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Low Probability Events and Determining Acceptable Risk: The Case of Nuclear Regulation

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Summary

This paper discusses two aspects of the problem of determining and managing risk policies for low probability events. The public choice problem concerns the difficulty of defining acceptable societal risk when there is considerable individual disagreement about acceptable risk. The information processing problem addresses how individuals and organizations perceive and make decisions about low probability, catastrophic events. Both problems, and their interactions, impact on policy design and institutional performance for this class of problems. The paper discusses these impacts and their implications for developing and managing public policies.

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INTRODUCTION [1]

Our society is now becoming increasingly concerned with the low probability catastrophic events often associated with many advanced technological developments. Nuclear power regulation, hazardous materials containment, airline safety, drug licensing, and flood and earthquake disaster programs typify this class of important public policy problems.

This paper contends that individuals and organizations determine acceptable risks for low probability-catastrophic events in a special way which impacts on policy design. We highlight two special features: the public choice problem and the information processing problem. We discuss each of these two generic problems in the main body of the paper by focusing on the decision making process with respect to nuclear regulation. In the concluding portion of the paper we contend that society, to address these issues, must drastically rethink its model of public institutions and the criteria used to organize public policy decision making.

THE PUBLIC CHOICE PROBLEM

Acceptable Levels and Types of Risks

The impossibility of determining a societal acceptable risk arises because these risks are classic examples of public goods.[2] People, regardless of personal preferences, are exposed to the same risks, many involuntarily, producing conflicting views about what alternatives are acceptable. Some value the increased availability of lower cost electric power more than the increased risks from building nuclear power plants, while others feel just the opposite. The collective, or public, nature of the risks means that they generally cannot be varied among these individuals.

The government must select and implement a policy that attempts to reconcile these conflicting interests. One clear problem, then, is: What and whose definition of "acceptable risk" is to be accepted? Standard economic analysis provides us with no guidance here since choices between alternatives involve interpersonal welfare comparisons. Consequently, we are unable to analytically determine a single value for acceptable risk.

The decision making problem is further complicated by the fact that there are different risks. A conventional risk measure is expected loss--the probability of an accident multiplied by its costs or consequences . However, alternative policies with the same expected loss may have very different characteristics. For example, Policy A might have a relatively high likelihood of low consequence outcomes, while Policy B has a greater probability of high loss events, but a lower frequency of low consequence accidents. (See Figure 1.) People will strongly disagree as to which policy they prefer, even though both have the same expected loss. Risk averse people will prefer A, because of the lower probability of large losses.

Differences in the levels and types of individually acceptable risks are important in two related ways. It is possible for large segments of the public to prefer an option with greater expected loss to a "safer" one, if this option is perceived to have a lower catastrophic probability. Secondly, this additional dimension adds to the complexity of the decision problem facing a regulatory agency. We contend that in any policy area such as energy, and even subareas like nuclear power, there will be many alternatives

