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Quality of life and comparative risk in Houston

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Abstract. Houston Environmental Foresight, an urban region comparative risk assessment, demonstrated the importance of process as well as analytic methodology. These features are best illustrated in the work of its Socioeconomic Subpanel, which assessed environmental risks to economic well-being and quality of life. Several issues are raised by the process and methods used by the subpanel. Some of these issues could be addressed through national research on comparative risk methods; other issues are most likely to be addressed through the incremental improvements of future projects.

Keywords: environment, risk, economics, process, methods

Introduction

Comparative risk analysis is an analytical process and set of methods used to systematically measure, compare, and rank environmental problems. Many comparative environmental risk analysis projects have been conducted at the local, state, regional, and national level around the world since the publication of *Unfinished Business* by the U.S. Environmental Protection Agency in 1987 (EPA, 1987, 1990). Comparative risk projects, such as the Houston Environmental Foresight project, often reflect a concern that environmental policy priorities are failing to emphasize actions that address the most serious environmental risks.

The use of comparative risk assessment as a framework for setting priorities among competing environmental programs has its origins in the use of health risk assessment (Andrews, 1995). The term "risk assessment" is used to reflect the one component of "risk analysis," which also includes risk communication and risk management. Health risk assessment is used to estimate the risks to human health associated with chemical hazards, often for regulatory purposes. The risk of a substance is determined by its inherent toxic properties, the manner in which these properties change with changing exposure, and the actual conditions of human exposure to it (e.g., amount, duration, frequency, age of exposed individual; Environ, 1988).

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In contrast to the absolute standards established through the regulatory use of health risk assessment, EPA developed comparative risk as a planning tool to help environmental agencies set priorities by considering the *relative* size and severity of environmental problems (Rosenbaum, 1990). In the early 1980s, EPA conducted Integrated Environmental Management Projects in Philadelphia, Baltimore, Denver, and elsewhere (Delhagen and Dea, 1996). EPA refined the ideas developed in these projects into the basic comparative risk structure used in later regional and state projects. By the mid-1990s, comparative risk projects typically went beyond human health risk assessment to include similar analyses of ecological and socioeconomic environmental risks.

A variety of published papers and guidebooks that compare and evaluate the different approaches have been used across the country; these publications describe the method of practice that defines the comparative risk discipline (Davies, 1996). While there is no typical comparative risk project, most projects use a generalized model with similar components.

1. Project planning and development
2. Public involvement (conducted throughout projects)
3. Risk identification and assessment
4. Risk comparison and ranking
5. Risk management options development and analysis (often separated into a separate phase)
6. Implementation (Delhagen and Dea, 1996)

Each comparative risk project contributed new methods and understandings of how environmental priorities can be set through a comparative process. For instance, the Arizona Comparative Environmental Risk Project conducted a "public values assessment" to develop a "portrait of how Arizonans from different parts of the state, and from different walks of life, approach environmental issues and the various policy options surrounding those issues in the mid-1990s." The Arizona project attempted to use the assessment to inform the work of its more traditional technical committees and its public advisory committee (Michalowski *et al*., 1995). Several other state projects with particularly influential methods include California, Texas, and Vermont (CCRP, 1994; SVTC, 1991; TNRCC, 1997).

Purpose and scope of this paper

Houston Environmental Foresight attempted to reshape the community's understanding of the relative importance of the area's environmental concerns by organizing available scientific information on the basis of scientific consensus rather than methodological rigor. As a result, process—the effective management of cultural issues, personality and participation—was as important as analytic methodology. Other projects, such as the Louisiana Environmental Assessment Project, have also recognized the importance of process to achieving a sustainable outcome (McCreary and Gamman, 1992). This paper is focused largely upon the work of one committee, the Socioeconomic Subpanel of Houston Foresight. Among those more recent projects that have considered risks to quality of life, Foresight published one of the more comprehensive analyses. This paper describes the advantages of the approach used by this subpanel to address risks and impacts upon quality of life and economic well-being, as well as the problems encountered, but it does not discuss in depth the results obtained or what they might mean.

Foresight derived its analytic methodology for assessing the socioeconomic impacts of environmental problems from the field of comparative risk analysis. Although challenges were present in every aspect of Foresight, the project's effort to compare quality of life risks best illustrates the interrelated challenges to process and method. Those who served on the Socioeconomic Subpanel, which examined risks to quality of life and economic well-being, faced several unique challenges.

