INFORMATION UTILIZATION IN THE FORMULATION OF HAZARDOUS WASTE FACILITY SITING REGULATIONS: A METHOD OF RESEARCH FOR ORGANIZATIONAL LEARNING

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ABSTRACT

The demand for siting new hazardous waste disposal facilities has grown nationally during the past decade while opposition to these facilities has also increased. At the heart of this controversy is the issue of risk. The meaning of risk in this context is subject to various interpretations. The task of resolving these controversies has been left to the states. This paper discusses the problem of defining risk in the context of hazardous waste facility siting regulations, and proposes a method of research for analyzing the process by which risk is defined and the implications of this process for organizational learning.

KEY WORDS: Defining Risk, Risk Acceptability, Organizational Learning, Hazardous Waste Facility Siting

INTRODUCTION

The problem of hazardous waste management has frequently been referred to as "the single most threatening environmental issue facing the country," (U.S. General Accounting Office, 1982:8) or the "environmental problem of the century" (Epstein et al., 1982:37). These characterizations of the problem are an acknowledgment of a serious predicament which this issue poses for a modern industrial society. On the one hand, society has come to depend on products and processes which require the ever-increasing use of complex and dangerous chemicals that must somehow be safely disposed of after they are no longer useful. However, in spite of the increasing demand each year for new hazardous waste disposal facilities (HWDF) to be built, there has been continuous opposition to the location of these facilities in almost every community across the nation.

At the heart of this siting controversy is the issue of the risks posed by these facilities to the communities in which they would be housed. The meaning of the concept of risk in this context is subject to various interpretations by all those who have a stake in the outcome of the decision. In particular, there have been disagreements over the proper boundaries of the risk debate (that is, the breadth and nature of risk in this context), as well as disagreements about what is an acceptable level of risk for a community to bear from these facilities.

The task of resolving these siting controversies has been left to the states; who, for the most part, have responded to these issues by developing regulations which codify what the states consider are acceptable levels of risk from a proposed HWD facility to any given community. In the course of developing the regulations governing the location of these facilities, the states have been guided in their decision making by certain norms, strategies and assumptions which are descriptive of and provide an explanation for their overall behavior (Schon, 1983:117).

Given that the problem of decision making in this area is fraught with uncertainties and incomplete information due to continuous changes in the technological, economic, and political environments which affect hazardous waste disposal, those responsible for developing HWDF siting regulations are presented with a difficult situation. Decision makers are not only confronted with the need to consider multiple and sometimes conflicting perspectives on this issue, but they must also remain ready to respond to the continuous challenges brought about by a changing environment which may require a rethinking of their theories-of-action; that is, the standard operating assumptions, strategies and norms which guide their decision making on risk. The question remains whether or not states have the capacity to cope with a changing environment regarding risk and thus make the necessary adaptations that are required for an organization to learn and therefore to survive and flourish.

The Theoretical Debate

There is a debate currently taking place among scholars of risk analysis and policy making regarding the proper scope and nature of the concept of risk. Traditionally, risk has been defined as, "a compound measure of the probability and magnitude of adverse effect. Thus a statement about risk is a description of the likelihood and consequences of harmful effect" (Lowrance, 1980:6). This approach to the definition of risk has been widely accepted in the past, but is currently being challenged by a growing number of scholars who say that it is not comprehensive enough to address issues which do not easily lend themselves to quantification and measurement. It has been asserted that the conventionally-accepted definition of risk, while appropriate for an engineering-type approach to risk, is inappropriate and, "misleading at the broader, more intractable, level of risk management" (Rayner, 1984:4). Along these lines, Nelkin and Pollak have also pointed out that when risk is being discussed within the context of controversial technologies it is not always viewed, "as a problem to be solved, but as a controversial question requiring dialogue and negotiation" (1979:313).

These scholars and others have pointed out the need for a new emphasis in the approach to defining risk. Fischhoff et al., have noted that because

> the definition of risk.. is inherently controversial, [that is] the choice of definition can affect the outcome of policy debates, the allocation of resources among safety measures, and the distribution of political power in society..., a highly flexible general approach to defining risk [is necessary] (Fischhoff et al., 1984:124).

An approach is needed which is more responsive to multiple and, perhaps, different meanings of risk grounded in different sets of values.

Hadden, (1984) states that the decision making process regarding technological risk has been dominated by technical considerations to such an extent that various political considerations have been considered illegitimate. In particular, decision makers have tended to overlook the importance of gathering information on the meaning of risk from those who are directly affected by it in favor of gathering more analytical information.

> Domination of the risk analysis field by economists, psychologists, and toxicologists has caused this simple truism to be lost in a forest of strategies for measuring risks and treating them efficiently. Issues that are redistributive, that are based on technical information that is characterized by uncertainty, and that affect individuals' own health and quality of like are issues that must forever be political. Refinements of political institutions should therefore be designed to improve participation of affected parties and to elicit relevant information--in other words, to perfect the process by which all public decisions are made...(Hadden, 1984:17). Emphasis added.

Defining risk differently can lead to alternative ways of thinking about the acceptability of various risks (Fischhoff et al., 1984). For instance, Rayner (1984) has pointed out that although public acceptance of risks has always been

> framed in terms of differential perceptions of probabilities... the choices between those probabilities are incomprehensible to most of the public and...I would guess that the truth is that the public doesn't care about probabilities in choosing between two courses of action when the differences in probability are so small as they are in most of the risk-management decisions that policy makers currently face (Rayner, 1984:8).

Starr (1984) has pointed out that what people are concerned about is trust. Societal acceptability of risk depends on its confidence in the capability of its institutions to manage various risks rather than on rigorous, scientific assessments. What is being underscored by all of these writers is the need for changes in the approach to risk assessment, that is, changes in the process by which decisions are made about the scope and nature of risk.

The Meaning of Risk in the Hazardous Waste Context

It has been noted that there are at least three questions which concern the public most when it is confronted with a situation involving societal risk.

1. Is the procedure by which collective consent is obtained for a course of action acceptable to those who must bear its consequences?
2. Is the principle that will be used to apportion liabilities for an undesired consequence acceptable to those affected?
3. Are the institutions that make the decisions that manage and regulate the technology worthy of fiduciary trust? (Rayner, 1984:9).

Judging by the type of issues that have been raised regarding the risks from hazardous waste disposal facilities, the above questions accurately summarize the scope of public concerns. Although the reasons for opposition to HWD facilities vary from community to community, they generally include some combination of the following factors.

1. Fear and uncertainty...about the safety of these facilities.
2. Both real and perceived impacts from facility construction and operation activities (noise, traffic, public service burdens, risks and aesthetic impacts etc.)...

3. A fear that property values will drop...
4. ...[A] perceived stigma associated with becoming a 'hazardous waste dump.'
5. ...[Distrust [of] industry and government's ability to assure the long run safety of these facilities.
6 ...[Inability] to fully comprehend the extent of the costs, risks and benefits associated with these facilities, and thus how they should appropriately respond to a proposal.
7 ...[The suitability of the site including] soil permeability, seismic stability, groundwater contamination and alternative uses for a site.
8 ...[A biased] siting process [favoring developers at the expense of local citizens]...
9. The types of wastes to be treated or disposed of...
10 The information provided to communities is viewed as insufficient or too technical for them to confidently make a decision (Clark-McGlennon, 1980:6).