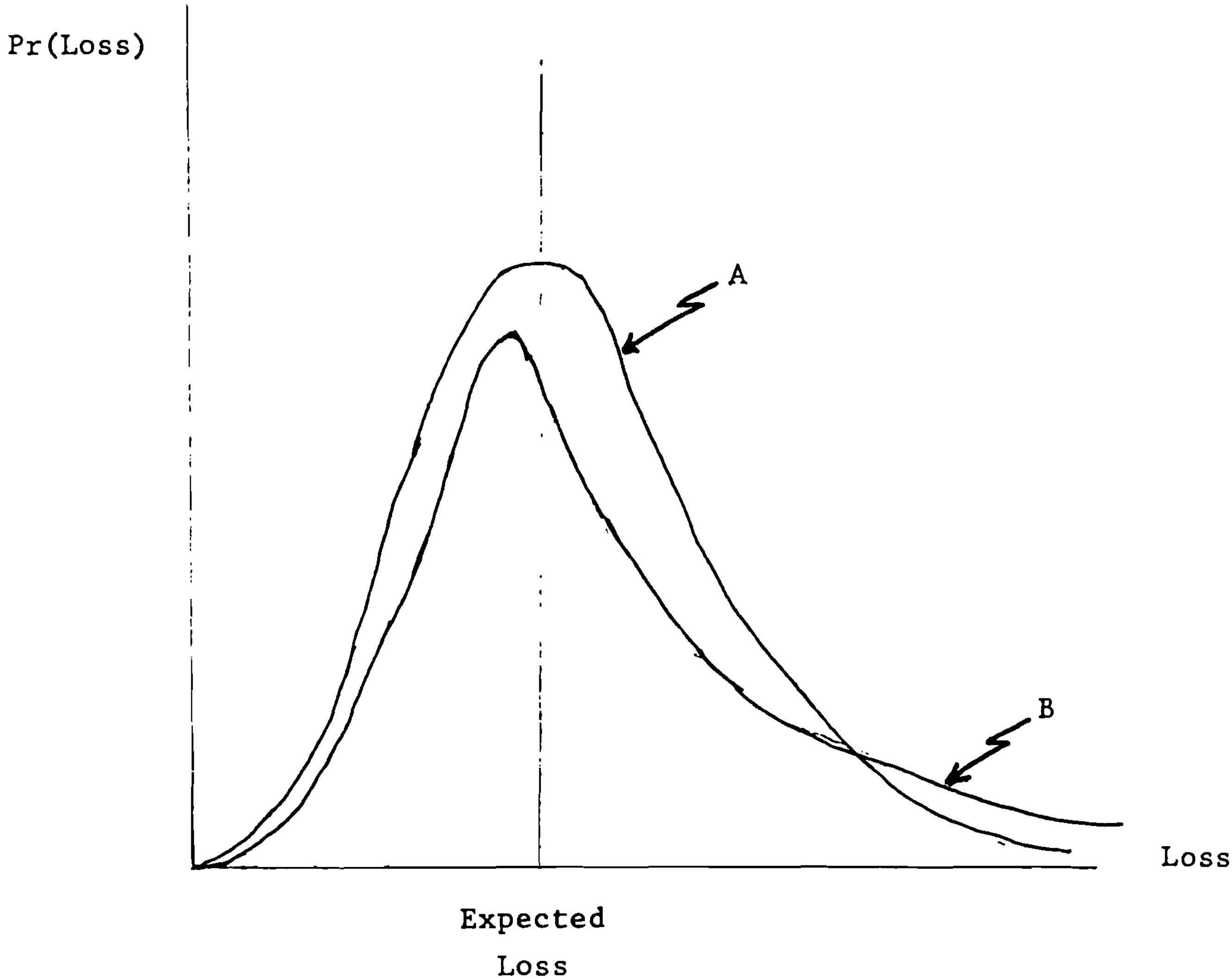

Figure 1: Different Policies with Same Expected Loss

with significant variations among types and levels of risk. Agencies must assess the diversity of individual differences over acceptable expected losses and over trade-offs between expected loss and catastrophic probabilities, and then determine whose definition of acceptability and whose trade-off to adopt.

THE INFORMATION PROCESSING PROBLEM

Individual Decision Making

The concept that individuals use simplified rules for making decisions is well documented. There is substantial evidence from field and laboratory experiments to suggest that the simplified decision rules dealing with risk and uncertainty follow systematic patterns.[3] Two significant findings from these studies are relevant to the low probability event syndrome:

(1) People frequently do not protect themselves against uncertain events if they perceive the probability of occurrence to be below some critical threshold level, even if the loss to them may be catastrophic. Their behavior is equivalent to treating the probability of a catastrophic event as if it were zero.

(2) Specific events, such as a catastrophic accident or a severe flood, focus attention on the loss dimension so that individuals are then concerned with taking extensive protective action (e.g. purchase large amounts of insurance). Yet if pressed, people often respond that the chance of the event occurring again is the same or lower than before the accident or disaster.

The 35 year history of nuclear power parallels the above descriptions.[4]

This process is considerably different from commonly proposed analytical methods such as decision analysis and utility theory. These formal models assume that individuals estimate the probabilities and losses associated with a hazard as well as the costs and effectiveness of alternative safety measures. The final choice is presumably made by comparing the expected costs and benefits of the alternatives and choosing the most attractive one according to some prespecified criterion.

The task of evaluating the public's "acceptable risk" level for low probability events becomes extremely difficult in the context of the above description of individual behavior. One has to have a clear understanding of individual decision processes in order to anticipate evaluations of a given technology and the reaction to possible events. People reject the concept of expected loss evaluations and adopt rather arbitrary, and possibly unstable, notions of what is "safe" and what is "unsafe", behave accordingly, and expect public policy to "protect" them.