Applying health-based risk concepts to economic and quality of life concerns
Measuring risks to a community's image, recreational opportunities, and aesthetic quality
Measuring risks to aspects of the individual other than his or her health
Managing a sometimes overwhelming amount of data that is only tangentially related to the actual question at hand
Analyzing "risks" without a clear baseline of zero risk to compare against
Applying the "risk" concept to long-term steady impacts as opposed to one-time catastrophic impacts
Gathering data without a standard reference assessment guide

To meet those challenges, the subpanel created innovative analytic methods and accommodated a particularly wide range of professional disciplines by using a process that leads to consensus, because the methodology could not result in a complete and rigorous answer.

A particular challenge raised by Houston Foresight is the difficulty of estimating "risk" to economic-well being and quality of life. Although the intensity of socioeconomic problems may be correlated with environmental conditions, such problems rarely have an absolute baseline. For instance, the cost of drinking water treatment may vary with different environmental conditions, but an absence of drinking water treatment costs is not a useful baseline. In contrast, risk assessment of health effects is conceptually easier because the baseline could be described as "people free of disease" (although that is an unrealistic ideal). As a result, Foresight described some "risks" in terms of expected impacts, such as ongoing costs.

This paper describes the process used by the Socioeconomic Subpanel to analyze environmental risks to the Houston region's quality of life and economic well-being. It begins with a brief background of the Houston comparative risk project that highlights the role of the subpanel. The Methods section describes the general steps of Foresight's comparative risk analysis. The Results section describes the challenges faced by the subpanel in its choice of methodology, analysis, and risk ranking. Finally, we discuss lessons learned from the subpanel's experiences in using a consensus-based scientific analysis.

Organization of Foresight

Foresight is a non-governmental effort[1] established by the Houston Advanced Research Center (HARC) with the support of community leaders to assess environmental concerns and to encourage broadly acceptable changes to improve Houston's environment. Its first phase concluded with the findings of the Foresight Committee, which included over thirty members with a broad range of interests from throughout an eight-county region surrounding Houston (Foresight Committee, 1996). The Foresight Committee was responsible for oversight as well as representing the public in determining the overall findings of the program. The foundation for the Foresight Committee's findings is an extensive comparative risk analysis conducted in 1994 and 1995 by the Foresight Science Panel. The Socioeconomic Subpanel (one of three subpanels) focused on impacts to quality of life and economic well-being in the Houston region.

The Science Panel began work in June 1994, completed its analytic work in the summer of 1995, and continued revisions through early 1996. Its findings were released in early 1996 in a 460-page volume, *Houston Environment 1995* (Foresight Science Panel, 1996). The Science Panel originally included four distinguished at-large members and the chairs of three Science Subpanels.

Background

In 1996, the Houston Environmental Foresight Committee ranked outdoor air pollution, indoor contamination, habitat alteration and loss, and parks and undeveloped areas as the four environmental risks of the highest concern in the region. The Foresight Committee, consisting of 32 community leaders, reached consensus on its report after extensive discussion and study of reports from scientific panels. *Seeking Environmental Improvement*, the report of the Foresight Committee, and *Houston Environment 1995*, the report of the Foresight Science Panel, describe these findings in detail (Foresight Science Panel, 1996). The authors played important roles in Foresight. Kohlhase was the chair of the Socioeconomic Subpanel and a member of the Science Panel. Wilson and Strawn were research associates of HARC and the two main staff members for Foresight. Wilson and Strawn were involved in all aspects of Foresight with activities including fund raising, organizing, and coordinating the progress of the entire effort.

Foresight selected an eight-county area surrounding and including Houston. This area is defined by the federal government as an air quality nonattainment region; nearly all of the Galveston Bay watershed below Lake Livingston lies within the area.

Methods

In most respects, the risk assessment efforts of the subpanels were directed by the Science Panel as the panel was established with independent authority for review and final release of all subpanel products. However, the Foresight Committee and the program's staff had a significant role in establishing the basic outline of each subpanel's task.

HARC established the Science Panel at the same time as the Foresight Committee as a consensus-based body, including three expert subpanels to study risks to ecosystems (Ecosystems Subpanel), human health (Human Health Subpanel), and quality of life (Socioeconomic Subpanel). The Science Panel was responsible for oversight of the work and techniques of its subpanels.

The Science Panel's first task was to select the all-volunteer membership of the subpanels. Members of the subpanels were all from the Houston region and were selected for their technical expertise and familiarity with Houston's environmental condition. The thirty members of the Socioeconomic Subpanel included professionals in economics, sociology, anthropology, environmental engineering, environmental management, recreation, and other relevant fields from academic, business, and government institutions (members are listed in Foresight Science Panel, 1996). Most participants held advanced degrees, but because most lacked formal experience with environmental risk analysis, the membership reflected the panel's emphasis on scientific consensus.