"Opposition to the siting of hazardous waste management facilities...is in part a consequence of conflicting perceptions of how best to manage the risks associated with hazardous waste" (Elliott, 1984:397). In most states, local citizens' interests and perceptions of the problem differ from those of other stakeholders-namely, regulatory agencies, hazardous waste generators, and operators of treatment and disposal facilities. Those who have been arguing on behalf of the siting and construction of new treatment and disposal facilities have often utilized the following types of arguments to neutralize the opposition of their critics. It is often said that the risk from HWD facilities is no greater than the risks from other commonly-accepted industrial operations and therefore, these types of facilities should not be feared. A corollary statement that is also often put forth is that because individuals often voluntarily engage in activities that are far more riskier than living near a hazardous waste treatment or disposal facility, it is illogical for them to oppose the siting of such a facility in their community. Thus, involuntary risk is equated with voluntary risk. Finally, it is often argued that opposition to hazardous waste facilities is based on irrational fears and lack of information and education about such facilities; and that once opponents are educated about the technological safety of the facility they will no longer oppose the siting process.

Many of those who have been arguing in favor of the immediate siting and construction of hazardous waste treatment and disposal facilities, often have not been speaking the same language of risk as their opponents. Gaming research has shown that citizens involved in hazardous waste facility siting issues, "are concerned with a richer array of risk management options" than was previously realized (Elliott, 1984:398). That is, laypeople are often more concerned with strategies of risk management which emphasize risk detection and mitigation versus risk prediction and prevention. The former strategies stress such issues as:

> If hazardous conditions develop, do we have the means to detect these changes? If so, will that data be collected and scrutinized so as to detect changes quickly? If serious hazards are detected, do we know how to reverse the dangers and the negative impacts? Will these mitigation measures be applied with sufficient speed and skill to be effective? (Elliott, 1984:398).

Previous approaches to risk management have not focused on these types of issues. Rather, risk management has traditionally dealt with the risks from hazardous waste facilities by means of improving systems for predicting and preventing problems from occurring, and relying on technological control mechanisms rather than on social control mechanisms (Elliott, 1984).

A Proposal for Research

The very nature of the theoretical debate regarding the meaning of risk provides a compelling reason to examine the process by which risk has been defined in the context of developing hazardous waste facility siting regulations. The states have the primary responsibility for determining what the risks are from HWD facilities and what are acceptable levels of risk for individuals and communities to bear. Given the variation in the meanings of risk and the fact that in this issue area continuous changes are occurring in the technology, economics and politics of hazardous waste management, the following question needs to be researched. How have the states responded to the need for a dynamic decision making process regarding the definition or risk?

The subject of the present research is a comparative analysis of the process by which risk has been defined in the hazardous waste facility siting regulations of Pennsylvania (by the Department of Environmental Resources-DER), and New Jersey (by the Department of Environmental protection-DEP), to determine whether or not learning has occurred within these two organizations during the process of developing the siting regulations.

At the present time, approximately one-half of the states have regulations governing the siting of HWD facilities. States such as Pennsylvania and New Jersey are among the largest generators of hazardous waste and as such, have the greatest need for new disposal facilities to be located and constructed. In response to this need Pennsylvania and New Jersey passed comprehensive legislation in the early 1980's governing the management of hazardous wastes. This legislation called for the respective states to develop criteria and standards for siting HWDFs and to review and amend these criteria on a regular basis.

The development of the siting criteria and standards (which were finalized as departmental rules and regulations) was an iterative process which took place over the course of five years in Pennsylvania and two years in New Jersey. Decision makers in each of these states initially drafted siting criteria (e.g. wetlands, flood hazard areas etc.) which reflected their respective departments' assumptions about what they considered were the greatest risks from hazardous waste disposal facilities to the surrounding areas in which they would be located. The initial siting standards, were a measure of an acceptable level of risk from a proposed facility to any given criterion.

Once the initial siting criteria and standards were drafted, the states allowed a public comment period. The comments represented a variety of individual and organizational views of risk; some of which, were based on an entirely different set of norms, strategies and assumptions than those used by the states. Following this period of public input, the DER in Pennsylvania and DEP in New Jersey considered the comments and revised the initial siting criteria and standards. This process was repeated in each state until final siting regulations were approved -- in August, 1985 for Pennsylvania in September, 1983 for New Jersey.

A Method of Research for Organizational Learning

There are several major questions which research on organizational learning addresses: Has learning occurred, or is it occurring? If so, what kind of learning is involved? Is it organizational? What is its quality? (Schon, 1983; Argyris and Schon, 1974). To study these types of questions, it is necessary to have access to at least three interrelated phenomena.

1. Organizational theory-in-use at Time 1
2. Organizational inquiry
3. Organizational theory-in-use at Time 2

An organization's theory-in-use is implicit in the norms, strategies and assumptions that govern its regular task performance. Thus, an organizations' theory-in-use may be inferred from the way in which it detects and corrects errors (Schon, 1983). In order to tell whether there has been a change in theory-in-use, it is necessary to identify and describe two successive states of the theory-in-use. In order to tell whether the change is attributable to organizational learning, it is necessary to study the process of inquiry that mediates the shift from one state of theory-in-use to the next.

For organizational learning to occur, the organization must first engage in a process of inquiry; which has been described as a combination of "thinking and doing" (Schon, 1983:121). Organizational inquiry is preceded by the occurrence of some phenomenon (in this case, the input from the public hearings) which triggers the organization to, "...reflect on previously unquestioned assumptions, gather new information, experiment with new patterns of action, or argue over conflicting interpretations rooted in different values" (Schon, 1983:121).

Although there are different types of organizational learning, Schon (1983) draws a distinction between two types; both of which involve the restructuring of an organization's theory of action. One involves changes only in an organization's strategies whereas, the other involves a change in both the organizations' strategies of action and the underlying norms. This research will determine whether, and to what extent, the various revised drafts of the HWDF siting criteria reflected change in the respective states' theories of action. That is, any change in their norms, strategies and/or assumptions.

How states have responded to challenges to their operating assumptions and norms during the course of preparing the siting regulations may indicate their capacity for learning and suggest ways to improve it. Whether or not states have the capacity for organizational learning is important in this context because it will affect the states' ability to update and revise the siting regulations on an ongoing basis as changes occur in the technology, economics and politics of hazardous waste.

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PUBLIC JUDGMENT OF AN ENVIRONMENTAL HEALTH HAZARD: TWO STUDIES OF THE ASARCO SMELTER*

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ABSTRACT

Results from two studies focusing on public risk judgment concerning the ASARCO Smelter in Tacoma, Washington are reported. The first study examines the factors affecting risk judgment among persons directly exposed to emissions from the smelter. Two public samples were studied, one composed of participants in public hearings and one generated by a telephone sampling of the general population of Tacoma. For these public groups, risk judgments and risk tolerance were closely associated with judged benefits of the hazard source, among other factors, and not with level of technical information about the hazard nor to residential distance from the smelter. The second study employed college students as subjects in a "simulated hazard" where subjects were instructed to respond " as if they lived in an area of Tacoma affected by the smelter." Where the primary purpose of the first study was substantive, that of the second study was methodological, exploring the use of a longitudinal panel design to study risk judgment. Data were collected from the same subjects at three points in time, a week separating the first from the second and the second from the third. Information about the hazard was made available to subjects during the breaks between sessions. In each testing period, subjects provided information on judgments of risk, on their information seeking behavior and on risk mitigation. These data were used to test and revise a structural model of the effects of information on risk judgment and risk mitigation.

KEY WORDS: Risk Judgment, Risk Communication, Hazard Information, ASARCO Smelter

The public information activities undertaken by the Environmental Protection Agency as part of the hazard management process for the ASARCO smelter in Tacoma, Washington, provided a rare opportunity to study the effects of formal risk estimates on public risk judgments. Two such studies are described in this report. The first study is a field study,

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examining the factors affecting risk judgments among persons directly exposed to emissions from the smelter. The results of this study raise doubts about the direct effects of formal risk estimates (i.e., calculated, scientific or technical estimates of the ill effects of a hazard). The second study is a laboratory study, exploring the factors affecting the use of hazard information by college-student subjects acting as if they were residents of Tacoma. A local earthquake hazard is used as a comparison case to help demonstrate those conditions that lead to the seeking out and use of hazard information.

