potential severity of injury associated with particular tasks and hazards, followed by risk reduction. To be as effective as possible, risk assessment needs to be rapid and well-grounded. The purpose of this paper is to aid OSH practitioners in understanding the probability of occurrence concepts for performing the risk estimation step in risk assessment. This assistance will enhance your risk management process as you develop policies, procedures, and practices to identify, analyze, assess, control, and avoid, minimize, or eliminate unacceptable risks. Risk assessment is a process with six steps:

1. Prepare for/set limits of the risk assessment
2. Identify hazards;
3. Assess risk based on potential severity and probability of occurrence;
4. Reduce risk to an acceptable level;
5. Document the results; and
6. Follow-up.

While step 3 is performed, you should have a good understanding of how to effectively estimate the probability of occurrence. This can be because you want to educate your risk assessment team about what they are doing. You certainly want to understand and guide risk decisions by others so they are informed decision-makers who can make decisions that can be understood by management to maintain an at-least-as-safe-as condition in the workplace. Also, you may also want to better understand why you yourself make specific risk decisions. Such self-awareness can give you confidence in the risk decisions that you make.

Probability estimates can be of several types:

Probability type	**Task/hazard type**	**Risk matrix entry examples**	**Source of estimate**
Quantitative	Equipment reliability	2×10^{-4} failures/yr	Company or published database
Subjective	Irregularly occurring tasks	High; medium; low	Comparison with other similar conditions
Chronological	Periodic tasks	Annually; monthly	Maintenance logs; personnel files
Experiential	Wage-grade specific tasks	Master; novice	Personal or group experience
Ergonomic	Human reliability	p = 0.03	Published databases

Table 1. Probability Estimates

These probability types can sometimes be difficult for risk estimators to conceptualize. Human reliability and how to make estimates of probability of occurrence with respect to human actions is one focus of this paper. We will see that both facts and values are at play in making estimates of probability. Problems arise if a pattern of divergence is apparent between high probably and low probability estimates.

One can ask many questions about the role of probability in making good risk estimates. "How accurate are probability estimates anyway?" "Why should I be basing my preventive measures on probability estimates?" "How large can the errors in choosing preventive measures be if I get the probability estimates wrong?" "Can I choose my preventive measures without doing risk assessments?" "When do good probability estimates make a difference?" This paper is intended to help you understand what you are doing when you make probability estimates and when you may need additional input in making an estimate. We will explore questions having to do with what style of probability estimator you want on your team; making estimates for your company; and making estimates about the hazards that you face. We will be looking at four perspectives on probability estimating: rational risk assessment, risk perception, black swan theory, and human reliability theory.

Risk Reduction Decisions Based on Rational Probabilities

To start this discussion, we will give a formal definition of probability. Probability is the quantifiable likelihood (chance) of the occurrence of an event expressed as odds, or a fraction of 1. Probability is estimated usually through repeated random sampling, and is represented numerically as between 0 (impossibility) and 1 (certainty). Likelihood, in a statistical sense, implies an interval over which the result can be expected. The accuracy of estimates of the average occurrence of events is based on quantifying the error from the mean.

The rational use of probability is a touchstone for much of the work that we do as OS&H professionals. Bernstein (1998) tells us that the notion of rationally bringing risk under control is one of the central ideas that distinguish modern times from the distant past. He emphasizes the notion that we have learned that the future is more than the whim of the gods, and men and women are not passive before nature. Decisions are now made in accordance with disciplined procedures that far out-perform the seat-of-the-pants methods of the past. Further, the importance of probability can only be derived from the judgment that it is *rational* to be guided by it in action; and a practical dependence on it can only be justified by a judgment that in action we *ought* to act to take some account of it. It is for this reason that probability is to us "the guide of life." In other words, probability, weight, and risk can be highly dependent on a judgment that they are rational.

The utility (value) of a risk decision is inversely proportional to the size of the loss from a negative outcome of the risky activity and is likewise rational. In industrial safety terms, safety committee members can be more or less risk-averse. This often means that they demand (in the course of risk assessments) that risks be minimized, even at the cost of losing the utility of the risky activity. It is important to consider the opportunity cost when mitigating a risk, the cost of *not* taking the risky action. Making risk reduction decisions without the balance of the utility can misrepresent the workplace's goals.

