

Part Two

Purpose and Results

I. Announcement and Agenda

Workshop on Integrated Research in Risk Analysis and Decision Making National Science Foundation July 17 - 18, 2002

The National Science Foundation (NSF) is bringing together a small number of scholars (see attached list) who will engage in a 1½ day dialogue to identify needs and opportunities for integrated scientific research in risk analysis and decision making. The workshop will focus on how the methodological tools and empirical findings of all disciplines that deal with risk analysis and decision making could be applied more effectively to address societal problems.

A primary goal of this workshop is to identify obstacles to effective use of existing research findings and tools, to suggest ways of overcoming these obstacles, and to identify crucial areas for future research. The ultimate goal is to help NSF shape a research agenda to improve decisions that involve risk. This agenda could include new theoretical work, empirical studies, cross-disciplinary collaboration, and training for a new generation of scholars, policy makers, and decision makers.

The research issues to be considered should relate to one or more of the following areas that comprise risk analysis and decision sciences:

- **Risk Assessment:** organize and analyze scientific knowledge and information for potentially hazardous events, activities, or substances that might pose risks under specified circumstances
- **Risk Perception:** describe and explain what factors people use in evaluating and responding to risks
- **Information Integration:** collect and combine data from different sources in making choices between alternatives

- **Decision-Making Approaches:** use formal (e.g., decision analysis, cost-benefit analysis) and intuitive (e.g., heuristics) methods to identify and select between alternatives
- **Risk Management Strategies:** devise and evaluate policies (e.g., subsidies, fines, insurance, regulations) designed to reduce risks

THREE ILLUSTRATIVE PROBLEM AREAS

Some of the challenges in undertaking research in this area are illustrated with the following three problems areas. They should be viewed as examples of the types of issues that might be considered in applying risk analysis and decision science to societal problems.

Homeland Security

Homeland security involves a variety of challenges for risk analysts and decision scientists. Risk assessment is difficult for several reasons. Decision-makers have difficulty in evaluating and mitigating low-probability high consequence (lp-hc) events in a cost-effective manner. Homeland security not only involves lp-hc events but presents additional challenges because terrorists can respond to mitigation efforts: Better security of one target may merely shift their efforts to another target. Risk communication regarding homeland security also faces difficult obstacles. Most people report that they care deeply about homeland security, yet their information needs and desires may be unclear and not link in obvious ways to management options.

The nature of risk assessment and perceptions regarding homeland security raises a set of challenges regarding the types of methodologies for evaluating different alternatives and the types of risk management strategies to pursue. The goals are to reduce the likelihood and consequences of future terrorist activities and to deal effectively with the short and long-term impacts following an attack. Some strategies could lead to additional protection if the improved security at the first target causes other parties to also invest in risk mitigation. The variety of potential targets, the political nature of the underlying factors causing terrorist activity, and the economic consequences of security measures mean that homeland security necessarily involves multiple disciplines in both the natural and social sciences. Collaborative efforts between scientists from different fields may therefore be particularly fruitful in identifying mechanisms for achieving better protection against terrorist threats.

Catastrophes from Natural Disasters

Society faces challenges in dealing with the increasing losses from natural catastrophes. With increased knowledge regarding the causes of disasters and new advances in information technology, physical scientists and engineers are better able to assess the risks associated with natural hazards. However, there is still considerable uncertainty surrounding these estimates that needs to be appreciated by those concerned with managing the risk. Many individuals residing in hazard-prone areas are reluctant to invest in loss reduction measures and/or purchase

insurance before the event occurs for a variety of reasons. These include difficulties in dealing with low probabilities and focusing on short time horizons so that the expected long-term benefits of protective action are not appreciated. Many decision makers also utilize simplified choice models which including the heuristic that the disaster *will not happen to me*.

With respect to managing risks the insurance and reinsurance industry is concerned with the uncertainties surrounding risks and the possibility of highly correlated losses from a catastrophe. Firms have concluded that they cannot provide coverage against these catastrophic risks without exposing themselves to the danger of insolvency or significant loss of surplus. The research challenges in the risk management arena revolve around questions as to how one deals with ambiguity associated with these low probability-high consequence events, the role of new financial instruments such as catastrophe bonds in providing protection against these risks and the challenges in developing private-public partnerships to reduce future losses from natural disasters and to aid the short and long-term recovery from these events.