Regulatory Agency Decision Making

Our research suggests that regulatory agencies, such as the NRC, follow a pattern similar to an individual's in dealing with uncertainty and low probability risks. Through a variety of procedures, agencies adopt strategies based on arbitrary criteria and the implicit premise that certain events can be precluded by proper regulation, i.e., that some probabilities can be made so low as to be treated as zero. Arbitrary criteria remove uncertainty the agency faces by giving the appearance of precision, and the premise that certain accidents will not happen removes the need to estimate the consequences of some outcomes. These procedures greatly simplify the agency's decision making.[5]

The problems faced by the NRC present two enormous uncertainties that encourage the behavior just described--those associated with the conflicts produced by the variations in and the unstructured nature of public attitudes and those associated with the complex technical nature of nuclear energy. We hypothesize that agencies such as the NRC repress these uncertainties, direct the regulatory process towards specific technical problems, and restrict the use of procedures and analytical tools that best address these fundamental issues.

Regulatory agencies generally resolve the uncertainty created by the lack of structured public attitudes and by the difficult task of choosing among competing interests by defining issues in technical terms. A regulatory standard is then set, based on this technically defensible criteria. In the case of nuclear safety, the issues of socially acceptable risk and the value of additional exposures versus additional power generation are treated as problems of establishing uniform exposure standards for a person located at the boundary of a power plant and for the total population within a given radius of a plant during different phases of operation (10 CFR 50). These standards were set after analyses of technical feasibility and of the natural levels of radiation people experience.[6] They then regulate plant design.

Criteria so established are insensitive to people's perception of how any possible accident affects them or the fact that there may be variation among individuals and among possible sites on the acceptability of this level of radiation. The advantage of this method, of course, is that it provides a fixed standard which can be used to rationalize plant design and facilitate the review of proposed and existing plants. It structures the debate around specific technical and scientific issues and away from the more difficult and uncertain problems of perception and interpersonal differences associated with probabilities and value judgements about expected losses.

From the vantage point of an agency, these arbitrary criteria may be a sensible procedure. Without such decision rules it is extremely difficult to undertake any detailed analysis and arrive at a defensible decision. Technical criteria and threshold rules facilitate decisions, provide justification for guidelines, and eliminate the need to confront the conflicts and uncertainty associated with public goods.[7]

An important way regulatory agency behavior differs from that of lay individuals is their reaction to accidents. Many members of the public who have treated the probability of such an event as zero react by taking equally extreme positions in the opposite direction, by overestimating the probabilities and consequences of future accidents, and by demanding severe policies.[8] Experts, who believe they understand the basic nature of the problem, tend to maintain the assumption that it has been designed away and to treat malfunctions by some additional engineering to remove the causes of that particular failure.[9]

Regulatory agencies' ability to analyze and choose among alternative risks, to trade off among designs, and society's ability to oversee these choices, is further inhibited by an extensive specialization and division of labor. This specialization is common and necessary in all organizations, especially so for ones dealing with such complex matters as nuclear power. However, when this process is coupled with the use of fixed, technology based design standards, it makes assessment of alternative risk policies for low probability, catastrophic events extremely difficult.

<u>Empirical Examples</u>

We illustrate these hypotheses about regulatory decision making with several nuclear power examples. These examples are not unique to nuclear power and the NRC, but are present in all our efforts to regulate low probability, catastrophic events.

<u>Core Overheating and the Consideration of Catastrophe</u>: One of the most potentially dangerous emergencies with the current pressurized water reactors is core overheating. To confront this danger, the NRC requires an extensive

and expensive emergency core cooling system (ECCS). Once satisfied with its design and operation, the NRC excludes core overheating and damage to the fuel rods and the surrounding material, defined as a class nine accident, from its list of credible accident scenarios by which they evaluate plants. All licensing requirements, tests, and evaluations address other accident scenarios, based on the assumption that the ECCS works.[10]

This process, where the probability of a class nine incident is treated as zero, precludes an important set of possible accidents, circumstances, and risks from analysis. Furthermore, precluding certain outcomes and their consequences means that alternative reactor designs with desirable control features if the core does overheat are never evaluated and compared with the present technology for this class of events.[11] This is a situation where the choice among types of risks is relevant. This alternative technology might differ substantially from the current light water reactors in the probability of different types of accidents. A more analytical decision analysis would compare the costs and benefits of a number of technologies, and include the possibility, however small, of serious overheating. The NRC procedures, by focusing on ways to exclude certain events and by assuming success, do not provide utilities or vendors with incentives to explore such technologies, and therefore rob society of a means to evaluate questions of acceptable types of risks.