The Science Panel deferred to the Foresight Committee to structure the research by identifying the risks to assess based on:

Staff recommendations based on the experiences of other comparative risk assessment projects across the country
Input from the Science Panel and its subpanels
Discussion during three Foresight Committee meetings

Twenty areas of concern were selected by the Foresight Committee; each subpanel assessed most of them. However, some were not relevant to a particular subpanel's area of study. For instance, indoor contamination was not relevant to the Ecosystems Subpanel report.

Each Subpanel adopted its own criteria subject to the approval of the Science Panel and with comments of the Foresight Committee. For instance, the Socioeconomic Subpanel decided that it would evaluate the risks to "economic well-being and quality of life" in the eight-county Houston region using novel analytic criteria, which are listed and described in detail later in the paper. Each subpanel then directed its members to use those criteria as the basis of short reports that assessed the residual risk associated with each area of concern, based on the risk that remained unaddressed under policies in effect as of 1995.

The Science Panel directed a peer review of each risk analysis report prior to its approval. The review criteria were technical competence, logic and clarity, accessibility to an interested lay audience, usefulness as background to a risk ranking, and comments on data or studies not included in the report that would have influenced the report's analysis and/or conclusions. The revisions that resulted from the peer review addressed questions of both methods and the basis for consensus, reflecting the balanced approach envisioned by the Science Panel.

Finally, each subpanel completed an independent ranking of environmental risks based on its analyses and submitted the rankings to the Science Panel for approval. The Science Panel commented on the initial draft rankings, and the final rankings reflected a consensus of subpanel members and the consent of the Science Panel. No integrated scientific ranking was attempted; that task was left to the Foresight Committee and is described in its report, *Seeking Environmental Improvement* (Foresight Committee, 1996).

Results

The importance of process was illustrated throughout the experience of the Socioeconomic Subpanel's effort to assess and rank the risks to the quality of life and economic well-being in the Houston region. Its choice of analytic methods, assessments, and ranking each reflect the challenges of process and analysis.

First work product: choice of analytic methods

The analytic methods for comparing risks to quality of life and economic well-being were probably the least developed available to the three subpanels. (Comparative risk methods for human health and ecological risks were more widely practiced at the time.) Comparative risk analysis differs from the more familiar techniques often used in project evaluation, cost–benefit analysis and cost-effectiveness analysis. These two techniques are used for evaluating policy options, not for making relative risk rankings of environmental issues (Kahn, 1998). The development of analytic methods for the Socioeconomic Subpanel reflected the tension between professional standards for rigor akin to that found in cost–benefit analysis and the reality of a diverse, volunteer-based consensus process.

From the beginning, several academics and consultants pushed the subpanel to develop a sound and rigorous method of assessment. The basic idea for measuring and comparing residual risks among environmental concerns comes from quantitative techniques developed for assessing human health risks. One approach used to assess human health risks expresses risks in such terms as the potential number of cases of disease or potential number of lives lost. Unfortunately, the carryover to analyzing socioeconomic issues is not as straightforward because socioeconomic residual risks are more difficult to define and measure and perhaps even more difficult to compare.

Various work groups were established to consider the methodology from a variety of perspectives, including methods used for environmental impact assessments. Several state projects' criteria influenced the group, particularly those from California, Texas, and Vermont (CCRP, 1994; SVTC, 1991; TNRCC, 1997). After a lengthy process of refinement, the subpanel agreed to measure risks to quality of life and economic well-being in terms of impacts to economic, community, and human resources.

Foresight was the first comparative risk study that attempted to distinguish between economic, community, and human resources. Each resource represents a different pathway by which environmental problems affect quality of life. In contrast, other comparative risk studies only look at one resource (e.g., economic) (NCCR, 1992; State of Washington, 1989b) or do not distinguish among the three pathways (CCRP, 1994).

Definition of economic resources

Economic resources are defined as income and wealth, employment, entrepreneurial skills, capital goods and infrastructure, such as housing and businesses, and natural resources. One characteristic of many economic resources is that a dollar value can be inferred to their use value, and environmental economists value a wide range of tangible and intangible goods (Kahn, 1998; Serageldin and Steer, 1994). For instance, Galveston Bay seafood is a source of direct economic value. Conserved habitat is a source of future direct and indirect economic value. Site-specific health risks such as contaminated soil can reduce property values. Flood control provided by bayous and wetlands is an important indirect functional economic benefit of a sound environment. Beyond these use values, environmental economists often attempt to measure nonuse values, such as biodiversity or conserved habitats (Kahn, 1998; Serageldin and Steer, 1994). Nonuse valuations are more controversial and problematic—none of the analyses completed by the Socioeconomic Subpanel significantly reflect nonuse values.

