THE ROLE OF INTERDISCIPLINARY ANALYSIS IN BRIDGING THE GAP BETWEEN THE TECHNICAL AND HUMAN SIDES OF RISK ASSESSMENT *

Miller B. Spangler

Special Assistant for Policy Development
Division of Systems Integration
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, C. C. 20555

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ABSTRACT

It is readily observable that there is a wide gulf in the manner by which the lay public and technical experts assess the risks of complex technologies and assimilate these assessments in decisions regarding the acceptance or rejection of technological options. On the public side, this gap in methods and value assessments is a major source of distrust of technical experts and disaffection with the social management of technology. From the viewpoint of the technical experts who introduce or regulate technologies, this gap is both a cauldron of frustration and a perceived justification for paternalistic, technocratic decisionmaking that further alienates important segments of the public. It is the author's belief that unless our society learns how to progress in bridging these gaps within the framework of a comparative mode of risk-cost-benefit analysis of options, the potential net benefits of certain technologies such as commercial nuclear power could well be lost to our society. Research on public risk perception, while potentially an important component in achieving this objective, needs to be restructured from its present static orientation to meet the needs of forward-looking decisionmaking that accommodates dynamic learning processes of both the public and technical experts as well as the "learning curves" of technological improvements historically accompanying successful innovations. Moreover, no less attention needs to be devoted to improved benefit assessment along with ethical and equity considerations in decisionmaking involving the reconciliation of conflict between individual and societal interests. This paper examines the vital importance of interdisciplinary analysis in fulfilling these needs.

1. GAPS IN THE TREATMENT OF TECHNOLOGICAL RISKS BY TECHNICAL EXPERTS AND THE LAY PUBLIC

In a variety of energy, chemical, and bio-engineering industries, public perception of risks to the natural and human environment have become significant stumbling blocks to the regional, if not national, acceptance of these technologies. This has introduced issues in public policy development such as: "How safe is safe enough?" "How remote is remote enough?" -- and, in the case where risk assessment is fraught with a high order of scientific uncertainty, "How certain is certain enough?" and "Who should bear the burden of proof?" Since there are trade-offs between risks, costs and benefits in technological systems designs, siting considerations, and the costs of added

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[1]This article is based on seminars presented by the author on October 16, 1981 at the Carnegie-Mellon University, Department of Engineering and Public Policy.

knowledge, the proper questions should be: "How safe is too safe?" "How remote is too remote?" and "How certain is too certain?"

There is probably no technology that is presently more beseiged by issues of these kinds than commercial nuclear power. In the view of many, if nuclear power is not a dying industry, it is at least suffering from a bad case of hypothermia. No new nuclear plants have been ordered in the United States for three years, a period in which several dozens of coal-fired electric generating plants have been ordered. A number of reasons have been suggested for this state of affairs by Denton(1) and others. One such explanation, expressed by Ahearne(2) (Commissioner of the U. S. Nuclear Regulatory Commission) emphasizes that nuclear power's fatal flaw in the United States is that it cannot get public acceptance and concludes:

> "I do not foresee that fatal flaw being eliminated. The deep hatred and divisions within the United States public on the issues of nuclear power, the uncertainties of accidents, the confusion over what is radiation, the fear of abnormalities and serious cancers in future generations, I believe will lead to the demise of commercial nuclear power in the United States."

In a recent report(3) the President's Nuclear Safety Oversight Committee stressed such factors as a decline in the growth of electricity demand, high interest rates, and tightness of capital markets; but also it highlighted political uncertainties conditioned by public opinion as potential risk deterrents to utility investments in nuclear power:

> "If the decision to order the new nuclear power plant were made today, the plant could begin producing power in 1993-95. What could happen in the interim? Could some President or Congress, Governor or State Legislature, Nuclear Regulatory Commission or Public Utilities Commission be anti-nuclear? In fact, this period is likely to include 2-3 Presidents, 3-4 Governors, and 6-7 Congresses, State Legislatures, NRCs and PUCs. Is there a reasonable likelihood of an accident of Three Mile Island (TMI) proportions, or worse, during the ensuing 12-14 years at one or more of the 200 nuclear power plants operating in the world? How could that affect public opinion, political referanda, and thus the prospects for the utility's new nuclear plant? (TMI-1 is an operable plant that has not been permitted to restart after the TMI-2 accident.) These "political" uncertainties may not be quantifiable in the more precise terms in which analysts compare costs of alternative projects. But can the prudent director ignore these risks in his investment decision?
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> Obviously there is some risk that the coal-fired plant might be subjected to crippling delay. The possibility of a new wave of environmentalism that highlights the health effects of burning coal beyond the company's ability to abate air pollution by modifying the plant or its operations cannot be excluded. (In fact, the best current scientific studies indicate that the mortalities and morbidities from coal are likely to exceed those from nuclear power generation.)