Brown's Ferry and the Response to Accidents: The NRC's response to the serious fire and potential core overheating incident at Brown's Ferry is a further test of the above hypothesis and of our description of regulatory agencies' reactions to accidents that might alter the premise that certain events will not occur. The USNRC Annual Report for 1978 relates that, "Following the fire at the Brown's Ferry Plant in March 1975, the NRC initiated a review of the fire protection programs of all operating plants and for plants not yet operational." The result of this review was new guidelines for fire protection and required modifications to be completed by 1980. In effect, the modified design reduces the chances of an accident to below the necessary threshold, and the previous assumptions about the impossibility of some events is maintained. The NRC rejected challenges that the modifications were inadequate and arguments that the incident showed that cores could overheat.

As a consequence of this behavior, fundamental beliefs that the fuel cycle is inherently safe or that class nine accidents cannot happen are never challenged and evaluated. Any public concerns about safety are dismissed as irrational, based on a lack of knowledge of how the system really works. The public, naturally, becomes suspicious and antagonistic towards the experts. These suspicions and the regulators unwillingness to consider catastrophic outcomes inhibit the important function of informed public debate that will help refine, clarify, and reveal definitions of acceptable risk.

The Reactor Licensing Process: In reviewing proposed plants the NRC is organized so that standards are specified for each part of the plant through a standard review plan, and different offices within the agency are responsible for insuring that their part of the plant is designed to specifications. There is little concern with trade-offs among parts of the system nor for how these parts will interact. It becomes virtually impossible for anyone to evaluate an alternative technology of radically different risk characteristics, given this type of decentralized review process.[12]

No office or department is in a position to recommend or even evaluate an alternative which would affect other parts of the reactor design. Accomplishing and forcing these trade-offs is presumably the responsibility of the higher administrators in the agency; the Atomic Safety and Licensing Board Panel, the Atomic Safety Licensing Appeal Board and the NRC Commissioners. Unfortunately Commissioners never see the alternative options; thus, they are never forced to explicitly consider questions of acceptable types and levels of risks. Furthermore, this process will be ineffective since the natural consequence of a decentralized structure is subunit autonomy.[13] Any effort by higher administrators to force trade-offs among these units upsets the decision routines adopted to handle the assigned functions, decreases autonomy, and is therefore strongly resisted. Such intervention, then, is rarely used. The ASLBP almost never overturns the recommendations from the staff and the Appeals Board accepts the decisions of the ASLBP.[14]

The only coordinated review of a utility's application for a construction or operating permit occurs after each of the individual divisions have reviewed the various parts of the proposed plant. At this point, the plant is subjected to simulated accident scenarios that test the entire design. If the performance meets the established standards for each scenario, the application is approved. These scenarios, which exclude core overheating, are well known to the utilities and manufacturers and therefore serve to guide the design of each plant. The use of such scenarios cannot force consideration of trade-offs among design criteria, comparison of technologies with different risk characteristics, or investigation of the interactions among component parts of the system, or between person and machine.

Control of Routine Emissions and Arbitrary Criteria: The NRC's exposure standards for emissions during routine operations (10CFR50) were mentioned earlier. The Commission, in the accompanying statement to these regulations suggests that up to $1000 be spent for each expected man-rem reduction.[15] Our expectation however is that regulation of plant design and operations will be more concerned with the certainty of achieving the standard than with applying the benefit-cost rule. The nuclear power industry claims quite vociferously that NRC procedures do not follow any benefit cost evaluations.[16] They contend that regulations are promulgated simply on the basis of the exposure criteria, regardless of the expected cost per man-rem saved. The utilities term this an "As Safe As Possible" rather than a benefit cost strategy and argue that this strategy results in over-regulation, needlessly increased costs for power, and an inefficient use of resources.