An economic issue not considered by the Socioeconomic Subpanel was the social cost of implementing environmental regulation because such costs are not a direct result of environmental problems (although they are a legitimate economic issue when considering policy). For example, the increased cost of cars due to catalytic converters was not included because catalytic converters are a technological method to reduce pollution. Certain control costs that vary with the level of pollution present in the environment, however, are considered. For instance, if water pollution worsens, the treatment of drinking water to achieve a given standard may become more expensive, so such increases in treatment costs are considered. Thus the Socioeconomic Subpanel's report is neither a cost–benefit study nor an attempt to consider whether current environmental regulations are cost-effective or efficient.

Definition of community resources

Community resources include the cohesiveness of the community, its image, recreational opportunities, and its aesthetic quality. The subpanel wrote that cohesiveness (or social capital) is important because a functioning society requires a degree of common identification with the forms of governance, cultural expression, and social behavior. Institutions that the community take for granted as essential to a functioning society must be grounded in a common sense of belonging by its members. These institutions must reflect a sense of legitimacy in their mediation of conflicts and competing claims. For instance, a sharply divided community may be harmed by the loss of respect and cooperation among community members. The accountability of decision makers and a balance of liberty and community authority are also important aspects of cohesiveness.

The image of a community, especially to outsiders, is important, particularly because subpanel findings recognize that Houston is perceived as a highly polluted city. The variety of recreational opportunities and aesthetic values available to residents of the Houston region are also important resources.

Although the measurement of community resource effects was difficult and imprecise, the subpanel's generally descriptive and often indirect findings were used in the consensus ranking. The subpanel concluded that it was not possible to quantify or verify impacts to community resources because little local research had been done. Thus the consensus-based process for evaluating risks to community resources was more important than demonstrating methodological rigor.

Definition of human resources

Human resources, as defined by the subpanel, describe those aspects of quality of life that are not economic and best relate to the individual rather than the community. Health is a particularly important human resource which was addressed by the Human Health Subpanel.

(Costs of health care are addressed as part of economic resource impacts.) Education is another important human resource but is not considered particularly vulnerable to environmental risk. Human resources included in the Socioeconomic Subpanel's analyses are personal security, peace of mind, the potential of future generations, confidence in public and private institutions, and empowerment, access, and individual choice. Admittedly, such concerns and consequences are quite difficult to discuss and perhaps impossible to measure. However, the subpanel did identify specific impacts to human resources caused by environmental concerns that are relevant to people's lives and decisions. A consensus-based process for evaluating risks was essential to the analysis since rigorous methodology does not exist.

Measuring risks to the resources

The risks (or impacts) to each resource from a given environmental concern were measured by up to seven indicators. Two examples of how such measurements were summarized are illustrated in Tables 1 and 2. The seven indicators were selected by the Socioeconomic Subpanel after a review of various approaches used in the social science literature and by other similar projects.

Table 1. Assessment of quality of life risks due to flooding.

Criteria	Economic resources	Community resources	Human resources
Population exposed	Medium	High	Medium
Population impacted	High	Highest	High
Trend	Highest	High	High
Severity	Medium	Medium	Medium
Irreversibility	Low	Low	High
Inequity	Least	Medium	Medium
Uncertainty	High	High	High

Source: Foresight Science Panel, 1996.

Table 2. Assessment of quality of life risks due to water supply.

Criteria	Economic resources	Community resources	Human resources
Population exposed	Highest	Highest	Highest
Population impacted	Highest	Highest	Highest
Trend	High	High	High
Severity	Low	High	Medium
Irreversibility	Low	Low	Low
Inequity	Low	Low	Low
Uncertainty	Medium	Medium	Medium

Source: Foresight Science Panel, 1996.

Population exposed: number of people exposed to environmental concern; the risk may be caused by production, distribution, use, and/or disposal of products.
Population impacted: number of people actually affected by an environmental concern; for some effects, distinction between exposure and impact was difficult.
Trend: the degree to which an environmental concern is expected to persist or worsen in the future and/or the degree to which the costs of current activities are shifted to people in the future.
Severity: the intensity of the effect on economic, community, or human resources; defined by constructing scales based on the definition of each resource.
Irreversibility: the degree to which an impact resulting from an environmental problem can be reversed, remediated, or mitigated.
Inequity: the degree to which the exposure or impact is distributed in an inequitable fashion; defined by explaining inequity in terms of economic, community, or human groups; scales constructed to support comparison between the areas assessed.
Uncertainty: the degree to which an exposure or impact cannot be detected, data are not available, or causal relationships have not been established.