FIELD STUDY

INTRODUCTION

Other participants in this symposium have addressed the many technical problems associated with estimating and attempting to manage the risks of the ASARCO smelter. The complexity of those problems and the uncertainties that accompany them would in themselves make determination of the best course of regulatory action a difficult task. In the ASARCO case, as in most risk management cases, the technical and scientific difficulties are compounded by complex social questions and by the legal and ethical right of the affected public to have an influence on the risk management process.

From a social science perspective the ASARCO case presented a unique opportunity for research. It raised the difficult questions of risks versus benefits, and, at the same time, involved a natural population of potential subjects who were directly exposed to the risks and had an opportunity to influence their level of exposure. Along with these characteristics, the Environmental Protection Agency's efforts to publicize its formal risk estimates and proposed controls made it possible to examine the effects of such information on public reactions. In light of the other papers describing elements of the formal risk estimation process, this paper will emphasize findings relating to the effects, or as the case may be, the lack of effects of formal risk estimates on public opinions and risk tolerance.

Method

The findings to be reported here are based on data collected from questionnaires distributed at the EPA-sponsored public hearings in Tacoma, and from a concurrent systematic telephone survey of persons living within a twelve mile radius of the smelter. A total of 347 completed questionnaires were collected at the hearings, an estimated 80% of the hearing attendees who were residents of the affected area. Two hundred and sixty-six persons completed the telephone survey.

Questionnaire items were essentially the same for both the hearing and phone samples. They were designed to measure such variables as respondents' informal risk estimates, judgments of the risks versus benefits of the smelter, voluntariness of the risk exposures, environmental ideology, and factual knowledge of the formal risk estimates and proposed regulations. A variety of demographic factors were also examined, the most important of these including distance of residence from the smelter, length of residence in the area, age and family member employment at the smelter.

In the data analyses all of the variables just described were considered in relation to respondents' attitudes toward additional controls for the smelter given the possibility that such controls might lead to the smelter's closure and the resultant loss of jobs. Based on their attitudes toward additional controls, respondents were identified as either <u>More Tolerant</u> (less controls) or <u>Less Tolerant</u> (more controls) of the smelter risks.

<u>Results and Discussion</u>

In reporting the study's results, data obtained from respondents at the hearing must be distinguished from data obtained from the telephone survey. Because respondents who attended the hearings showed themselves to be more interested and informed about the ASARCO issue, and in view of the fact that many in this group provided input directly to the EPA, results from the hearing will be given more attention here. At the same time, however, it is important to keep in mind that because the hazard in question affected all of the residents of the area, not just those who attended the hearings, the opinions of the general population also warrant attention. Thus, along with the main findings from the hearing, key findings from the telephone survey will also be reported where appropriate.

Because the purpose of the hearings was to obtain public input about the need for additional pollution controls for the smelter, it is appropriate to consider first how respondents felt about this question. Table 1 presents the results of two questions, the first asking simply if additional pollution controls were favored for the smelter, the second if additional controls were favored if it meant the smelter might have to close and jobs would be lost. As can be seen in the table, the explicit reference to the possibility of plant closure and job loss produced notable changes in the response percentages for both hearing and phone survey respondents. While a majority of those at the hearing still favored additional controls even if they might lead to closure, among phone survey respondents the weight of opinion shifted from a plurality support for controls to a plurality in opposition. The different responses to the two questions illustrate the importance of the jobs versus health question on public risk tolerance. The differences between the opinions of hearing and phone survey respondents suggests that input received at such public hearings may not be representative of the sentiments of the public at large.

Turning to factors that may have shaped the opinions just examined, Table 2 presents selected correlational results from the Hearing data, showing the 9 items having the highest correlations with risk tolerance as reflected in desires for additional controls. Consistent with what we have just seen, respondent's judgments of the relative costs versus

Table 1

Attitudes Toward Additional Pollution Controls

	Support additional controls (no mention of closure)			Support additional control (if closure might result)		
	Yes	No	Don't Know	Yes	No	Don't Know
Hearing	58%	34%	8%	51%	42%	7%
Phone	42%	29%	30%	32%	47%	21%

Table 2

Correlation With Risk Tolerance

Item	Pearson r*
Harmful effects vs benefits of smelter	.863
Do you think the smelter is a health hazard	.818
"Real risks" (in S's judgement) are higher or lower than EPA estimates	.807
Personal immunity to cancer caused by ASARCO emissions	.525
Voluntarines of exposure to ASARCO emissions	.470
Should standards be based on affordability	.454
Personal immunity to general environmentally caused cancer	.387
Agencies should not wait for certainty before acting to reduce risks	.386
Costs versus benefits of pollution controls in general	.374

*All correlations presented are significant at less than the .001 level.

benefits of the smelter provided the best predictor of tolerance for the smelter risks. As one would expect, those who rated the benefits as greater than the risks were more willing to tolerate the existing risk levels, while those who viewed the risks as greater than the benefits were more likely to demand further risk reductions.

Just behind cost-benefit judgments, tolerance for the smelter risks is most closely related to three items associated with subjects' "informal" risk judgments. The first of these asked for subjects' impressions of whether or not the smelter is a "health hazard." The second reflects subjects comparisons of their personal estimates of the smelter risks with the formal EPA risk estimates. The third item tapped the process of personal risk denial.

For present purposes, the most interesting element of all three items as well as the risk benefit item just examined is that they show informal risk estimates to be perhaps the key variable in shaping risk tolerance.

Lest this conclusion sound self reflexive, it is important to realize that in the ASARCO case, as in most "real world" risk management situations, people evidently do not experience the question as that of tolerating one level of clearly specified statistical risk versus another higher or lower statistical risk. Instead, they ask themselves what they think the existing risk is from a specific hazard and if they will tolerate the risk or would like it lowered. Thus, peoples' informal judgments of a risk will naturally have a profound impact on their tolerance for that risk "as they estimate it."

Because informal risk estimates are shown to have such an important influence on risk tolerance, it is appropriate at this point to consider the relationship between informal estimates, tolerance, and factual knowledge of formal estimates and regulations. Table 3 presents the response percentages for two questions demanding factual knowledge. The first asked respondents to give the EPA's estimate of the lifetime risk of arsenic-causing lung cancer among the 1000 people living nearest the estimate was actually 2, but answers ranging from 1 to 5 were scored as correct. The second item asked respondents simply to indicate whether or not proposed regulations would establish an ambient air standard for arsenic.

Examining this Table, the first thing to note is that in spite of the extraordinary efforts the EPA made to inform the public, and notwithstanding the fact that the purpose of the hearings was to obtain public comment on the risk estimates and proposed regulations, barely half of the respondents demonstrated accurate knowledge of the risk estimate, while less than forty percent were knowledgable about a key element of the proposed regulations. The corresponding figures from the telephone survey are not shown in Table 3, but they reveal the vast majority of the public to have been virtually ignorant of the factual information. Only 9% of the telephone survey respondents provided a risk estimate within the range scored as correct, while only 12% correctly indicated that the proposed regulations would not establish an ambient air standard.