International Trade and Health

The 1994 World Trade Organization Agreement on Sanitary and Phytosanitary Measures, negotiated in the Uruguay Round, requires that countries either adopt harmonized international standards or, if they choose to maintain stricter regulations, base them on "scientific justification" based on "risk assessment...". The resolution of several disputes among member countries requires a clear understanding as to what is needed to evaluate the risks underlying these disputes. In addition there is a need to understand the social and economic consequences of possible outcomes and their long-term implications for health, incomes, and employment.

One example of an issue involving international trade is the dispute between the European Union (EU) and the United States about the import of hormone-treated beef into the EU. There is currently scientific disagreement about the possible long-term consequences of prolonged exposure to low levels of hormones on human populations. We lack a well-defined probability distribution over the space of possible outcomes and are unable to describe fully the outcomes and their consequences. There are both immediate and long-term socio-economic consequences of a European ban on imports of hormone-treated beef on raising cattle in the US. Similarly, there are impacts of free importation of such beef on the same industry in Europe. Aside from the two extreme strategies of either banning or allowing all imports, other measures include labeling hormone-treated beef so that those who feel that it poses health risks can avoid it even if its importation is permitted. The debate about genetically modified organisms raises similar issues.

RESEARCH QUESTIONS

These three cases suggest a number of challenges for risk and decision analysts. Below we have listed some questions that link risk analysis and decision making to these three problems.

- For some hazards (e.g., natural disasters) there are well-developed models specifying probabilities and consequences yet there is still considerable uncertainty regarding these risks. How can these uncertainties be quantified and presented to interested parties using the data?

- For other risks (e.g., terrorism) the risks are much more difficult, if not impossible to estimate. To what extent can existing methods be applied to this type of risk? Do we need new methods (e.g. scenario analysis) for dealing with these more “ambiguous” risks?
- What are the causes of widely varying public perceptions and acceptances of risk and what can be done to address these differences? Does research on risk perception have implications for ways that risk assessment processes can be improved?
- How should policy makers respond when the public’s perception of risk differs from the results of scientific risk assessment? How should information be presented and evaluated when experts disagree with each other?
- What are the alternative ways that information on the probabilities and consequences associated with specific be presented and framed to decision makers and what impact will different formats have on choices?
- What types of incentives (e.g. subsidies, fines) are appropriate encouraging certain behaviors by the stakeholders?
- What types of regulations and standards are appropriate to deal directly with what kinds of problems, and how can they be well enforced?
- What types of public-private partnerships can be developed utilizing existing institutional arrangements or creating new ones?
- Given the nature and importance of transboundary risks, can common international risk management strategies be developed and shared?
- What are the equity and distributional issues that need to be taken into account in evaluating strategies?

PLANNING FOR THE WORKSHOP

By **June 28** we are asking each participant to draft a 2-4 page note that address the following three questions:

- What problem areas would be appropriate for consideration in a new integrated research program on risk analysis and decision making?
- For the above problem areas, what are the most significant research challenges that we should consider?
- How can an NSF initiative most effectively promote future research in risk analysis and decision making that brings together the natural and social sciences?

We will post each of the 2-4 page notes on a restricted-access website so that participants in the workshop can learn the ideas the other participants have. These notes will also form the basis for structuring the content of the July 17-18 workshop. Please send your note to roconnor@nsf.gov.

As shown in the attached **Preliminary Agenda**, the first day will include a discussion of a set of key issues in risk assessment, risk perception, information processing, decision making methodologies and risk management strategies. We will then break into small groups to suggest a set of key problem areas and intellectual challenges in risk analysis and decision making that will form the basis of the new initiative. The second day will include a comparison of the summaries of the small group sessions and an open discussion on research priorities.

We look forward to receiving your 2-4 page notes in the next several weeks and being together with you at NSF on July 17-18 for a lively and informative dialogue.

Preliminary Agenda
“Integrated Research in Risk Analysis and Decision Making”
National Science Foundation
July 17 - 18, 2002

Day One – July 17, 2002

8:30 - 9:30 a.m.	Introduction to the Roundtable <ul style="list-style-type: none">• Objectives of the Roundtable• Introduction of Participants
9:30 - 10:30	Risk Assessment
10:30 - 11:00	<i>Break</i>
11:00 – 12:00	Risk Perception and Information Processing
12:30 - 1:00	<i>Lunch</i>
1:00 - 2:00	Decision Making Methodologies
2:00- 3:00	Risk Management Strategies
3:00-3:30	<i>Break</i>
3:30 – 5:00	Small Group Meetings: Problem Areas and Intellectual Challenges in Risk Analysis and Decision-making
6 p.m.	<i>Dinner followed by Continuation of Small Group Meetings</i>

Day Two – July 18, 2002

8:30 – 10 a.m.	Summary of Small Group Meetings
10 –10:30	<i>Break</i>
10: 30- noon	Discussion of Priority Areas for Research and Next Steps
Noon – 1 p.m.	Concluding Lunch

II. Participant List

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John Graham, Cass Sunstein, and Steven Wofsy participated in preparations, but were unable to attend the workshop.