The first six of the criteria are used to measure potential impacts to each resource base (economic, community, and human). The seventh characteristic, uncertainty, is used to describe the quality of the data and existing research used in the analysis.

The subpanel was enthusiastic about this approach and further established “constructed scales” as guidelines for subpanel members to use in estimating whether a risk was, for instance, of “highest” severity to economic resources. The scales were fairly specific, defined either qualitatively or quantitatively, and can be found in *Houston Environment 1995* (Foresight Science Panel, 1996). However, the relationship of the subpanel’s measurements to the constructed scales should be understood in the context that the precision of the scales was higher than the precision of the data and available research findings.

Tables 1 and 2 illustrate 21-element risk matrices for two sample issues, flooding and water supply. Impacts on each of the three resources, economic, community, and human, are categorized according to the seven criteria. A level of impact is assigned to each resource box using one of five general categories of risk (least, low, medium, high, and highest). The risk matrices provide a way for organizing the multiple criteria into a concise format and provide a starting point for the risk assessments. They can be viewed as an organizational device but are not the final risk rankings.

The mixture of methods from various scientific and professional disciplines, as well as the process used to integrate those methods, was an early indication that Foresight’s strategy of a consensus-based scientific review was feasible. The capability to flexibly integrate diverse perspectives was also critical to the subpanel’s later work.

Second work product: assessments

The assessment phase, resulting in eighteen risk assessment reports covering nineteen concerns, illustrates several methodological issues, some of which could be addressed through national research efforts. This phase was completed though the volunteer efforts of individuals or small groups on the Socioeconomic Subpanel. In a few cases, project staff provided considerable assistance or members from other subpanels collaborated, but resource limitations often made such assistance impractical. Two research issues, data and methodology, often limited the quality of the reports.

First, data often did not exist or, more commonly, available data did not directly address the subpanel's queries. For instance, the trend of ozone air pollution is well documented, but the effect of the trend on quality of life has not been conclusively estimated. (Useful indicators might include health care costs, property values, community image, or anxiety and stress.) In this and other cases, the volume of available data challenged the subpanel when discussion necessarily turned to speculation about points not well addressed by the data.

Second, methodologies available for individual reports were often inadequate or somewhat inappropriate to the subject matter being discussed. Socioeconomic assessments are often performed when comparing among various policy options. Without a clear baseline or ideal reference point, it is very difficult to estimate "risk" to economic well-being and quality of life. In contrast, risk assessment of health effects is conceptually easier because the baseline could be described as "people free of disease" (although this is an unrealistic ideal). The tradeoffs, interrelationships, and variable cultural standards associated with quality of life resources are often too complex to simplify into meaningful baselines.[2] As a result, the Socioeconomic Subpanel typically described risks in terms of expected impacts to each resource: economic, community, and human.

Furthermore, the risk concept does not apply well to situations involving government provision of ongoing services such as garbage collection or wastewater treatment. In contrast to health impacts, where individuals may bear the "cost" of pollution as increased risk of disease or death, quality of life impacts are often reflected in relatively stable economic costs such as garbage collection and water supply fees. Although there is a risk that such fees may go up in response to environmental problems, the cause-and-effect relationship is not as directly evident as it is in the case of health problems. While the concept of risk can be applied in theory to economic impacts, in practice it is often difficult and not necessarily the most effective way to communicate environmental concerns to a lay reader.

Two steps that could be taken to address the difficulty of addressing risk to quality of life include developing a standard reference assessment guide and revising the risk concept to be a risk and/or impact concept. A standard reference assessment guide would review relevant methodologies for estimating socioeconomic impacts, particularly environmental impact assessments, on a problem area basis, and would provide the information (including standard damage estimates) to comparative risk projects. Such a guide would provide a common starting point for assessments and avoid duplication of research effort.

Comparative risk assessments are also challenged by the ambiguities of defining the term risk in a socioeconomic context. Revising and extending the risk concept to include impacts is needed so that the analysis can more coherently measure both risks and ongoing impacts to socioeconomic resources (for example, garbage fees).