Summary

We thus observe a regulatory process that relies on technically defined problems and standards instead of considering conflicts over fundamental social questions about risk, that represses consideration of possible outcomes and their policy implications, and that limits innovation and the consideration of potential trade-offs by extensive specialization and decentralization. We recognize that all organizations do, and even must, follow some of the strategies illustrated here. This is particularly true of agencies dealing with complex, technical, and contentious public issues. What concerns us, and should concern regulatory agencies, is that in simplifying operating procedures, they establish very narrow technical criteria and eschew the fundamental problems associated with risk assessments. By treating every subsequent situation in terms of its technical aspects and by defining some outcomes as not credible, the regulatory agency avoids public conflict about what is an acceptable level of risk and represses debate that would reveal options, clarify these conflicts, and lend aid in their resolution.

REGULATION AND THE POLITICAL PROCESS

Can the regulatory process simultaneously resolve the difficulties of weighing conflicting individual interests and following rational decision procedures? We believe that the answer is yes, but a different concept of the regulatory process is required.

Regulation: The Hierarchical Model

The traditional hierarchical model of government policy making is depicted by the solid lines in Figure 2. The conflicting interests and values of the public choice problem are recognized, but are the responsibility of our political institutions, such as Congress and the Presidency. They set public priorities, and in so doing define individual preferences, reconcile conflicts over acceptable risks, and accomplish the required interpersonal comparisons required to define society's acceptable risk.[17] Emerging from this first stage in the process are the goals, priorities, and policies which are to guide the regulatory agency's decisions. In the NRC's case, these goals are vaguely stated--protect public health, national security, and the environment--and require considerable judgment about whose assessment of acceptable risk and what valuation of benefits and costs to accept.

In the traditional view the agency's responsibilities are purely technical, regardless of the specificity of the legislation. They are to choose and implement programs which meet the prespecified set of objectives and policies at the lowest cost. The agency fulfills this role with sophisticated analytical studies and scientific judgments to set criteria and to determine ways to meet these criteria. The NRC, for example, translates its objectives and analysis into quantifiable standards, e.g., so many rems or body rems, and specific design requirements to eliminate certain accidents,