The rational benefit of risk prevention and mitigation actions can be assessed as follows:

$$\textit{Benefit} = \textit{unmitigated risk} - \textit{mitigated risk}$$

The ratio of the benefit to the cost of mitigation can be used to justify the allocation of resources (Ayuub, 2010). The benefit-to-cost ratio can be computed, and may also be helpful in decision-making. The benefit-to-cost ratio can be computed as:

$$\textit{Benefit-to-Cost Ratio (B/C)} =$$

$$\frac{\textit{Benefit}}{\textit{Cost}} = \frac{\textit{Unmitigated Risk - Mitigated Risk}}{\textit{Cost}}$$

Rational Calculation Using Risk Probability Exercise

By using a risk assessment's accepted value for injury probability and injury cost, expected value of the savings for a risk reduction measure can be calculated. Following is an example:

Task: Cleaning a machine
Hazard: Point of operation
Potential Severity: Amputation
Probability of occurrence without safeguard: 0.001
Probability of occurrence with safeguard: 0.00001

OSHA guidelines (2010) indicate that the total cost (direct and indirect cost) for an amputation is $101,468.

For this exercise, we will say that the prorated cost of providing a lockout device and procedure for this machine is $100. Taking the rational perspective that a savings results from no injury, we can establish:

Probability of occurrence difference by adopting the safeguard = 0.001 – 0.00001
= 0.00099

Expected value of the probability reduction = $101,468 × 0.00099 = $100.45

Essentially, the company has equivalent cost and benefit with the lockout device and procedure. The adoption of the risk reduction measure has additional benefits in that the lockout device and procedure also controls for other risks on the same machine, as well as the intangible desire to increase protection against injury for another human being.

Qualitative Risk Perception

All estimates of the likelihood of risky endeavors are not arrived at in a purely rational way. Risk perception is the belief (whether rational or irrational) held by an individual, group, or society about the chance of occurrence of a risk or about the extent, magnitude, and timing of its effect(s). This way of looking at probability emphasizes that we can be both rational and subjective in our ways of thinking about risk. Questions often addressed in the field of risk perception include such big-picture risks as nuclear power, water quality, and global warming.

A significant step toward understanding the importance of subjective factors for risk perception was taken by Alhakami and Slovic (1994), who observed that the inverse relationship between perceived risk and perceived benefit was linked to an individual's general affective evaluation of a hazard. If an activity was "liked," people tended to judge its benefits as high and its risks as low. If the activity was "disliked," the judgments were opposite: low benefit and high risk.

Culture plays an important role in how people think about the probabilities of events. Risk perceptions are distributed across persons in patterns better explained by culture than by other asserted influences. The *cultural cognition of risk*, sometimes called simply *cultural cognition*, refers to the hypothesized tendency of persons to form perceptions of risk and related facts that cohere with their self-defining values. Our values shape how we deal with facts. When probability estimates are made qualitatively, people will culturally and cognitively have perceptions about discreet future outcomes.

Cultural cognition researchers (Kahan, 2008) use attitudinal scales that reflect worldviews, or preferences about how society should be organized, along two cross-cutting dimensions: “group,” which refers to how individualistic or group-oriented a society should be; and “grid,” which refers to how hierarchical or egalitarian a society should be. A high group cultural worldview inclines people toward a communitarian way of life, in which the interests of the collective take precedence over the interests of individuals, and in which the collective is responsible for securing conditions of individual flourishing. A low group cultural worldview inclines people toward an individualistic way of life, in which individuals are expected to secure the conditions of their own flourishing without collective assistance or interference.

A high grid cultural worldview supports a hierarchical social structure, in which entitlements and obligations, goods and offices, are distributed on the basis of fixed and largely immutable characteristics, such as race, gender, lineage, and wealth. A low grid worldview, in contrast, supports an egalitarian ordering in which these sorts of distinctions are deemed irrelevant to the distribution of entitlements and obligations, goods and offices, and so forth.