Third work product: ranking

After completing the assessment, the final task of the Socioeconomic Subpanel was to compare and rank the nineteen areas assessed. The subpanel compared and ranked the

Table 3. Ranking of Houston Environmental Foresight Socioeconomic Subpanel.[a]

Category (description identifies common concerns among issues ranked within category)	Environmental concerns ranked (listed within categories in alphabetical order—no ranking within categories is assigned)
Highest: Regionwide economic, image, and personal well-being effects	Hazardous material and waste Parks and undeveloped areas
High: Significant for many, but not entire region; distributional concerns for some issues	Habitat alteration and loss (includes biological management) Contaminated and abandoned sites Flooding Outdoor air pollution Indoor contamination Water pollution
Medium: Significant effects for many individuals, but trend flat or decreasing; current or past inequities identified	Community aesthetics Food supply quality Lead in homes and soil Introduced species Solid waste
Low: Relatively little concern, but potentially serious if adequate efforts are not maintained	Drinking water quality Water supply
Least: Due to lack of current evidence, least significant risks in the Houston region	Global climate change Ozone layer thinning Radiation

[a]This ranking reflects impacts to quality of life and economic well-being only and is a partial basis for the final integrated ranking completed by the Foresight Committee (Foresight Committee, 1996).
Source: Foresight Committee Panel, 1996.

areas it assessed in a group decision process to reach the final ranking, illustrated in Table 3.

One alternative to the group decision process used by the Socioeconomic Subpanel would be to convert the assessment directly into a numerical ranking using a quantitative approach. For instance, the assessment (usually summarized in a matrix as illustrated in Tables 1 and 2) could be quantitatively evaluated using a weighted approach based on assigning numerical values to criteria "boxes." These values would then be used in a formula to create a ranking. The subpanel did not choose the quantitative option because of the impracticality of designing a single index to capture the complex decisions inherent in multicriteria decision making. Some of the difficult issues, which would need to be addressed to use such an approach, would be how to assign weights that reflect trade-offs between the various criteria and how to account for the interrelationships among the many criteria. Instead, the assessment was qualitatively evaluated during consensus-based meetings of the subpanel.

The ranking began at a full-day meeting of the Socioeconomic Subpanel. The ranking was facilitated by two staff members with the Texas Natural Resource Conservation Commission, Quality Management Division as a favor to the Foresight program. The facilitators led a computer-assisted, sequential, pairwise comparison voting method to rank topics in numerical order.[3]

The pairwise comparison approach involved selecting two issues by a computer, essentially at random, for comparison by the subpanel members. Using a radio transmitter much like a TV remote control, members could vote anonymously as to which they felt was the greater socioeconomic risk. Discussion occurred before and/or after the vote and, if necessary, additional votes were taken until the facilitator felt that reasonable consensus had been reached. The computer did not allow people to vote for a tie, although sometimes issues were effectively tied if the vote was not resolved. After more than 50 pairwise votes, the subpanel had created an ordered list of the issues.

A particularly significant aspect of this approach was the ability of people whose votes were in the minority to raise substantive points in an attempt to convince the majority to change its opinion. In some cases, the persuasion was dramatically successful and the results were quickly visible on the projection screen. In other cases, people raised points that prompted discussion that led to the entire group accepting the majority position. As the day wore on and decisions became more difficult, the earlier effort to reach near unanimity was replaced by the use of majority vote. However, the voting was based on an understanding that adjustments could be made after the computer-guided comparison was completed. After all areas discussed were ordered, the subpanel placed them into five groups indicating the relative degree of risk or impact (highest, high, medium, low, and least). Members agreed that all issues would be considered roughly equivalent in risk within categories. The draft ranking reflected a creative tension between the consensus-based process and the analyses that fueled the debates.

After the subpanel's draft rankings and reports (both oral and written) were presented to the Foresight Committee, the eighteen written reports were sent out for blind peer review as directed by the Science Panel. Reviewers were selected on the recommendation of Science Panel members, staff, and a few other interested persons. Subpanel members were invited to suggest reviewers, but virtually none took the opportunity, even those who had voiced strong criticisms of various aspects of the program. Subsequent to the return of most reviews, the Science Panel approved well over half of the drafts, but also returned many for revision and/or completion. All of the reports (including those being revised) were made available to the Foresight Committee for its first meeting to consider an integrated ranking.

The process of a peer review was as important as the analytic methods for ensuring a useful product. Outside reviews were invaluable to prodding subpanel members to improve their work or get work reassigned away from members who did not provide satisfactory work. Other comparative risk projects may also wish to use a meaningful, but simple, outside review. The review should be based on the understanding that the reports are a background for risk comparison.