III. Conclusions and Recommendations

Integrated Research in Risk Analysis and Decision Making In a Democratic Society

Need for the Initiative

In the last decades of the 20th century, the United States became the beneficiary of – as well as increasingly dependent on – complex, interdependent social and physical structures. Large-scale trends and changes such as globalization, advances in computer technology and a range of other economic and technological innovations have greatly improved our quality of life. At the same time, these and other changes helped to produce new threats to health, safety, and the environment and have altered the nature and scope of many older, more traditional hazards. For example, increased interconnectedness increased susceptibility to cascading effects whereby a disturbance in one part of a system can reverberate and amplify throughout the system. The public's perception of the vulnerabilities caused by the increased complexity and interdependency of our physical, economic, social, and communications infrastructures increased sharply in the last year, particularly as a consequence of financial scandals and the terrorist attacks of September 11th. The ongoing threat of additional attacks has further increased public fear and societal concern about the institutions charged with protecting our safety and security.

Part of any response to these developments should be a substantial increase in research in risk analysis and decision science. An NSF initiative in this area, which we propose, would advance basic science in ways that would enable the nation to deal more effectively with vulnerabilities arising from the ever-increasing complexity and interdependency in social, natural, and built-environment systems, as well as from natural hazards, technological risks, and intentional harms such as earthquakes and terrorism. The overall objective of the proposed initiative is to create technically sound, behaviorally realistic, and socially viable approaches to risk management that are consistent with decision making in a democratic society. Advancing the scientific analysis of risk and decision-making and providing new knowledge and tools for decision makers to deploy are ways of reducing the human casualties, social disruption, economic losses, and harm to societal values that result from natural and human-induced threats and catastrophes.

In an age of growing uncertainty and emerging risks, society requires new knowledge and tools to assess and manage risk. The research community is well positioned to provide those tools. The last few decades have witnessed an explosion of innovative empirical, theoretical, and analytic methods and tools for analyzing risks and for making decisions under conditions of uncertainty. This knowledge improves our ability to anticipate and respond appropriately to threats and provides ways to analyze the consequences of decisions made by governments, organizations, and individuals. Risk analysis and decision science are already helping us deal more effectively with both “extreme events” and ongoing risks, but they can do much more.

Rationale for the Program

Recent developments in risk analysis and decision science illustrate the progress that has been made and the potential for further contributions:

Forecasting and Managing Extreme Events Current methods and technologies make it possible to assess probabilities and consequences across risks arising from environmental, natural, and technological hazards, as well as from intentional acts designed to exploit societal vulnerabilities. For example, basic research on climate variability has resulted in significant improvement in society's ability to anticipate and respond to atmospheric extreme events using climate-based information forecast systems. In 1997-98, the world experienced the strongest El Niño in 100 years. Losses were large in many areas of the world, but because of advances in atmospheric science and risk communication, some local communities, states, businesses, and households in the U.S. had the information they needed to anticipate problems and take protective measures. Similarly, social science, coupled with research in geology and seismology, has led to advances in earthquake loss estimation that have provided governments, members of the general public, businesses, and insurers with information to better mitigate and manage earthquake hazards.

Modeling Complex Interdependencies The terrorist attack on the World Trade Center produced not only tragic losses in deaths, injuries, and physical damage, but also extensive ripple effects that shocked the fabric of economic and social institutions. These included widespread psychological suffering, a temporary plunge in the stock market, and the bankruptcy of at least one airline. Such is the case with many extreme events. The social and economics dimensions of the loss can far outweigh the damage to physical structures. New methods of modeling complex interdependencies in economic and social systems can help engineers and social and behavioral scientists predict more accurately how and where social systems will react to unforeseen events. More importantly, such methods will facilitate the development of policies and institutions that minimize damage when surprises occur.