In the case of the telephone survey results it is immediately apparent that factual information probably exerted little influence on people's attitudes toward the smelter risks. If scarcely anyone in the general public knew what the formal risk estimates were, those estimates could not have been an important factor in shaping their informal risk estimates or tolerance decisions. The situation is somewhat different for

Table 3

Results of Factual Knowledge Questions for Hearing Respondents

	Risk Estimate Question		Regulation Question	
	Correct	Incorrect(1)	Correct	Incorrect
Less Risk Tolerant	62%	38%	47%	53%
More Risk Tolerant	41%	59%	26%	74%
Overall Percentage	52%	48%	37%	63%

1. Percentages cited as incorrect include those who gave incorrect anwers as well as those who did not answer or selected the Don't Know response option.

2. Chi square analyses reveal the differences between MT and LT groups to be significant at less than the .001 level for both questions.

respondents at the hearings, but the conclusion is similar.

Looking again at Table 3, it can be seen that the percentage of knowledgable respondents is significantly higher among Less Tolerant than among More Tolerant respondents. Yet simply noting that greater percentages of one group were knowledgeable than another does not indicate whether factual information or lack of it was a key factor in shaping tolerance. A better insight into this question is gained from strength association measures when knowledge items are compared with the risk tolerance item. In this case the association between knowledge and tolerance is not found to be strong. The squared correlation coefficient between the tolerance and formal risk estimate item was .04, while another measure of association, Asymmetric Lamda, with tolerance dependent on knowledge of the risk estimate was only .125. Thus, knowledge of the factual information was not found to be closely related to or highly predicative of risk tolerance, and it seems improbable that such information had a large effect on shaping the opinions of most respondents.

Considering the time, energy, and money that were devoted to establishing and publicizing the risk estimates and proposed regulations in the ASARCO case, policy makers may find it disheartening to discover that such information played at most a relatively small role in shaping public reactions. The next questions that need to be asked then are: Why was the information about formal risk estimates not more important? and, If formal risk estimates and regulatory information do not influence public reactions to risk what does?

To account for the non-effects of factual information it is possible to identify three contributing factors which became apparent during the course of the present study. These are, first, a general lack of knowledge of the factual information, second, difficulties the public faces in trying to make sense of whatever information was known, and third, the influence of non-informational characteristics on shaping reactions to factual information.

The first reason for information's lack of impact has already been mentioned, that is, information cannot influence people's decisions unless it is known, and most people know very little about formal risk estimates. Confronted by this finding it would be possible, but unfortunate, to simply write it off as evidence of ignorance or apathy on the part of the public. A preferable response is to ask what factors contribute to the apparent lack of knowledge.

For example, it may be that in cases such as this people consciously or unconsciously choose not to become informed lest information threaten their established beliefs and raise the possibility that they might feel a need to change their opinions or, more threatening still, change such important parts of their lives as where they live or work. If this is the case, apathy and ignorance are not at the root of the problem; fear of change, uncertainty or responsibility are. An alternative possibility is that people want to be informed, but the selected means of informing the public were not appropriate to the task. This would be analogous to a marketing problem with the formal information as the product (see Earle and Cretkovich, 1984).

Turning from the problem of not having information to the closely related problem of not understanding information, the present study indicates that an important contributor to the non-effects of information is the fact that normal people do not know what to make of the language and numbers of formal risk analysis. While professional scientists and administrators become accustomed to the principles, statistics, and language of risk analysis, to most people such things are meaningless at best and frustratingly confusing at worst. This was revealed in the ASARCO case through responses to open ended questions asking what could be done to better inform the public. Comments such as "Cut out the Jargon!!", were frequently scribbled angrily in the space provided below this question. Other evidence that formal risk estimates are apart from normal public thinking comes from responses to telephone survey requests to indicate the EPA risk estimates. In response to this question it was not uncommon for people to offer comments such as "Oh, I don't think the risk is very high. Maybe only about 10 or 15% of the people will get cancer because of the smelter." It is obvious to members of the risk analysis community that such informal risk estimates are several orders of magnitude greater than the levels which are debated as acceptable bases for policies, but the fact that some members of the general public are able to view such extreme risks as "not very high" reveals just how alien risk analysis and the magnitude of the probabilities it involves are.

The final process to be discussed here concerns how people who do know the formal risk estimates interpret those estimates and make their tolerance decisions in relation to them. This process reflects the other side of the coin of information's non-effects. Much as information cannot affect people's reactions unless it is known, when people are equally knowledgable of formal risk estimates, but still react differently to the risks, the risk estimate information alone cannot be the key variable shaping the different reactions.

One of the ways this is demonstrated is in the finding that although only 52% of the hearing respondents knew the correct figure for the EPA's risk estimate, 96% of the respondents offered an opinion about the accuracy of that estimate, and only 22% considered it to be roughly correct. Thus, whether they knew what the formal estimate was or not, most people were willing to offer an opinion about its accuracy, and even among knowledgeable respondents, only a small minority considered the formal estimates to be correct. In such circumstances it is not surprising that knowledge of the formal estimates had little effect on risk tolerance. Instead, it appears that other factors, such as respondents' attitudes toward health, jobs, industry, the environment, ethics, the EPA, and perhaps to statistics themselves, shaped both how they made informal judgments of the risks and how they reacted to information about the formal risk estimates.

LABORATORY STUDY

Results from the field study described above indicate that, in the ASARCO case, scientific hazard information had little effect on public judgment and tolerance of health risks. In this section of our report we describe a laboratory study that was designed in part to identify factors that may contribute to increasing the impact of scientific and other hazard information on public risk judgments and on risk mitigating and reducing behaviors.

Method

The aim of our research procedures was to simulate in a controlled setting the essential elements of public risk judgment processes. One central element of risk judgment is that it is a dynamic process. That is, an individual's risk judgment at a particular point in time is the result of preceding events, particularly experience with the hazard in question and the processing of information about that hazard. Also, subsequent events and information may modify an individual's judgment of risk. In order to capture the dynamic character of risk judgment processes, a longitudinal research design must be used. A panel design was used in this study, with the same group of 132 subjects providing data at three points in time. This type of design facilitates a causal analysis of the relations among the variables measured. We can therefore identify which factors, if any, lead to increases in risk judgments, for example, or information seeking and risk mitigation activities.

One week separated the first wave of data collection from the second and the second from the third. The 132 subjects were recruited from the subject pool of the Psychology Department of Western Washington University. At the end of the first two data collection sessions, information regarding the two hazards under study (the ASARCO smelter and the seismic hazard in Whatcom County, Washington, the location of WWU), was made available on an optional basis to the subjects. The information consisted, for example, of reproductions of Tacoma News Tribune articles on the ASARCO case (detailing EPA's role, etc.) and pamphlets describing the local seismic hazard and how to deal with it. Subjects were instructed that they were free to take or leave the information provided; they were also free to seek out any other information they desired during the weeks separating the data collection sessions.

In responding to the questionnaires, subjects were asked to roleplay their responses to certain items. With regard to the Whatcom County earthquake hazard, respondents were asked to "respond as an individual (yourself) living in a single-family house located somewhere in the general WWU area of Bellingham..." For the ASARCO hazard, subjects were instructed to "respond as if you lived in an area of Tacoma that is affected by the emissions from the ASARCO smelter. Aside from where you live, all other aspects of your life would remain the same: <u>You should respond as you would if you lived in an area affected by ASARCO</u>..." Measures designed to evaluate these simulation procedures indicated that they were effective.

The contents of the questionnaires were derived from our dynamic model of risk judgment (Earle and Cvetkovich, 1983). In brief, this model includes subject background variables (e.g. scientific training), risk judgment variables (described below), hazard information variables (e.g. information seeking and information content) and risk mitigation variables (e.g. what has or should be done to reduce the effects of the hazard). The risk judgment variables were derived from the work of Fischhoff and his colleagues (Fischhoff, Slovic and Lichtenstein, 1983; Fischhoff, Watson and Hope, 1983) who make two basic points: 1) there is no single definition of risk suitable for all problems (and this is true for both scientists and the public); 2) the choice of definition in any individual case is a political one, in the sense that it expresses someone's values about the importance of different adverse effects.

