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Science, Values, and Risk

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1.0 Introduction

The practice of risk assessment has steadily increased in prominence during the past several decades, as risk managers in government and industry have sought to develop more effective ways to meet public demands for a safer and healthier environment. Dozens of scientific disciplines have been mobilized to provide technical information about risk and billions of dollars have been expended to create this information and distill it in the context of risk assessments.

Ironically, as our society has expended this great effort to make life safer and healthier, many in the public have become more, rather than less, concerned about risk. These individuals see themselves as exposed to more serious risks than were faced by Americans in the past, they believe that this situation is getting worse rather than better. Nuclear and chemical technologies (except for medicines) have been stigmatized by being perceived as entailing unnaturally great risks.[1] As a result, it has been difficult, if not impossible, to find host sites for disposing of high-level or low-level radioactive wastes, or for incinerators, landfills, and other chemical facilities.

Public perceptions of risk have been found to determine the priorities and legislative agendas of regulatory bodies such as the Environmental Protection Agency, much to the distress of agency technical experts who argue that other hazards deserve higher priority. The bulk of EPA's budget in recent years has gone to hazardous waste primarily because the public believes

that the cleanup of Superfund sites is the most serious environmental threat that the country faces. Hazards such as indoor air pollution are considered more serious health risks by experts, but are not perceived that way by the public.[2]

Great disparities in monetary expenditures designed to prolong life, as shown in Table 1, may also be traced to public perceptions of risk. As noteworthy as the large sums of money devoted to protection from radiation and chemical toxins are the relatively small sums expended to reduce mundane hazards such as automobile accidents. Other studies have shown that serious risks from national disasters such as floods, hurricanes, and earthquakes generate relatively little public concern and demand for protection.[3,4]

INSERT TABLE 1 HERE

Such discrepancies are seen as irrational by many harsh critics of public perceptions. These critics draw a sharp dichotomy between the experts and the public. Experts are seen as purveying risk assessments, characterized as objective, analytic, wise, and rational—based upon the **real risks.** In contrast, the public is seen to rely upon **perceptions of risk** that are subjective, often hypothetical, emotional, foolish, and irrational.

In sum, polarized views, controversy, and overt conflict have become pervasive within risk assessment and risk management. A desperate search for salvation through risk-communication efforts began in the mid-1980s—yet, despite some localized successes (see the paper by Leiss in this volume), this effort has not stemmed the major conflicts or reduced much of the dissatisfaction with risk management.

2.0 The Need for a New Perspective

We believe that new perspectives and new approaches are needed to manage risks effectively in our society. We also believe that social science research has provided some valuable insights into the nature of the problem that, without indicating a clear solution, do point to some promising prescriptive actions.

For example, early studies of risk perception demonstrated that the public's concerns could not simply be blamed on ignorance or irrationality. Instead, research has shown that many of the public's reactions to risk (including reactions that may underlie the data in Table 1) can be attributed to a sensitivity to technical, social, and psychological qualities of hazards that are not well-modeled in technical risk assessments (e.g., qualities such as uncertainty in risk assessments, perceived inequity in the distribution of risks and benefits, and aversion to being exposed to risks that are involuntary, not under one's control, or dreaded). The important role of social values in risk perception and risk acceptance has thus became apparent.[5]

More recently, another important aspect of the risk-perception problem has come to be recognized. This is the role of trust. In recent years there have been numerous articles and surveys pointing out the importance of trust in risk management and documenting the extreme distrust we now have in many of the individuals, industries, and institutions responsible for risk management.[6] This pervasive distrust has also been shown to be strongly linked to the perception that risks are unacceptably high and to political activism to reduce those risks.

A third insight pertains to the very complexity of the concept "risk." We shall argue for a conception of risk starkly different from the view that is the foundation for most current approaches to risk assessment and risk management.