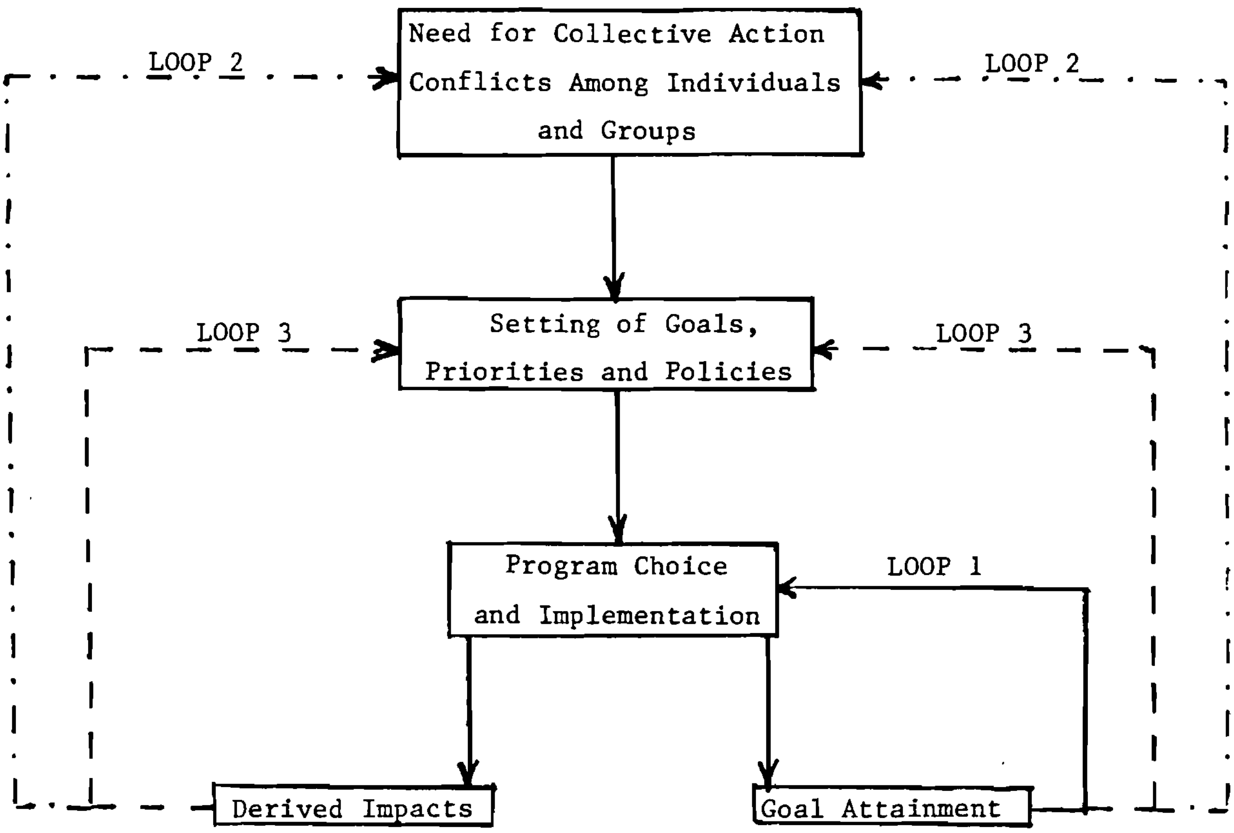

Figure 2: An Expanded View of the Regulatory Process

e.g., to keep the occurrence probability below a given threshold level. Agencies are not expected to set and apply objectives or undertake analyses that involve "political" conflicts and judgments about interpersonal comparisons. "The AEC staff role is typically not to 'resolve a controversy between private interests or between a private interest and the public interest but simply to reach a sound judgement as to the safety of a proposed reactor.'"[18] Agencies resist demands for such controversial decisions, even when pressed by outside groups (letter to Joseph Hendrie from Advisory Committee on Reactor Safeguards).

The NRC's behavior initially appears to fit the hierarchical model described by the solid lines in Figure 2. The Commission assumes that its objectives have been given by Congress and the President and that its tasks are primarily the technical ones of execution, including the monitoring of performance relative to the technical criteria established. Little explicit recognition is given to the political, or collective, nature of Commission decisions or to their impact on the structure of the collective choice process.

Regulation: An Expanded View

The proper agency role and the performance of all political institutions in addressing the problems of regulating low probability, catastrophic events outlined at the beginning of this paper can be better discussed with the non-hierarchical model, Loops 2 and 3 in Figure 2.

In reality, regulatory agencies operate within a broader arena than simply executing the goals and priorities set by Congress or the President. Most importantly, the agency's decisions are political in that they are making, and not just implementing, choices among competing interests and definitions of acceptable risks which imply a set of value trade-offs and interpersonal comparisons. Our discussion of setting a specific acceptable risk level illustrates this point. Some people, if given the choice, would prefer more stringent requirements and values than 10 CFR 50 (35 man-rems and $1000/man-rem) while others would opt for more relaxed standards.

Agency actions affect the perception and collective evaluation of risk, Loop 2. Preferences are not stable, but will change as a result of new information and situations produced by previous actions. We contend that agency decisions play an important role in the development and structure of these preferences.

Administrative agencies' procedures and decisions also affect the political process itself, Loop 3 in Figure 2, by altering the composition and relative influence of interest groups. The agencies themselves, as we have described, constitute an important interest group with a particular set of objectives and with considerable influence on outcomes. In addition, the technically based, legalistic regulatory process gives a substantial advantage to better organized outside interest groups. The tasks of monitoring the administrative process, of reanalyzing technical studies, of legally contesting decisions, and of confronting experts require considerable expertise, resources, and organization. Unfortunately, the ultimate levels and types of risks to which the public is exposed are more the result of bargaining among the organized interests, including the NRC, than a reflection of society's definition of acceptable risk.[19]

Our view of the policy process emphasizes the political nature of any regulatory agency. Agency behavior, manifested by its problem definition, its decision routines, and its administrative procedures, conveys greater influence to some interests than to others, one of which is the agency itself. Consequently, the fundamental aspects of the public choice problem are poorly handled. This deficiency results from assumptions that the political and technical aspects of policy issues are separable and that an agency deals only with technical questions, not from a lack of analytical tools or from poor individual performance.

IMPLICATIONS FOR RISK MANAGEMENT

The public issue is can we accommodate the public choice and information processing problems and the technical and political character of risk decisions and still achieve both good analysis and the proper integration of individual preferences? Unhappily, there is no certain methodology or approach to achieve this purpose.