Risk is thus multidimensional and variably defined both within and among individuals. And, further, risk is just one of several factors considered by individuals when making risk decisions. People don't ordinarily judge abstract levels of risk. Instead, they engage in risk decisions, choosing among several alternatives (among employment opportunities, for example). Risk is only one among several possible significant aspects of the alternatives. The other important aspects may include costs and benefits, each of which is also, of course, subjectively defined. Application of this approach to a "real-life hazard" would require a preliminary determination of an acceptable general structuring of the risk decision for the particular hazard and group of respondents. This laboratory study is the first use of these procedures. The research process was simplified somewhat, therefore, through the provision of general, pre-structured sets of judgments for the two hazard cases.

To illustrate the item-generation process, an outline of the major risk decision aspects is given in Table 4. This general structure was adapted to the two hazards. With ASARCO, for example, items referring to the morbidity of workers were included; none were included for the earthquake hazard. Aside from such necessary differences, the items referring to the ASARCO hazards were the same as those referring to the

Table 4

Risk Decision Aspects Used in Item Generation

- **Risk**
  - **Mortality**
    - **Self**
    - **Others**
      - **General Public**
      - **Workers**
      - **Future generations**
  - **Morbidity**
    - **Self**
    - **Others**
      - **General Public**
      - **Workers**
      - **Future generations**
  - **Knowledge of hazard**
    - **Self**
    - **Science and government**
  - **Dread of hazard**
    - **Self**
    - **Others**
- **Benefits**
  - **Economic**
    - **Self**
    - **Others**
  - **Non-economic**
    - **Self**
    - **Others**
- **Costs**
  - **Property damage**
  - **Income loss**
- **Environmental effects**
  - **Plants and animals**
  - **Non-living environment**

Table 5

Risk Decision Variables Included in Analysis

Endogenous variables

- Risk
  - ASARCO — Mortality/morbidity: Self
    - Mortality/morbidity: Other
  - Earthquake — Mortality/morbidity: All
- Benefits
  - ASARCO — Benefits: All
  - Earthquake — Benefits: Economic
    - Benefits: Non-economic
- Information seeking
  - (Same for both hazards)
- Risk mitigation/reduction
  - (Same for both hazards)

Exogenous variables

- Scientific background
- Attitude toward science/technology
- Attitude toward government
- Concern in hazard information

seismic hazard. Examples of the ASARCO items are: "How likely is it that some employee of ASARCO will die as a result of emissions from the smelter?" (Risk-mortality-others-workers.) Answered on a five-point scale ranging from Very Unlikely to Very Likely); "To what extent do you gain economically by living in an area exposed to emissions from the ASARCO smelter?" (Benefit-economic-self. Answered on a five-point scale ranging from No Economic Gain to Great Economic Gain.).

Results and Discussion

Results on a selected subset of variables are reported here, with focus on the effects of hazard information on risk judgments and risk mitigation activities. The variables analyzed are listed in Table 5. These variables were derived form the original questionnaire items through a factor analysis data reduction procedure. All of the questionnaire items relating to risk, for example, were factor-analyzed to determine the number and make-up of the risk dimensions generated by the respondents. With respect to the ASARCO case, four factors were generated: mortality/morbidity: self; mortality/morbidity: other; knowledge of the hazard; and dread of the hazard. (Note that only the first two of these factors are included in the present analyses). In the case of the earthquake, only three factors emerged due to subjects distinguishing less between themselves and others on mortality/morbidity than they did with the ASARCO hazard. A similar situation occurred with the benefit items. For ASARCO, subjects related all of the items to a single benefits dimension while dividing benefits into economic and non-economic for the earthquake. These simple results demonstrate the important basic idea that different types of hazards may be classified or otherwise dealt with cognitively in significantly different ways. Knowing how particular individuals classify specific hazards may point the way to improved hazard communication.

The variables in Table 5 are divided into endogenous and exogenous. The endogenous variables are the "dependent variables" in our structural equation models of the risk judgment process. The exogenous variables are the "independent variables." since our models cover three time periods, an endogenous variable that is "dependent" in Wave I will be a predictor variable for later endogenous variables. An endogenous variable can also be both dependent and a predictor. In addition to the risk and benefit variables, the endogenous variables for the present analysis also include information seeking (a measure of the time and effort spent obtaining information about the hazard) and risk mitigation/reduction (a measure of the number of steps subjects say they or the government have taken plus the number of steps subjects say they or the government should take).

Four exogenous variables are included in this analysis: scientific background (a measure of the science courses completed in high school and college); attitude toward science and technology (a high score on this variable indicates a negative attitude); attitude toward government (a high score indicates a negative attitude); and concern in hazard information (a measure of the level of concern experienced by a subject as the result of processing information about the hazard). This last exogenous variable, concern, is a key variable in our analyses since it sums up the emotional impact on subjects of the information they have sought out and used. Estimates of the relations between this variable and the other variables in the model provide an indication of some of the effects of hazard information on hazard-related judgments and behaviors.

The relations among the variables in our models were estimated using the LISREL procedure developed by Joreskog and Sorbom (1981). The parameter estimates for our model of the ASARCO case are given in Table 6. The endogenous variable names are coded in this way: MMO = mortality/morbidity: other; MMS = mortality/morbidity: self; BEN = benefits: MIT = risk mitigation/reduction activities; and INFO = information seeking. The exogenous codes are: SCI = scientific background; STA = attitude toward science and technology: GOVA = attitude toward government; and CON = concern in hazard information. The parameter estimates for our model of the earthquake case are given in Table 7. The endogenous codes are: MMA = mortality/morbidity: all; EBEN = economic benefits; and NBEN = non-economic benefits. The remaining codes are the same as in the ASARCO model. In both models, the numerical suffixes indicate the wave on which the variable was measured.

Many points of comparison can be made between the ASARCO model and the earthquake model. It can be noted, for example, that the background variables (SCI, STA and GOVA) were important predictors of mortality/morbidity judgments in the ASARCO case but not in the earthquake case. In the ASARCO model, subjects with stronger scientific backgrounds and positive attitudes toward science/technology and government tended to give lower judgments of mortality/morbidity. These individuals apparently believed that the ASARCO hazard could be well managed by government officials, and their scientific training contributed to their faith in that management. The earthquake, on the other hand, was apparently seen as an "unmanageable" hazard, with judgments of mortality/morbidity independent of the activities of technologists and government officials. While such substantive findings in comparisons between the two models are intriguing and suggestive, they will not be pursued in this report. Our focus here is primarily methodological, with the aim being to demonstrate a method by which the effects of hazard information can be studied.

One method of demonstrating the effects of hazard information in these risk judgment models is to compare a model that includes estimates of the parameters associated with the information variables with a model that sets those parameters equal to zero. For the ASARCO case, this comparison can be seen in Table 6 in the two columns of R^2s, one for a model with hazard information (the variables INFO and CON) and one for a model without. The decrease in R^2 as the result of information removal demonstrates its effects. See, for example, MIT1 which goes from an R^2 of 0.19 to 0.00. Similar comparisons can be made in Table 7 for the earthquake case. Removal of hazard information effects from the earthquake model, however, results in relatively small decreases in R^2s. It can be concluded, then, that hazard information had significant effects in the ASARCO case but not in the earthquake case.