Translating Subjective Judgments into Usable Information Since the early 1930s, social scientists have made significant advances in the development of quantitative measures of subjective beliefs. Recent advances in game theory, decision theory, and classical economics have led to the development of new tools for translating dispersed subjective judgments into usable quantitative information. Expanding and testing these new techniques will provide ways to extract this previously untapped powerful source of information.

Behavioral Economics The field of behavioral economics combines insights from cognitive psychology with formal models in economic theory. Based on the methods psychologists devised to test the assumptions and predictions of widely used economic models (i.e., expected utility theory), behavioral economics provides increasingly realistic models of human decision making that allow us to understand behavior that eluded prior formal models. An important aspect of this new approach to economics is experimental findings that have facilitated the development of new principles that integrate and extend our understanding of decision making under uncertainty and risk.

Integrating Values, Emotions, and Other Factors that Affect Risk-Related Perceptions and Decisions. Effective risk and decision analysis depends on integrating analytical capabilities with an understanding of the variety of perceptual, emotional, and value-related considerations that affect judgments concerning risk. Studies of the social dimensions of risk have improved our understanding of the roles of values, interests, individual and group perceptions regarding different types of risks, as well as the role of social institutions in decision making about risk. Further research will illuminate the processes through which social actors –including technical analysts, policy makers, and the general public and other stakeholders – assess the credibility of expert advice about risk and reach judgments about questions of feasibility, equity, voice, and procedural fairness.

These examples illustrate the valuable risk management research that exists within different disciplines and indicates how the perspectives and contributions of the disciplines begin to overlap. For example, behavioral economics has been described as the marriage of cognitive psychology and economics. The analysis of “interdependent systems” rests on advanced technical models found in several subfields of economics, the enhanced understanding of the spatial relationships that is the province of geography, and research on networked social relationships that has occurred in psychology, sociology, political science, and science and technology studies. “Forecasting and managing extreme events” requires an understanding of basic natural science, human decision processes, quantitative risk analysis, spatial analysis, statistics, organizational and inter-organizational analysis, and risk communication research. Effective implementation of advances in any of these areas requires understanding individual, group, and organizational behavior as well as policymaking, politics, and professional norms and ethics. This work involves many social science disciplines as well as philosophy and ethics. At this point in the evolution of the sciences, breakthroughs will occur both as a result of continuing basic research and through closer integration among relevant disciplines.

The types of risks that this initiative would explore vary along several dimensions:

Extreme and Sudden-Onset Events vs. Chronic Risks: “Extreme events” refer to low probability/high consequence events such as major earthquakes, very large hurricanes, major accidents at nuclear facilities, terrorist attacks, and other severe perturbations to the social, built, and natural environments. Due to their rarity, these events present significant challenges to traditional statistical analysis. Low-probability/high consequence threats present many other challenges with respect to risk communication, policymaking, and the design and implementation of effective risk management strategies.

Other less extreme sudden-onset events, such as natural and technological disasters, strike the U. S. on a regular basis. Losses from natural hazard are increasing as a result of population demographics and changing settlement patterns, decisions regarding development and construction that fail to take hazards into account, and the increased complexity and interdependency of our infrastructural systems. Since 1989, natural disaster losses in the U. S. have averaged \$1 billion per week. Research on both extreme and other sudden-onset events must include collaboration among natural scientists, social scientists, and engineers.

Although extreme events often capture greater media attention, many chronic risks have historically imposed large losses on citizens. These risks include Alzheimer’s disease, obesity, auto accidents, pollution-related illnesses, and capital losses from investments. Because a large

proportion of the population experiences chronic risks over long periods of time, scientists can assess these risks using statistical data and models. Often, however, data have not been systematically collected for many such risks, or even if they have been collected, such data are frequently not available in a form that lay citizens and other decision makers can employ. As with extreme events, advances in our understanding of chronic risks depend on basic disciplinary research as well as integrated research that brings together communication specialists, decision theorists, economists, engineers, psychologists, statisticians, toxicologists, epidemiologists, other natural and social scientists, and legal scholars.

Impacts Occurring as the Result of Human Behaviors: Risks can be ordered on a continuum from intentional human behavior (e.g., terrorist attacks), to unintentional side effects of human behavior (e.g., meltdowns at nuclear power plants), to events that originate in earth and atmospheric systems independent of human intention (e.g., earthquakes). Risks that arise from intentional actions designed to threaten lives and create social and economic disruption require multiple levels of analysis, including traditional risk analysis and decision science as well as models of strategic behavior (e.g., game theory). These risks present unique challenges, because they involve intelligent actors capable of changing their strategies and tactics in response to societal risk-reduction efforts. The question of how to deal with intentional threats is complex and the subject of many disciplines of engineering and the social and economic sciences.