Several considerations should dominate any consideration of regulatory reforms. Formal analysis must assess the level, type, and incidence of the risks posed by different options, but a scientific determination of socially acceptable risk is impossible. Our sophisticated decision models provide decision tools, not decision rules. Good analysis improves and enlightens public debate by identifying the potential conflicts among individual positions and by facilitating their management. Secondly, the decision process must use this information and the subsequent debate in a way that forces (or at least strongly urges) people and organizations to confront the possibility of accidents and their consequences and to develop knowledge about their own preferences. Finally, redesign of the regulatory process must recognize the political and technical nature of all decisions and provide strong incentives for Congress and the regulatory agency to do likewise. Congress as a whole must be informed about the technical aspects of nuclear power and the performance of current policies in order to legislate appropriately and effectively. Simultaneously, the NRC must explicitly consider the conflicting interests and demands of the public and give less weight to their own, natural organizational interests. These changes cannot be accomplished by fiat or by simply appointing the "right" people to office. They must be achieved by restructuring the information and incentives offered to analysts, Congress, vendors and utilities, the NRC, and the public.

Performance Standards and Consideration of Risk

At this point, we analyze a very modest proposal to illustrate the way we think information and incentives should be structured. A direct way to force evaluation of the perceived probabilities and consequences of various risks is through a system of legislated fees tied to performance criteria. The size of the fee can vary for different accidental and routine emissions and types of hazardous behavior. They need not be linear with performance, but can increase as rapidly as desired as performance falls. For example, if Congress accepts studies showing few health effects from low levels of exposure, penalties for such emissions could be small but then increase rapidly with higher levels of exposure, with more serious types of radiation, and for reactors in more densely populated areas. Quite conceivably, the fee for emissions beyond some level will be high enough to force plant shutdowns. We also believe that Congress should establish a means of using the revenues collected from such a penalty system to directly compensate the individuals exposed, rather than simply to increase the U.S. Treasury.

A system of performance standards with fees based on the unacceptability of behavior and outcomes has several advantages over the current system of design standards. Briefly, they make the debate about the unacceptability of outcomes more visible and accessible to the public; they increase the interaction between Congress and the regulatory agency, thereby giving each institution greater incentive to confront the entire range of technical and political questions; they offer the private sector greater discretion and more flexibility to innovate at the same time that the penalties for poor decisions and performance are more explicit; and they provide for more sensitive and flexible responses to changes in preferences and performance levels.

Legislative determination of performance criteria and fees concentrates debate and analysis on the fundamental aspects of the problem. Conflicts will arise from the central question of how different sectors in society evaluate the hazards relative to the benefits of additional nuclear power, not from some technical study of whether a particular design is "safe". Decision making addresses the basic conflict and takes place in a more public arena with greater likelihood of all interests and positions being articulated than when safety decisions are confined to technical matters decided by administrative agencies.

The performance based system promotes a more stable and manageable process of adapting policy to changes in people's perceptions and evaluations of risks and consequences. Just as we now have periodic changes to the income tax code to take into account changing objectives and circumstances, the fees can be marginally altered in response to public demands and past experience. These marginal changes will be easier for firms to respond to than sudden, massive changes in required designs or standards. Changes in the fees, reflecting shifts in the public's acceptable risk level and determination of the costs of radiation releases, are comparable to fluctuations in any input prices a firm faces and should cause no greater disruption to operations than these fluctuations.

This process does not substitute political decisions for analysis, but simply serves to make analysis the information device for better political decisions. Congress will need to know about probabilities, consequences, and comparisons with other energy sources and risks. What will change is the way this information is used to educate the public and to improve decision making about the public's collective view of low probability, catastrophic events.

The ultimate concern is whether people--be they the experts or the general public--will continue to believe and act as if low probability events will not happen. So long as such behavior is manifest, no set of public policies, institutional arrangements or methodologies for considering risk can protect society from the consequences. The only relevant reforms and policies are ones that will prevent such blindness.