The comparison of R^2s between models is not a very clear way of demonstrating information effects because the effects become hidden in the changes in the variables over time. A more dramatic demonstration involves the calculation of the total effects of information content on each of the endogenous variables over time. These total effects are given in the final columns of Tables 6 and 7. There are two key sets of comparisons here. The first is on the MIT variables: For ASARCO, concern had significant effects on mitigation activities; concern had no effect on MIT for the earthquake. (Interestingly, benefit judgments predict MIT for the earthquake.) The second set of key comparisons is on the INFO variables: In both cases, information seeking was strongly affected by concern in hazard information. It seems, therefore, that concern about a hazard will lead to the seeking and use of hazard information, and the concern generated by that information will tend to lead to risk mitigation/reduction activities when the hazard is considered to be manageable.

SUMMARY AND CONCLUSIONS

Two studies of the effects of hazard information on risk judgments have been described. The first was a field study of the ASARCO smelter case in Tacoma which demonstrated that formal EPA risk estimates had little effect on the risk judgments or tolerances of persons living in the affected area. The second study was a laboratory study that demonstrated a method for the studying of hazard information effects over time. By comparing the risk judgment models for the ASARCO and earthquake hazards, it was shown that hazard information can have strong effects on hazard-related judgments and behavior.

Table 6

ASARCO: LISREL Maximum Likelihood Parameter Estimates
(All t-values greater than 2.0)

Dependent Variable	Predictors	R^2	R^2 (Without Hazard Information)	Total Effects of Concern
MMO1	SCI (-0.21), STA (0.20), GOVA (0.33), CON (0.26)	0.25	0.25	0.26
MMS1	MMS1 (0.43), STA (0.22	0.28	0.28	0.11
BEN1		0.00	0.00	0.00
MIT1	CON1 (0.43)	0.19	0.00	0.43
INFO1	MIT1 (0.17), CON1 (0.40)	0.25	-	0.48
MMO2	MMO1 (0.46), STA (0.21), CON (0.35)	0.45	0.36	0.46
MMS2	MMS1 (0.16), MMO2 (0.37), INFO2 (0.20)	0.28	0.27	0.29
BEN2	BEN1 (0.63)	0.39	0.39	0.00
MIT2	MIT1 (0.40), CON2 (0.42)	0.36	0.27	0.60
INFO2	MMS1 (0.26), CON2 (0.45)	0.27	-	0.48
MMO3	MMO1 (0.25), MMO2 (0.59), INFO3 (0.24)	0.64	0.58	0.47
MMS3	MMS2 (0.53), MMO3 (0.24), CON3 (0.14)	0.46	0.49	0.40
BEN3	BEN1 (0.24), BEN2 (0.46), CON3 (0.25)	0.40	0.40	0.00
MIT3	MIT1 (0.33), MIT2 (0.20), MMO3 (0.24), CON3 (0.25)	0.40	0.36	0.63
INFO3	INFO2 (0.38), CON2 (-.28), CON3 (0.63)	0.48	-	0.53

Table 7

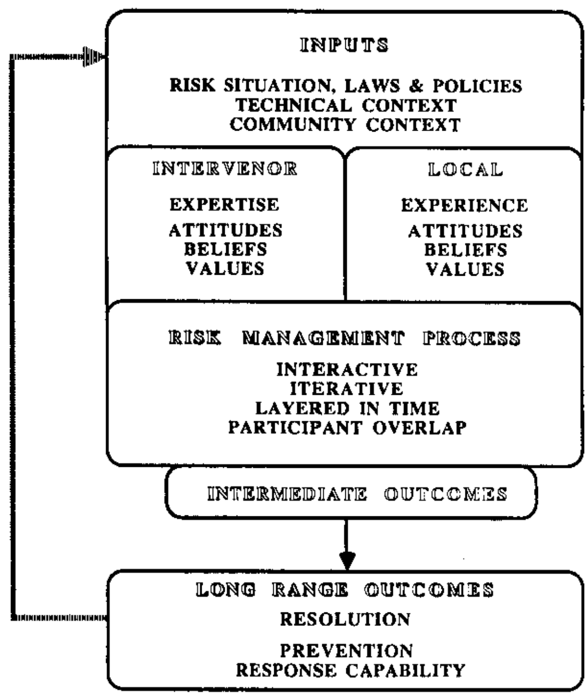
Earthquake! LISREL Maximum Likelihood Parameter Estimates
(All t-values greater than 2.0)

Dependent Variable	Predictors	R^2	R^2 (Without Hazard Information)	Total Effects of Concern
MMA1		0.00	0.00	0.00
EBEN1	MMA1 (0.33), GOVA (-0.27)	0.18	0.18	0.00
NBEN1	EBEN1 (0.40)	0.16	0.16	0.00
MIT1	EBEN1 (0.27)	0.08	0.08	0.00
INFO1	CON1 (0.35)	0.12	-	0.35
MMA2	MMA1 (0.59), INFO2 (0.17), CON2 (0.21)	0.50	0.44	0.28
EBEN2	EBEN1 (0.43)	0.18	0.18	0.00
NBEN2	NBEN1 (0.40), MMA2 (0.14), EBEN2 (0.28), INFO2 (0.16)	0.36	0.35	0.11
MIT2	MIT1 (0.45), NBEN2 (0.27)	0.30	0.29	0.03
INFO2	CON2 (0.42)	0.17	-	0.43
MMA3	MMA2 (0.78), CON3 (0.10)	0.62	0.64	0.32
EBEN3	EBEN1 (0.20), EBEN2 (0.28), MMA3 (.12), NBEN3 (0.48)	0.60	0.61	0.10
NBEN3	NBEN2 (0.58), MMA3 (0.20)	0.42	0.46	0.13
MIT3	MIT2 (0.58), NBEN3 (0.20)	0.44	0.44	0.04
INFO3	INFO2 (0.32), CON3 (0.49)	0.40	-	0.52

The question, then, is why there were no information effects in the field study while there were large effects in the laboratory study. There no doubt are many reasons for this, including aspects of methodology, etc. We wish to emphasize another set of factors, however. These factors are developed elsewhere (Earle, 1984) and present a useful guide to effective hazard communication. In brief, hazard information will affect hazard-related judgments and behavior when: a) individuals are involved (interested) in the hazard; b) they are motivated (i.e. concerned) to process information; and d) the information available meets their

Figure 1

A Conceptual Framework for Integrated Risk Management at the Local Level



individual needs (i.e. there are large individual differences and customized information is necessary). With respect to the field study, we know that the persons at the public hearings were involved and motivated. It would seem, therefore, that the formal EPA risk estimates failed to affect the public because of information processing difficulties: How is a person in Tacoma to integrate such a formal estimate into her/his risk decision processes?

In noting the "non-effects" of the formal EPA risk estimates, it must be emphasized that we are not claiming that all EPA risk management activities had no significant effects on public risk judgment in the ASARCO case. Results from the laboratory study suggest that government risk management activities outside the realm of formal risk estimates can have strong effects on public risk judgment. These "informal" risk management activities affect public confidence in the government's ability to manage, and this confidence may, in the long run, be more significant for public risk judgment than formal estimates of risk.

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RISK ASSESSMENT AND RISK MANAGEMENT: A SURVEY OF RECENT MODELS

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The rational management of health and environmental risks ideally requires a well defined structured approach in order that risk may be dealt with in a complete and equitable fashion. In this paper, formal models of the process of risk assessment and risk management which have been proposed in the literature in recent years are reviewed. Common elements amongst these models are identified, and the potential impact of these approaches on practical decision making is examined.

KEY WORDS: Risk Assessment, Risk Management, Hazard Identification, Risk Estimation, Risk Evaluation.

INTRODUCTION

In recent years, growing public awareness has led to increased concern over potential risks to human health and the environment. Controversy surrounding health risk has often been fueled by sensational media reports concerning the pending dangers of adverse lifestyles, food additives, drugs, pesticides, and contaminants in air, water, and the general environment.