3.0 The Subjective and Value-Laden Nature of Risk Assessment

Attempts to manage risk must confront the question: "What is risk?" The dominant conception views risk as "the chance of injury, damage, or loss."[7] The probabilities and consequences of adverse events are assumed to be produced by physical and natural processes in ways that can be objectively quantified by risk assessment. Much social science analysis rejects this notion, arguing instead that risk is inherently subjective.[8,9,10,11,12,13] In this view, risk does not exist "out there," independent of our minds and cultures, waiting to be measured. Instead, human beings have invented the concept **risk** to help them understand and cope with the dangers and uncertainties of life. Although these dangers are real, there is no such thing as "real risk" or "objective risk." The nuclear engineer's probabilistic risk estimate for a nuclear accident or the toxicologist's quantitative estimate of a chemical's carcinogenic risk are both based on theoretical models, whose structure is subjective and assumption-laden, and whose inputs are dependent on judgment. As we shall see, nonscientists have their own models, assumptions, and subjective assessment techniques (intuitive risk assessments), which are sometimes very different from the scientists' models.

One way in which subjectivity permeates risk assessment is its dependence on judgments at every stage of the process, from the initial structuring of a risk problem to deciding which

endpoints or consequences to include in the analysis, identifying and estimating exposures, choosing dose-response relationships, and so on.

For example, even the apparently simple task of choosing a risk measure for a well-defined endpoint such as human fatalities is surprisingly complex and judgmental. Table 2 shows a few of the many different ways that fatality risks can be framed.

INSERT TABLE 2 HERE

An example taken from Wilson and Crouch[14] demonstrates how the choice of one measure or another can make a technology look either more or less risky. For example, between 1950 and 1970, coal mines became much less risky in terms of deaths from accidents per ton of coal, but they became marginally riskier in terms of deaths from accidents per employee. Which measure one thinks more appropriate for decision making depends on one's point of view. From a national point of view, given that a certain amount of coal has to be obtained, deaths per million tons of coal is the more appropriate measure of risk, whereas from a labor leader's point of view, deaths per thousand persons employed may be more relevant.

How should we decide what measure to use when planning a risk assessment, recognizing that choice of measure is likely to make a big difference in how the risk is perceived and evaluated?

3.1 Framing the Risk Information

After a risk analysis has "negotiated," all the subjective steps of defining the problem and its options, selecting and measuring risks in terms of particular outcomes, determining the people at risk and their exposure parameters, and so on, one comes to the presentation of this information to the decision maker, often referred to as "framing." This process of presentation is also rife with subjectivity.

Numerous research studies have demonstrated that different (but logically equivalent) ways of presenting the same risk information can lead to different evaluations and decisions. One dramatic example of this comes from a study by McNeil, Pauker, Sox, and Tversky,[15] who asked people to imagine that they had lung cancer and had to choose between two therapies, surgery or radiation. The two therapies were described in some detail. Then, some subjects were presented with the cumulative probabilities of surviving for varying lengths of time after the treatment. Other subjects received the same cumulative probabilities framed in terms of dying rather than surviving (e.g., instead of being told that 68% of those having surgery will have survived after one year, they were told that 32% will have died. Framing the statistics in terms of dying dropped the percentage of subjects choosing radiation therapy over surgery from 44% to 18%. The effect was as strong for physicians as for laypersons.

Equally striking effects result from framing the information about consequences in terms of either lives saved or lives lost,[16] or from describing an improvement in a river's water quality as a *restoration* of lost quality or an *improvement* from the current level.[17]

In sum, we now know that every form of presenting risk information is a frame that has a strong influence on the decision maker. Moreover, when we contemplate the equivalency of lives saved vs. lives lost, mortality rates vs. survival rates, restoring lost water quality vs. improving water quality, and so forth, we see that there is often no "right frame" or "wrong frame"—just "different frames."

3.2 The Multidimensionality of Risk

As noted above, research has also shown that the public has a broad conception of risk, qualitative and complex, that incorporates considerations such as uncertainty, dread, catastrophic potential, controllability, equity, risk to future generations, and so forth, into the risk equation. In contrast, experts' perceptions of risk are not closely related to these dimensions or the characteristics that underlie them. Instead, studies show that experts tend to see riskiness as synonymous with expected annual mortality, consistent with the dictionary definition given above and consistent with the ways that risks tend to be characterized in risk assessments. As a result of these different perspectives, many conflicts over "risk" may result from experts and laypeople having different definitions of the concept. In this light, it is not surprising that expert recitations of "risk statistics" often do little to change people's attitudes and perceptions.