Precedented v. Unprecedented Threats: Both experts and lay citizens often do not anticipate or treat with adequate seriousness some of the most significant threats to society. For example, few policy makers or members of the general public envisioned the massive financial losses imposed by the Enron – style scandals and their reverberations through society, or the deaths, injuries, physical damage, and psychological and economic harms associated with 9/11. Although earlier reports and studies contemplated such threats, those reports did not result in decisions by policy makers to manage them, in part because before they happened they were part of a large number of imagined but (seemingly) unlikely to be realized risk scenarios. The challenges associated with managing unprecedented risks are especially great when those imposing them do so intentionally (e.g., reporting inaccurate financial performance figures for personal gain, terrorist acts) because these parties deliberately seek to conceal risks. Major goals of this initiative will be to develop mechanisms that process diffuse information in ways that highlight significant unrecognized risks, to examine the decision and social contexts that keep the risks hidden and off the policy-making agenda, and to suggest options for risk identification and management.

In assessing the state of the science of risk analysis and decision making, we reach four conclusions:

- Scientists working in numerous disciplines have significantly advanced our capacity for risk analysis and decision making during recent decades.
- Unnecessary divisions between risk analysts, decision scientists, and hazards researchers as well as more traditional disciplinary divisions have impeded scientific progress.
- Advancing the basic science of risk analysis and decision making and increasing its practical utility require a new focus on interdisciplinary and multidisciplinary research, including engineering, information sciences, natural sciences, and social sciences.

- A NSF initiative can build upon a firm foundation by facilitating interdisciplinary and multidisciplinary research that will make significant advances in risk management—with a special emphasis on the distinctive challenges associated with managing risk in a democratic society.

The time is ripe for an initiative that will advance the risk and decision sciences so as to provide the knowledge and tools needed to reduce societal vulnerabilities, save lives, avoid societal disruption, and reduce psychological and economic losses from extreme events and other threats.

Program Structure

As part of a comprehensive research program, risk and decision issues need to be addressed at a variety of levels of analysis and aggregation:

- micro-level, involving decision-making and actions undertaken by individuals;
- meso-level, encompassing groups, public and private organizations, social networks, and local communities; and,
- macro-level, encompassing national and international institutions, the professions, and public policy arenas.

Further, this comprehensive program will consist of a mix of different approaches to advancing the state-of-the-art in risk management and decision science. In addition to basic research, the initiative should include:

- a focus on multi-disciplinary and interdisciplinary research
- a training component that includes undergraduate, graduate, postdoctoral, and mid-career training opportunities
- close ties with individuals and organizations whose role it is to evaluate, translate, and transfer research-based knowledge, including users of research and key stakeholder groups
- a component that develops networks and partnerships with both public and private entities to further the objectives of this initiative

We also recommend that NSF target some funds specifically for problem-focused, case study, and proof-of-concept projects.

Although the objectives of the initiative could be pursued solely through a combination of new centers and competitive individual grants (both of which we recommend), we also see the initiative as encouraging innovative institutional arrangements for accomplishing the program goals. These can include:

- Cooperative agreements establishing networks of individual projects designed to fulfill program goals

- Grants for small interdisciplinary teams
- The development of one or more handbooks for risk decision-making and management that can be regularly updated
- A national laboratory or center for advanced studies on risk analysis and management
- A panel on risk patterned on the successful Brookings Panel on Economic Activity in which the top senior scholars choose the best younger scholars to produce research papers on pressing risk policy questions, published in a time frame and format that is useful to policy makers
- Funding for quick response research teams to study sudden and unexpected crises in order to improve our knowledge base with respect to anticipating future risks and managing the consequences of risky events
- Summer institutes providing intensive training experiences for graduate students and young scholars
- National and international conferences designed to encourage knowledge sharing and collaborative research
- Small forums to bring risk and decision researchers together with those who must make decisions regarding anticipated or active risks

A comprehensive research program of the kind associated with NSF initiatives should validate and expand current knowledge through both center-based research and investigator-initiated programs, and it should provide a variety of innovative mechanisms to encourage researchers to undertake basic research and test its practical implications.