The selection of environmental hazards for government attention has often been handled in an ad hoc fashion in the past, usually in a reactive manner rather than as part of a carefully planned strategy. Issues which attract the public's interest have often been the focus of societal resources, at the expense of more serious but less popular problems.

Despite the pressures on regulatory agencies to respond to external initiatives and shifting priorities, several factors indicate the need for a more pragmatic approach to the management of health risks. These include the desirability of balancing risks and benefits across society in an acceptable way and the need to consider societal priorities other than human health. The need for an orderly and systematic approach to risk management is further supported by the existence of resource constraints, which prevent maximum control of all risks.

A number of formal models for risk assessment and risk management have been proposed in recent years. These models are of great value in clarifying the main elements of risk assessment and risk management, and have served to establish a well defined framework within which risk may be addressed.

In section 2 of this article, we discuss the different models which have been proposed in the literature. These models are then compared and a number of common elements identified (section 3). We conclude with a brief discussion of the key components of the models and their role in understanding and improving the overall process of risk assessment and risk management (section 4).

RISK ASSESSMENT AND RISK MANAGEMENT

Scientific Committee on Problems of the Environment (SCOPE)

The first formal model of the risk assessment and management process appears to have been formulated by SCOPE (Whyte & Burton, 1980). They outlined a three stage risk assessment process consisting of risk identification, risk estimation and risk evaluation. The first step involves recognizing that a hazard exists. A quantitative estimate of the magnitude of the associated risk is then prepared by scientifically determining its characteristics. This is followed by an evaluation of the significance and acceptability of risk probabilities and consequences. Following risk assessment, some decision regarding whether or not to intervene takes place. This is informally termed "risk management."

National Research Council (1983).

The NRC (1983) model consists of two stages: risk assessment, and risk management. Risk assessment refers to the use of a factual base to define the health effects of exposure of individuals or populations to hazardous materials or situations. The information obtained at this stage may be used to set priorities for regulation and for further toxicity testing. Risk management consists of the development of and selection regulatory options.

Risk assessment is subdivided into four components: hazard identification, dose response assessment, exposure assessment, and risk characterization. Hazard identification is the determination of a cause-effect relationship between a particular chemical and a decline in health status using epidemiological studies of human populations, animal bioassay data, mutagenicity tests, and examination of molecular structure. Dose response assessment involves examination of the relation of the magnitude of exposure and probability of occurrence of the health effects in question using extrapolation methods for high to low doses and for animals to humans as the primary research tools. Exposure assessment involves study of the extent of human exposure before or after application of regulatory controls. Risk characterization includes hazard identification, dose response assessment and exposure assessment, and involves a description of the nature and magnitude of human risk, including attendant uncertainty.

At the risk management stage, regulatory options are developed and evaluated. Selection of a particular regulatory option involves consideration of the public health, economic, social, and political consequences of implementation. Other factors of significance include the technical feasibility of the proposed solution, desired level of control, ability to enforce regulations, uncertainty in scientific data and the corresponding inferential bridges used to fill gaps in knowledge, and the public perception and level of information.

The implementation of one specific course of action requires efficient resource utilization, and should be accompanied by communication to affected parties regarding the reliability of the information used to make the decision, trade-offs, the values applied, and the relation of these factors in arriving at a specific policy.

The NRC model was subsequently adopted by the United States Environmental Protection Agency (1984) with no significant structural or definitional changes.

The Royal Society

The Royal Society model (Royal Society Study Group, 1983) is composed of only two stages: risk assessment and risk management. The former is further subdivided into risk estimation and risk evaluation.

Risk assessment is the general term used by the Royal Society to describe the study of decisions having uncertain consequences. Risk estimation refers to identification and estimation of the probability and magnitude of the consequences of a hazardous event. Risk evaluation is the complex process of determining the significance or value of the identified hazards and estimated risks to those concerned with or affected by the proposed decision. Embedded within this stage are the interrelated processes of developing alternative courses of action and decision analysis. These components take into consideration public awareness and perception, the acceptability of risk, and the analysis of risks, costs, and benefits. These latter factors include consideration of the level of justifiable risk, economic and technical feasibility, and resource requirements.

Based on this evaluation of risk, risk management is the making of decisions concerning risks and their subsequent implementation. Decision making itself involves consultations between industry, government, the public, and other special interest groups affected by the decision. Implementation of a decision, its monitoring, evaluation, and revision, are considered integral part of the process.

Interdepartmental Committee on Toxic Chemicals (ICTC)

The ICTC model developed by the Interdepartmental Working Group on Toxic Chemicals (1984) represents an elaboration of the SCOPE model. The first step in the process is hazard identification based on case reports, epidemiological studies of human populations, and toxicological experiments conducted in the laboratory. Another potential approach for the identification of chemical risks is a comparison of molecular structure and biological activity with that of known toxicants.

The next step is to obtain an estimate of the magnitude of the risk in question. This involves the statistical analysis of epidemiological and toxicological data to determine the level of risk associated with specific hazards and to establish acceptable criteria for exposure to environmental hazards. This process is subject to considerable uncertainty and may require strong assumptions, as in the conversion of animal pesults to the human situation.

The first step towards selecting a strategy for dealing with a given environmental risk is the development of a number of alternative courses of action. Available options can range from advisory to economic to strict regulatory control. In order to ensure a consistent approach to risk management, the set of options selected for further evaluation should be compatible with existing environmental health program objectives and remain cognizant of any overall risk management policy guidelines.

The decision as to the most appropriate course of action depends on a host of factors, including a balancing of health risks against health benefits in some cases. Consideration may also be given to the public's perception of risk, which may not always correspond to the actual risk determined by objective analysis. The technical feasiblity of each proposed course of action should be demonstrated, including the ability to enforce any proposed regulations. Economic effects are often important in evaluating alternatives, both in terms of program-related costs and the impact on productive output. Socio-political factors involving equity considerations and repercussions at the international level should not be overlooked.

Implementation of the selected risk management strategy will usually require some commitment of resources and should be accompanied by attempts to communicate the nature of the chosen control mechanism to all affected parties. Once the control mechanism is in place, continued monitoring is recommended. Continual evaluation and review of new health risk information may suggest modification to the risk management strategy currently in place.

World Health Organization (WHO)

The WHO (1985) considered a four stage process comprised of hazard identification, risk estimation, risk evaluation, and risk management. The process as a whole is influenced by a number of participating bodies including scientists, industry, special interest groups, the public, media, and politicians.

Hazard identification requires the collection of chemical, toxicological, ecotoxicological, clinical and epidemiological data. In addition, extrapolations from animal to man and from high dose/short time to low dose/long time may be required to evaluate the health effects. Toxicity and exposure information are obtained at this first stage.

Risk estimation characterizes the extent of harm and the probability of its occurrence. This stage utilizes the information gained in hazard identification, and exposure information, to predict the severity, extent, and distribution of the increased incidence of disease, disability, or defects caused by exposure to a hazard.

The risk evaluation stage involves comparative analysis between the risk in question and accepted risks, voluntary risks, and other risks, as well as examination of the acceptability of the risk in question. The latter process involves consideration of political factors, public perception, and industrial and public liability.

The risk management stage consists of decision making with a view to reducing or eliminating the risk in question. Decision making must take into account cultural, socio-economic, and political factors, and the type and nature of the risk in question. The possibility of reducing or eliminating the risk through control measures, technology changes, prevention or reduction of exposure, and product substitution must be considered in terms of feasibility, costs/benefits and magnitude and distribution. The decisions resulting from such analysis form the basis for regulatory action.