Following completion of the remaining reports and substantial revisions to several reports, the Socioeconomic Subpanel met once again to revise its rankings. A human factor that may have affected the results of the ranking was exhaustion, as only a dozen of the thirty members attended (during the summer, attendance was typically 15–20 volunteers). Two issues that had not been ranked were reported on for the first time and ranked. One issue that had been extremely contentious was revised to a new ranking with relatively little dissent thanks to an improved report.

One significant change to the methodology was important to reaching consensus. It was suggested that each category (highest, high, medium, low, and least) be defined, reflecting the subpanel's use of its criteria in the ranking process. With those changes and the categories defined (as presented in Table 3), subpanel members felt the comparative ranking to be internally consistent and complete.

These completed rankings, consented to by the Science Panel, were then forwarded to the Foresight Committee with the eighteen approved written reports. The Foresight Committee was then able to complete its integrated ranking, considering the conclusions of all three subpanels as well as its own values and perspective (Foresight Committee, 1996).

As noted above, the Foresight Committee ranked outdoor air pollution, indoor contamination, habitat alteration and loss, and parks and undeveloped areas as its highest overall risks. In contrast, as shown in Table 3, the subpanel ranked only two issues, hazardous material and waste, and parks and undeveloped areas, as its highest risks. The Foresight Committee's ranking fairly represented the input of the three subpanel rankings, although it necessarily differed significantly from each.

The experience of all the committees within Foresight suggests that two meetings are necessary in order to complete a widely accepted comparative ranking. Not only did the Socioeconomic Subpanel meet twice to reach consensus, but also the Human Health and Ecosystems Subpanels needed two meetings to reach consensus on their rankings. The changes made in the second meeting were critical to making the rankings much more meaningful. Two ranking meetings should be considered an integral part of a comparative risk project's group decision process.

Discussion

Assessing and comparing risks and impacts to economic well-being and quality of life remain difficult, but Foresight's experience demonstrates that a number of the challenges can be addressed satisfactorily if the goal is to organize available information for use by an educated lay audience. Foresight demonstrated new approaches to the field of comparative risk assessment in the areas of analytic criteria, group decision-making process, and participation.

Foresight's analytic criteria reflect a refinement of those used in other quality of life comparative risk projects. Foresight's approach allowed for a clear distinction to be made between the socioeconomic resource being impacted, and various measures of impact to those resources. The categorization of resources into three types—economic resources, community resources, and human resources—allowed the subpanel to assess different pathways by which environmental problems could affect quality of life.

To our knowledge, no other comparative risk project has differentiated the pathways of socioeconomic impacts. Other state and local comparative risk studies, too numerous to describe completely here, often looked at only a single resource or did not differentiate pathways that the impacts to quality of life resources could take. (Many are summarized in Davies, 1996, and at http://www.gmied.org, the web site of the Green Mountain Institute—formerly the Northeast Center for Comparative Risk—or at http://www.wced.org, the web site of the Western Center for Environmental Decision Making.) The Houston approach allows a more complete understanding of complex issues by virtue of the approach to organizing the data gathered.

Several other quality of life assessments have examined only one type of resource, typically economic resources, such as the studies for the state of Washington (1989a) and the state of Louisiana (Thompson *et al*., 1994). Other quality of life projects, such as those done for the states of Texas, Louisiana, and Vermont, did not differentiate the resource pathways as extensively as did Foresight. For example, the quality of life committee for the state of Texas comparative risk project had 14 quality of life characteristics (including a mixture of what Foresight considered resources impacted and criteria for comparing the impacts), as well as a list of five ranking criteria with no identification of pathways to link to characteristics and criteria (TNRCC, 1997). In a similar manner, the state of California's quality of life committee examined eight quality of life impacts with eight ranking criteria with no established pathways for linking the characteristics and criteria (CCRP, 1994). The state of Vermont mixed measures such as fairness of risk distribution with risks to economic well-being (SVTC, 1991). In contrast to Vermont's mixing, Foresight's approach offers a structured assessment that includes separate analyses of inequities to economic, human, and community resources. Even though Foresight was able to refine the approach to the quality of life analysis, the participants had to recognize that the scope of the questions meant that there would be a lack of complete data and often a lack of relevant studies of impacts to the resources under consideration. Endemic to all comparative risk studies is how to deal quantitatively and qualitatively with uncertainty. Foresight's results were reported with ranges of expected values (Finkel, 1996).