There are legitimate, value-laden issues underlying the multiple dimensions of public risk perceptions, and these values need to be considered in risk-policy decisions. For example, is risk from cancer (a dread disease) worse than risk from auto accidents (not dreaded)? Is a risk imposed on a child more serious than a known risk accepted voluntarily by an adult? Are the deaths of 50 passengers in separate automobile accidents equivalent to the deaths of 50

passengers in one airplane crash? Is the risk from a polluted Superfund site worse if the site is located in a neighborhood that has a number of other hazardous facilities nearby? The difficult questions multiply when outcomes other than human health and safety are considered.

4.0 The Risk Game

There are clearly multiple conceptions of risk.[18] Dean and Thompson[19] note that the traditional view of risk characterized by the event probabilities and consequences treats the many subjective and contextual factors described above as secondary or accidental dimensions of risk, just as coloration might be thought of as a secondary or accidental dimension of an eye. Accidental dimensions might be extremely influential in the formation of attitudes toward risk, just as having blue or brown coloration may be influential in forming attitudes toward eyes. Furthermore, it may be that all risks possess some accidental dimensions, just as all organs of sight are in some way colored. Nevertheless, accidental dimensions do not serve as criteria for determining whether someone is or is not at risk, just as coloration is irrelevant to whether something is or is not an eye.

We believe that the multidimensional, subjective, value-laden, frame-sensitive nature of risky decisions, as described above, supports a very different view, which Dean and Thompson call "the contextualist conception." This conception places probabilities and consequences on the list of relevant risk attributes along with voluntariness, equity, and other important contextual parameters. On the contextualist view, the concept of risk is more like the concept of a game than the concept of the eye. Games have time limits, rules of play, opponents, criteria for winning or losing, etc., but none of these attributes is essential to the concept of a game, nor is any of them

characteristic of all games. Similarly, a contextualist view of risk assumes that risks are characterized by some combination of attributes such as voluntariness, probability, intentionality, equity, and so on, but that no one of these attributes is essential. The bottom line is that, just as there is no universal set of rules for games, there is no universal set of characteristics for describing risk. The characterization must depend on which risk game is being played.

5.0 Policy Implications of this Contextualist View of Risk

5.1 Technical Solutions to Risk Conflicts

There has been no shortage of high-level attention given to the risk conflicts we described earlier. One prominent proposal by Justice Stephen Breyer[20] attempts to break what he sees as a vicious circle of public perception, congressional overreaction, and conservative regulation that leads to obsessive and costly preoccupation with reducing negligible risks as well as to inconsistent standards among health and safety programs. Breyer sees public misperceptions of risk and low levels of mathematical understanding at the core of excessive regulatory response. His proposed solution is to create a small centralized administrative group charged with creating uniformity and rationality in highly technical areas of risk management. This group would be staffed by civil servants with experience in health and environmental agencies, Congress, and OMB. A parallel is drawn between this group and the prestigious Conseil d'Etat in France.

Similar frustration with the costs of meeting public demands led the 104th Congress to introduce numerous bills designed to require all major new regulations to be justified by extensive risk assessments. Proponents of this legislation argue that such measures are necessary

to ensure that regulations are based upon "sound science" and effectively reduce significant risks at reasonable costs.

The language of this proposed legislation reflects the traditional narrow view of risk and risk assessment based ". . . only on the best reasonably available scientific data and scientific understanding . . . " Agencies are further directed to develop a systematic program for external peer review using "expert bodies" or "other devices comprised of participants selected on the basis of their expertise relevant to the sciences involved . . . " (pp. 57–58). Public participation in this process is advocated but no mechanisms for this are specified.

The proposals by Breyer and the 104th Congress are typical in their call for more and better technical analysis and expert oversight to rationalize risk management. There is no doubt that technical analysis is vital for making risk decisions better informed, more consistent, and more accountable. However, value conflicts and pervasive distrust in risk management cannot be reduced by technical analysis. Trying to address risk controversies with more science, in fact, is likely to exacerbate conflict.