Individuals gravitate toward perceptions of risk that advance the way of life they adhere to. That is, they are disposed—subconsciously—to notice and credit risk claims that cohere with their way of life, and to ignore and dismiss risk claims that threaten it. What drives one’s risk perception is one’s view of the workplace organization order and one’s view of personal responsibility. This risk perception bias then influences the probability estimates that determine the risk estimate, which determines preventive measure selection. In other words, attitudes about the workplace organization and personal responsibility influence the preventive measures that will be taken for workplace safety, based on how risk assessment procedures are followed.

Here are some survey questions (degree of agreement ratings) for the two poles each for group and grid that Dake (1990) used to classify the cultural condition of the person and their place in the social order of things on risk perception:

Group

Personal Responsibility:

- In a fair system, people with more ability should earn more.
- It is just as well that life tends to sort out those who try harder from those who do not.
- Making money is the main reason for hard work.

Fatalism:

- There is no use in doing things for people, you only get it in the neck in the long run.
- Cooperating with others rarely works.
- The future is too uncertain for a person to make serious plans.

Grid

Hierarchic Social Order:

- I think there should be more discipline in the youth of today.
- I am stricter than most people about what is right and wrong.
- I think it is important to carry on family traditions.

Equal Rights Social Order:

- If people in this country were treated more equally we would have a better country.
- The government should make sure everyone has a good standard of living.
- Racial discrimination is a very serious problem in our society.

To be clear, efforts at working to change the *safety culture of a workplace* differ from the work we are discussing here about applying the *risk perception of individuals in performing risk assessments*, although they are related. Safety culture describes the overall attitude and behaviors toward safety in an organization and the way things are accomplished. It has a lot to do with how well employees and managers work together strategically to tackle safety issues. Risk assessment understanding of culture is a more tactical concept. Cooper (2001) tells us that safety becomes a value when: (1) it is learned from others, and (2) everyday experiences either weaken or reinforce the value in forming attitudes, opinion, and behavior. Safety as a value requires consistent safety leadership whereby management visibly shows its commitment to safety on a daily basis.

In the industrial safety context, the *cultural cognition hypothesis* implies that workers, engineers, and managers are individually motivated by a variety of psychological processes to form beliefs about hazardous activities that match their cultural evaluations of them. Persons who subscribe to relatively individualistic values, for example, tend to value industrial productivity and are inclined to disbelieve that such activities pose serious workplace risks. Persons who subscribe to relatively egalitarian and communitarian values, in contrast, readily credit claims of workplace risks, consistent with their moral suspicion of industrial science as sources of inequality and symbols of excessive self-seeking.

Although "culture" is a notoriously complex concept, it can be broadly defined in terms of the shared practices, mental habits and norms that shape people's identities and influence their attitudes and behaviors (Vickers et al., 2003). These practices, habits and norms are generated and assimilated by people in a variety of settings, including in the context of particular national or ethnically based cultures (i.e., in terms of traditional practices and language), but also in particular institutional/organizational settings and professional contexts. All cultures are generally seen by academic commentators as subject to change and re-formulation over time, rather than being fixed and static. A number of studies confirm that men tend to judge risks as being smaller and less problematic than do women, although a striking finding of these studies is that gender differences were not true of nonwhite women and men, whose perceptions of risk were quite similar (Kalof *et al.,* 2002; Flynn *et al.,* 1994).

Cooper (1997) concludes that the biasing factors in risk perception should be taken into account in risk assessments. He suggests that this could be done by introducing a weighting factor into the risk assessment that would account for the degree of risk perception by the individual/group having input to the risk assessment. Sjoberg (2000) has further maintained that the relationship between a high risk perception and demand for strong hazard control methods is not always clear.

Risk Perception Exercise

A way to approach questions about culture having an impact on risk probability estimates is to examine the existence of excessively wide divergences that weaken the risk assessment activity.