However, the group decision-making process used by Foresight compensated for inevitable weaknesses in the assessments. In contrast to projects that attempted to create a formula for completing the final ranking or used a complicated voting procedure (such as in Louisiana's study), Foresight's consensus-based approach required that all participants in the decisions accept the final results before discussion ended (NCCR, 1992). The Socioeconomic Subpanel's ranking exercise involved several steps over a few weeks, as described above. Like Foresight, other quality of life rankings have used more than one meeting to assess the rankings, including Louisiana (Davies, 1996), Texas (TNRCC, 1997), and Vermont (SVTC, 1991), but only Texas made use of the computer-assisted voting procedure as employed in Foresight. The separation of the initial voting approach from the final ranking after revision of the technical reports was useful for achieving consensus among the subpanel members.

Any attempt at more quantitative approaches for the ranking exercise would have to address the problem of how to weight the relevant criteria in a rational and easily understood way and to assess the impact of the composition of the evaluators on the outcome of the ranking exercise. An article by Ding *et al*. (1996) discusses an empirical approach to comparative risk assessment for five quality of life indicators for 24 environmental issues in Taiwan. The work uses repeated measures and cluster analysis to create comparative rankings and concludes that their technique can only comparatively rank the disaggregated quality of life indicators, not an overall socioeconomic index. They state, "How to obtain an overall priority scheme is an interesting problem that needs further study." The complexities of multiobjective, multicriteria decision making have been well documented elsewhere

(Voogd, 1983), and such problems are inherent in any comparative risk exercise. Ultimately, the credibility of such complex quantitative methods might weaken the credibility of the comparative risk analysis with the public.

Participation in Foresight's Socioeconomic Subpanel was unusually broad and diverse. The wide variety of professional and educational backgrounds included within the group increased the quality of the analysis through the variety of methods used to assess the information but also required more attention to process than projects with more structured methods. However, even given the methodological improvements suggested by Foresight, the scientific consensus method fails to reach a scientific "ideal" since it is still dependent on the quality of available information and the expertise of the expert participants.

A continuing question troublesome to the techniques of comparative risk is the extent to which rankings are subject to possible composition effects: that is, how sensitive are the rankings to the composition (and associated values) of the various committees? This is an unanswered research question, but to mitigate any potential composition problems, careful screening of the membership of each committee to represent the intended broad opinion was an extremely important step in Foresight. The broad membership of the Socioeconomic Subpanel across industries and occupations ensured a membership mix such that no subgroup had agenda-setting ability. Special interest groups such as environmentalists and industry were represented on all subpanels, but each viewpoint was just one of the inputs into the discussion of the issues. The subpanel leadership and the members of the Science Panel were selected for their established credibility in assessing environmental concerns in the Houston region. Thus the quality of life analysis can be viewed as a consensus of one segment of the community—the technical and scientific experts—formed in a manner that maximizes its credibility with the public. An evaluation of whether that credibility was established, however, would require analysis that is beyond the scope of this paper.

The conclusions of Foresight's Socioeconomic Subpanel, as summarized in Table 3, by necessity differ markedly from the results obtained in similar comparative risk projects. The conclusions were reached considering evidence specific to the Houston region. For instance, the rankings differ significantly from the results of the Texas comparative risk project even though there were several people who participated in the socioeconomic analyses for both projects (TNRCC, 1997).

Of course, the rankings differed among the three subpanels themselves and from the Foresight Committee's overall ranking because each analysis was focused on a different subject. All other comparative risk studies have also found such differences among their committees. The differences in rankings may at first appear troublesome, but they can be explained by the differing missions and subjects of the committees.

If public decisions about environmental concerns and allocation of resources to address those concerns are to include quality of life considerations, methods such as those used by Foresight are important to a complete analysis. Without a systematic method for assessing the risk to socioeconomic resources, public policy decisions can be skewed to consider a more limited range of impacts. As Foresight demonstrates, each comparative risk project builds incrementally on the experience of previous efforts to bridge more effectively the gap between scientific information and public values. Successful projects can help establish a useful and defensible basis for public action on environmental problems.

Notes

1. Although most comparative risk projects are government sponsored, Foresight was initiated and is administered by the Center for Global Studies at the Houston Advanced Research Center (HARC), a not-for-profit independent research institution located in The Woodlands, Texas. Foresight was funded by a variety of government agency, philanthropic, and corporate sources, including a Cooperative Agreement with the U.S. Environmental Protection Agency. Foresight received considerable technical assistance from the US EPA, the Green Mountain Institute for Environmental Democracy, and the Western Center for Environmental Decisionmaking.
2. Economists often use a theoretical baseline of perfect competition within markets with perfect information, but such a baseline is difficult to use when nonmarket quality of life considerations are incorporated.
3. The computer-assisted variation of this technique is marketed by the Saunders Consulting Group of Toronto, Ontario.

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