Notes

[1]John E. Jackson is Professor of Political Science, The University of Michigan, and Program Director at the Institute for Social Research. Howard C. Kunreuther is Professor of Decision Sciences, The Wharton School, University of Pennsylvania. This paper was prepared for delivery to the Research Conference on Public Policy and Management, Chicago, Illinois, October 19-20, 1979. Revised March, 1981. We would like to express our appreciation to Meru Thakur for his helpful assistance throughout this project and to Raymond DiSalvo, Peter Linneman, Paul Slovic, and Anita Summers who provided us with useful material and comments which greatly aided our research. Support for the research was provided by the Nuclear Regulatory Commission under Subcontract 7656 from Union Carbide Corporation to Perceptronics, Inc. and the John Simon Guggenheim Foundation. None of the above organizations have responsibility for statements made in the paper.

[2]The definition of a public good is any service available to everyone at the same level, regardless of individual demands or actions. R. A. and P. B. Musgrave, *Public Finance in Theory and Practice* (New York: McGraw-Hill, 1976).

[3]A. Tversky and D. Kahneman, *Science* 185, 1124 (1974); P. Slovic, *et al.*, *Journal of Risk and Insurance* 44, 237 (1977), and in G. Goodman (ed), *Impacts and Risks of Energy Strategies* (New York: Academic Press, 1979).

[4]C. Hohenemser, *et al.*, *Science* 196, 25 (1977) and H. P. Green, *Science Policy* (1979).

[5]See R. M. Cyert and J. G. March, *Behavioral Theory of the Firm* (Englewood Cliffs, N. J.: Prentice Hall 1963) and J. Galbraith, *Organization Design* (Reading, Ma.: Addison-Wesley, 1977) on how organizations develop simplified decision routines to reduce the uncertainty of complex tasks.

[6]W. D. Rowe, "Optimization - Theory and Practice: US - 40CFR190 - A Case Study." The American University. Xerox, 1979.

[7]See H. C.. Kunreuther et al., Disaster Insurance Protection: Public Policy Lessons (New York: John Wiley & Sons 1978), for similar observations about other agencies and risk problems.

[8]H. C. Kunreuther et al., Ibid.; P. Slovic et al., in (3); and C. Starr and C. Whipple, Science 208, 114 (1980).

[9]B. Fischhoff, S. Lichtenstein, P. Slovic, S. Derby, and R. Kenney "Approaches to Acceptable Risk: A Preliminary Report to the Nuclear Regulatory Commission" (Eugene, Oregon: Decision Research, 1980).

[10]An independent review by the American Physical Society study group concluded that the ECCS would probably work as intended but that a really complete and quantitative basis for its performance was still not at hand, J. M. Hendrie, "Safety of Nuclear Power." In J. M. Hollandes and M. K. Simmons, (eds.), Annual Review of Energy (Palo Alto, CA.: Annual Reviews, Inc., 1976).

[11]J. M. Hendrie, Ibid., implies that such a choice is presented by the high temperature, gas cooled reactor alternative to the present light water reactors.

[12]See M. Rogovin, "Three Mile Island." Report to the Commissioners and to the Public, 1 (1980). Interviews with NRC staff indicate that this process has been reorganized subsequent to Three Mile Island and the Rogovin report.

[13]J. Galbraith, in (5).

[14]M. Rogovin, in (12).

[15]USNRC, WASH-1258 (1973).

[16]D. S. Duncan, "Application of Probabilistic Risk Assessment to Value-Impact Analysis." Paper presented at the Atomic Industrial Forum Workshop on

Reactor Licensing and Safety, Feb., 1977. D. H. Roy, "Risk Assessment in Licensing: An Industry Viewpoint." Paper presented to the Atomic Industrial Forum Workshop on Reactor Licensing and Safety, April 1978.

[17]Atomic Industrial Forum, June 1977; R. Haveman and J. Margolis, Public Expenditures and Policy Analysis (Chicago: Rand McNally, 1977); Joint Committee on Atomic Energy, Improving the Regulatory Process, Committee Print, 1961.

[18]H. P. Green, The George Washington Law Review 33, 121 (1964) quoting the JCAE, Ibid.

[19]The relevant outside interest groups include the newer issue oriented, "public" interest groups. See H. Margolis, The Public Interest (Fall 1977), and R. A. Leone and John E. Jackson, in D. M. Ginsburg and W. J. Abernathy (eds.), Government, Technology and the Future of the Automobile (New York: McGraw-Hill, 1980) for discussions of the political impacts of these interest groups.