In examining how we will go about directing others to perform risk assessments, we should be asking, "How do values (culture) shape probability estimates? And so what if they do?" The most important multicultural awareness resources are the members of your risk assessment teams themselves. Instead of trying to define what is culturally important to them through special techniques, it is our responsibility to draw them into the conversation, allow them to define themselves, and start there in the development of multicultural risk probabilities awareness. To open our sensitivity to higher probabilities for some populations because of their cultural experiences, some questions can be asked to engage your team members in a process of defining "culture" and examining its complexity.

Opening statement for a discussion of the effects of culture on risk probability estimates:

> *Culture is a shared, learned, symbolic system of values, beliefs and attitudes that shapes and influences perception and behavior -- an abstract "mental blueprint" or "mental code." Culture is what is true enough and important enough to be passed down and inculcated in the young as the true way of seeing the world. Culture is transferred via verbal and non verbal means beginning in childhood such that it is impossible for the young to believe that the cultural impression is not true.*

Discussion questions:

- What are the cultures in your workplace?
- Can you give examples of culture having an effect on how likely people think a dangerous event may be?
- Is ethnic background a reason for differences in probability estimates?
- Is economic status a reason for differences in probability estimates?
- Is gender a reason for differences in probability estimates?

Dealing with the Black Swans of Risk Probabilities

A somewhat more skeptical view of making risk probability estimates is taken by Nassim Nicholas Taleb (2007), author of *Black Swan: The Impact of the Highly Improbable.* The idea of the "black swan" is that occasionally an event will occur that is high-impact, hard-to-predict, and rare. For example, before the discovery of Australia, people in the Old World were convinced that *all* swans were white, an unassailable belief that seemed completely confirmed by empirical evidence. Then, suddenly, in Australia, black swans were found; a totally unexpected, seemingly unpredictable event. Taleb's perspective on the ability to foresee events and assign probabilities to these events is that it can sometimes be a particularly fruitless endeavor. Although he does shy away from predicting unexpected events, he offers tips to guide us in how we can deal with randomness and uncertainty. The three tips from N. Taleb with respect to estimating risk probabilities are:

1. *Taleb*: Skepticism is effortful and costly. It is better to be skeptical about matters of large consequences, and be imperfect, foolish, and human in the small and the aesthetic.

> *How this applies to being a risk assessor*: You will work hard on the large consequence risks. You should remain skeptical, even when you think you have them fixed. To balance this, let yourself be creative and less confined to the normal way of doing things when working on preventing the smaller risks.

2. *Taleb*: Go to parties. You can't even start to know what you may find on the envelope of serendipity. If you suffer from agoraphobia, send colleagues.

How this applies to being a risk assessor: Sit in on the discussions that line-workers have during coffee breaks and after work. They can let you know things in unexpectedly insightful ways.

3. *Taleb*: It's not a good idea to take a forecast from someone wearing a tie. If possible, tease people who take themselves and their knowledge too seriously.

How this applies to being a risk assessor: Be careful in following the advice about risk reduction measures from a "higher up" who knows exactly where the problems are, and exactly how likely they are to happen.

Black Swan Exercise:

- Name 3 situations that are high criticality on which you need to be working hard.
- Name 3 that are low criticality, and describe a creative way to work on their prevention.

Human Error Probabilities

For low frequency/high consequence task-hazard pairs, human reliability assessment (HRA) (Kirwan, 1994) may be needed to determine how likely it is that a task will be performed erroneously, resulting in injury. The purpose of HRA is to estimate the likelihood of particular human actions not being taken when needed, or other human actions that may cause hazardous events to occur. Failures to take action to prevent hazardous events, and actions that cause hazardous events, are commonly called "human errors" in HRA. Estimating the probabilities of human errors that can potentially result in injury due to hazard exposure is ideally based on the equation:

$$\text{Human Error Probability} = \frac{\text{The number of times an error has occurred}}{\text{The number of opportunities for that error to occur}}$$

Four main tasks need to be performed as part of an HRA (Wreathall et al., 2003). These tasks represent the general process by which human reliability analysis supports probabilistic risk assessment. The details of these steps may vary in each application.