Other models

Various individuals and regional organizations have also proposed models for risk assessment and risk management. Baram's (1981) framework consists of six steps: hazard identification, risk measurement, risk management options selection, economic and technical feasibility analysis, ordering of risk management initiatives, and deployment of risk management options.

Lave's (1982) model contains eight stages: hazard identification, risk assessment, identification of regulatory alternatives, decision analysis, regulatory decision, legal or political challenge, implementation, and monitoring. This model closely resembles that adopted by the ICTC.

Rodricks & Tardiff (1984) consider only two broad stages: risk assessment and risk management. The former is subdivided into three phases: hazard identification and evaluation, dose response evaluation, and identification of conditions of exposure. The latter stage also consists of three phases: examination of alternative courses of action, decision analysis, and implementation.

The model developed by the Ontario Advisory Council on Occupational Health and Occupational Safety (1984) is divided into four stages: hazard identification, risk estimation, risk evaluation (development of alternative actions, and decision analysis), and risk management (implementation).

Shrader-Frechette's (1985) framework includes three stages: risk identification, risk estimation, and risk evaluation. Although the framework lacks a risk management stage, its three stages closely parallel those of the SCOPE model.

COMPARISON OF MODELS

The models for risk assessment and risk management presented in section 2 follow the general framework devised by Whyte & Burton (1980), although the degree of similarity and level of detail presented in each of the models varies. In addition to delineating the steps comprising the risk assessment and risk management process, each model distinguishes between the scientific and extrascientific components of the overall process. A comparison of the major models examined in section 2, using the general framework established by Whyte & Burton is provided in Figure 1.

With the exception of the Royal Society model, each of these models explicitly designates hazard identification as the initial step. The NRC/EPA model emphasizes the use of scientific research as the basic tool for identifying risks. Several models correctly refer to this initial phase as hazard identification rather than risk identification since the probability of an adverse effect occurring is generally not calculated at this stage. In current usage, the term hazard is used to describe the nature of the adverse effect, whereas risk involves both hazard and the probability of its occurrence (Kaplan & Garrick, 1981).

With the exception of the Royal Society model, there also appears to be general agreement that hazard identification should be followed by risk estimation. (The Royal Society includes both hazard identification and risk estimation in their definition of risk estimation, but does not clearly identify these as distinct sequential steps.) In the NRC/EPA framework the term risk characterization is effectively equivalent to risk estimation.

All models cite the use of toxicological and epidemiological data as the primary sources of information for health hazard identification and risk estimation (Office of Technology Assessment, 1981). In the case of chemical hazards, structure/activity analysis may also be used.

As with the original SCOPE model, all models then proceed to some form of risk evaluation. At this stage, scientific method is subsumed by

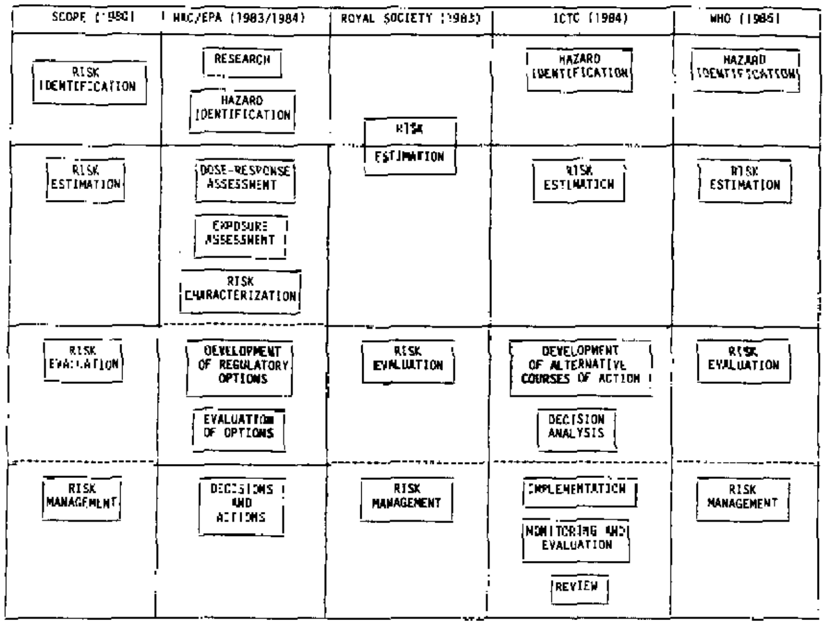

Figure 1

A Comparison of Models for Risk Assessment and Risk Management (dotted line indicates division between risk assessment and risk management)

public policy considerations. The subsequent models are generally described in more detail than is the scope model, and with the exception of the Royal Society model, differentiate between identifying alternatives, and the decision analysis tools used to choose amongst them. Alternative options may be of an advisory, economic or regulatory nature, and many factors need to be considered in selecting a preferred management strategy. These include the use of formal economic tools for program evaluation (Torrance & Krewski, 1985), tempered by the public's perception of the risk involved as well as prevailing socio-political factors. Again, although not highlighted as distinct components, similar considerations are included within the Royal Society's risk management phase.

The final stage, informally termed risk management in the SCOPE model, involves the implementation of the control strategy selected. Each of the models, except the NRC/EPA, and WHO models, I stresses the need for risk monitoring and follow-up, with a view to modifying the risk management strategy currently in place should this be considered in appropriate. All models, except the SCOPE model also stress the importance of communication at the implementation stage so that affected parties are properly informed as to both the risks and risk management strategy adopted.

One point which remains obscure is the location of the division between risk assessment and risk management. The original SCOPE model seems to consider risk assessment as encompassing both the scientific enterprises of hazard identification and risk estimation as well as the more politicized function of risk evaluation. In this model, the term risk management is thus reserved for the final implementation and follow-up stage. This point of view is also adopted in the Royal Society, ICTC and WHO models. The NRC/EPA, on the other hand, define risk assessment as consisting only of hazard identification and risk estimation.

Taking into account differences in terminology, all models essentially agree on the division of the scientific and social aspects of the risk assessment and risk management process. Hazard identification and risk estimation are clearly in the scientific realm, whereas risk evaluation and risk management fall within the domain of social decisionmaking. Thus, the responsibility for risk analysis rests largely with the scientific community, whereas those responsible for the establishment and implementation of risk management decisions play the leading role in extrascientific matters (Ruckelshaus, 1983).

Although there is general agreement that the risk assessment/management framework can be divided into scientific and policy concerns, Davis (1983) maintains that both science and values play a role in risk assessment and that the steps in the risk control process are more interactive than sequential. During the risk assessment process, analysts may overlook hazards, deem them unimportant, or ignore them because they are difficult to assess. Decisions are often influenced by judgments or policy due to gaps in scientific information.

CONCLUSIONS

In this article, we have reviewed the major models for the risk assessment and risk management process. All of these models reflect the basic elements of original SCOPE model (risk identification, risk estimation, risk evaluation, and risk management) as described by Whyte & Burton (1980). Subsequent models more correctly refer to the initial step as hazard rather than risk identification, reflecting the fact that risk estimation requires a quantitative rather than qualitative description of adverse health effects.

Although all models involve scientific and public policy considerations, the only model which equates these two dimensions with those of risk assessment and risk management is that of the NRC/EPA. In the remaining models, the social evaluation is included in the risk assessment phase, leaving only the implementation of the chosen control strategies to the risk management phase.

The application of the models of risk assessment and risk management discussed here, to practical decision making situations should facilitate identification and clarification of the many important considerations in the complex process of risk assessment and risk management. This is particularly true of some of the more recent models which describe the component steps in detail, including the distinctive development of a range of viable risk management options and the criteria and tools to be applied in choosing among these options. Other considerations which may otherwise be overlooked include the need for continual monitoring and review as well as communication of information on risks and risk decision to all affected parties.

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