5.2 Process-Oriented Solutions

In our view, the limitations of risk science, the importance and difficulty of maintaining trust, and the subjective and contextual nature of "the risk game," point to the need for a new and radically different approach—one that focuses upon introducing more public participation into both risk assessment and risk decision making in order to make the risk-decision process more democratic, improve the relevance and quality of technical analysis, and increase the legitimacy and public acceptance of the resulting decisions. Work by scholars and practitioners in Europe

and North America[21,22,23,24] has begun to lay the foundations for improved methods of public participation within deliberative decision processes that include negotiation, mediation, oversight committees, and other forms of public involvement.

5.3 An Illustrative Example: Siting Hazardous Waste Facilities

One important arena in which the need for improved public-participation mechanisms has been taken quite seriously is that of hazardous-waste facility siting. Public opposition has made it extraordinarily difficult to build new disposal facilities despite a desperate need for them. For example, during the 1980's, 28 of 34 solid-waste incinerators proposed for California were canceled or postponed[25] and only 6 hazardous-waste facilities were built out of 81 applications.[26] There is no indication that the situation has changed in the 1990's. Local communities are opposed to having a waste facility in their backyard no matter how small the experts claim the risks to health and the environment are from hosting it.[27]

In the past, some state governments have attempted to overcome local opposition to siting proposals by using a preemption strategy and effectively removing local government from the official decision. This strategy has often backfired because the siting procedure is still subject to judicial review which may lead to discoveries of flaws in the legislation or delays in the process. The siting issue can also be raised to a high enough profile that it threatens re-election prospects of elected officials, thus prompting a revision in policy.

In order to enhance public acceptance with respect to a facility and a sense of legitimacy, practitioners and researchers have recognized the importance of establishing a fair site-selection process. At a National Workshop on Facility Siting, a set of guidelines were developed which

increase the chance that the affected stakeholders would feel their major concerns had been met in the siting process.[22]

The central feature of these guidelines is a reliance upon informed public participation and consent. Residents of prospective host communities investigate the advantages and disadvantages of the facility and have the authority to negotiate the terms under which the facility will be sited. Incentives in the form of fines for violating standards as well as regular inspections are designed to insure that public and technical safety criteria are achieved. The process is designed to instill trust by inviting all interested and affected parties to be players in the siting debate and enabling any community to say "No" if it does not want to host the facility. Empirical evidence suggests that these principles have enhanced the "success" of a number of siting efforts.[28]

6.0 Conclusions

In this paper, we have endorsed what Dean and Thompson[18] refer to as "the contextualist view of risk." Under this view, risk can be conceptualized as a game in which the rules must be socially negotiated within the context of specific decision problems. The conception of risk as a game helps illustrate why strictly technical approaches to risk management often fail in contentious problems involving hazards such as radiation and chemicals. It also highlights the need to allow all interested and affective parties to define and play the game, thus emphasizing institutional, procedural, and societal processes rather than quantitative risk assessments.

Recognizing interested and affected citizens as legitimate partners in defining the rules of the risk game is no short-term panacea for the problems of risk management. But serious

attention to participation and process issues may, in the long run, lead to more satisfying and successful ways to manage the risks from modern technologies.

Notes

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Table 1

Costs of a year of life saved by various interventions

■ Flu shots	$500
■ Water chlorination	$4,000
■ Pneumonia vaccination	$12,000
■ Breast cancer screening	$17,000
■ All medical interventions	$19,000
■ Construction safety rules	$38,000
■ All transportation interventions	$56,000
■ Highway improvement	$60,000
■ Home radon control	$141,000
■ Asbestos controls	$1.9 million
■ All toxin controls	$2.8 million
■ Arsenic emission controls	$6.0 million
■ Radiation controls	$10.0 million

Source: Adapted from Tengs et al.[29]

Table 2

Some ways of expressing mortality risks

- Deaths per million people in the population
- Deaths per million people within **x** miles of the source of exposure
- Deaths per unit of concentration
- Deaths per facility
- Deaths per ton of air toxic released
- Deaths per ton of air toxic absorbed by people
- Deaths per ton of chemical produced
- Deaths per million dollars of product produced
- Loss of life expectancy associated with exposure to the hazard