<u>Evaluate Human Factors Issues</u>
Analyze the impact of the current work environment and new technology on human performance. This task requires study of operating rules, procedures, and available data, as well as direct observation of the work environment and interviews of individuals involved in the work. For example, bad weather, long shift times, and high workload all can increase significantly the likelihood of human errors. In turn, work environment and task conditions are often influenced by organizational factors like work rules, duty times, and so on. Therefore, the error estimation process needs to account for these contributing factors. In this regard, Kirwan (1994) sets forth the following performance-shaping factors (PSF):

- The time scale involved
- The quality of the interface
- Training; experience; familiarity
- The degree of adequacy of procedures

- How the task is organized
- The degree of complexity of the task

<u>Survey Databases for Human Error Probability Estimates</u>
Collections of data can be relevant to the quantification of errors. However, performance-shaping factors should be taken into account. Problems may be associated with direct application of that data. Experts in operations can help to evaluate and adjust that data to the case at hand. Table 2 is generic sample guideline data:

Description	Human Error Probability
General rate for error involving high stress levels	0.3
General error rate for oral communication	0.03
General error of omission	0.01
Error in simple routine operation	0.001
Human performance limit: single operator	0.0001

Table 2: Sample Data for Human Error Probability Estimates (*Source*: Kirwan, 1994)

This data can be used as a benchmark or guideline until better data is obtained. Other human error data banks exist (Swain and Guttman, 1983; Kirwan et al., 1990).

<u>Make Error Likelihood Estimates</u>
Estimates can be either qualitative or quantitative. Although carefully crafted quantitative methods have been formulated for high criticality systems (nuclear and chemical plants), qualitative estimates are more easily grasped by working personnel. If you wish to develop quantitative estimates of the likelihood of the human actions in question, the process for quantification always begins with an evaluation of the relevance of available data to the actions under analysis. Expert opinion about errors is often the best resource available, given that it is usually difficult to know the number of opportunities for error, and that there is a reluctance to publish data on poor performance. An expert panel can be formed. Such a panel might have as members: two operators (each with at least 10 years of experience); a safety or ergonomics staff person; and a facilitator. The facilitator's role is to prevent both biases from arising as a result of personality differences within the group, and biases arising during the making of expert judgments from distorting the results. Paired comparisons usefully determine whether each expert has been consistent in the judgment he or she has made. Inconsistency of judgment would suggest a lack of substantive expertise.

<u>Documentation</u>
To permit review and later understanding of the details of the HRA probability estimates, all results and processes must be well documented, providing the bases for all estimates.

Human Reliability Exercise
A maintenance task is to be performed on the tooling of a dangerous machine. It is late at night, the work area is poorly lit, and supervision is not present. Neglecting to perform lockout on the hazardous energy source can be considered a general error of omission with a database probability of occurrence of 0.01. How likely is it that an injury-producing situation will arise for this task-hazard, taking into account the conditions of the situation? Formulate your risk probability estimate using the following steps:

1. What are the shaping factors?
2. What is the database likelihood?
3. What does your expert team say about it?
4. Make your estimate and note the basis for it on the risk assessment documentation.

Conclusion

It has been the objective of this paper to show that both facts and values are at play in making estimates of probability. Problems with risk probability estimates become apparent when a pattern of divergence appears between high probably and low probability estimates for the same event. Given the four perspectives on risk probabilities estimates in this article, what can be done to calibrate your estimation capability? Here are some guidelines to help you calibrate your risk estimating capability.

- If you have probability data, use it.
- If you are the lone assessor and must make probability estimates, do not exceed your limits of personal experience. Take your personal values into account and base your own estimates on:
    - personal experience;
    - observation;
    - actual injury records; and
    - input from an experienced operator.
- If you are facilitating a group of risk assessors, gauge the divergence or convergence of values within the group.
- Be skeptical of unsubstantiated probability estimates.

In sum, your goal should be to become a qualified risk estimator and to lead qualified risk estimating teams. Thus, when your risk probability estimates prove correct over time, injuries do not happen.

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