But these risks appear of a markedly lower order than those posed by the new nuclear power plant."

In a nuclear policy statement issued on October 8, 1981, the President(4) announced a series of initiatives to reduce regulatory uncertainty with the objective of shortening the time involved to proceed from the planning stage of a new nuclear plant to an operating license to 6-8 years, as is typical in some other countries. In recognition of deep-seated problems besetting the nuclear option that may not quickly be resolved, the President directed the Secretary of Energy and the Director of the Office of Science and Technology Policy to meet with representatives from universities, private industry and the utilities to report on the obstacles which stand in the way of increased use of nuclear energy and the steps needed to overcome them.

It seems clear to the author that among these deep-seated problems is the persistent wide gulf between how technical experts assess the risks of nuclear power and integrate these assessments into policy or case-related decisions and how the lay public perceives these risks and decides to accept or oppose the nuclear option. Elemental considerations of treatment comprising these gaps are set forth in Table 1 which highlights differences in risk assessment methods, the basis for trusting information used in these methods, the scope and importance accorded various risk attributes, technological considerations of design as related to Murphy's Law and empirical data on equipment and operator failure, and decision criteria used in risk acceptance or rejection.

2. INTERDISCIPLINARY ANALYSIS: THE PURSUIT OF UNCONVENTIONAL WISDOM

There are a number of analysts who point out that the term "risk acceptance" is an improper perspective: society, or an individual within a society, does not accept or reject risks; rather they accept or reject technological developments that have a multiplicity of risk attributes as well as inherent benefits and costs of other kinds.(6,7) These include a wide range of beneficial and adverse effects on the natural and human environments that are direct and indirect, intended and unintended, quantifiable and intangible, short and long term, and rather certain or probabilistic of realization.(8) Sec. 307(c) of Title III of the Energy Reorganization Act of 1974, as amended, imposes annual reporting requirements for the Nuclear Regulatory Commission (NRC) to provide a "clear statement of the short-range and long-range goals, priorities, and plans of the Commission as they relate to the benefits, costs and risks of commercial nuclear power."

It is quite obvious that the assessment of such a wide diversity of beneficial and adverse consequences involves knowledge and scientific methods from a large number of scientific disciplines. Indeed, the National Environmental Policy Act of 1969, as amended, requires (Sec. 102) that all federal agencies shall "utilize a systematic, interdisciplinary approach that will insure the integrated use of the natural and social sciences and the environmental design arts in planning and decisionmaking which may have an impact on man's environment." On an international level, the Scientific Committee on Problems of the Environment (SCOPE) -- an organization of the International Council of Scientific Unions -- has recognized at the outset of its activities that environmental science cannot be effectively pursued except on an

TABLE 1. GAPS IN THE TREATMENT OF TECHNOLOGICAL RISKS BY TECHNICAL EXPERTS AND THE LAY PUBLIC

(Some generalizations having notable exceptions)[a]

APPROACH	TREATMENT COMMON TO EXPERTS	TREATMENT COMMON TO THE PUBLIC
1. Decision Criteria for Risk Acceptance/Rejection		
a. Absolute vs. relative risk	Risk judged in both absolute and relative terms	Greater tendency to judge risk in absolute terms
b. Risk-cost trade-offs	Essential to sound decisionmaking because of finite societal resources for risk reduction and impractability of achieving zero risk; tends to ignore non-dollar costs in such trade-offs	Since human life is priceless, criteria involving risk-cost trade-offs are immoral; ignores risks of no-action alternatives to rejected technology; gives greater weight to non-dollar costs
c. Risk-benefit comparisons of technological options	Emphasizes total (net) benefits to society, neglecting benefits that are difficult to quantify; also neglects indirect and certain long-term benefits	Emphasizes personal rather than societal benefits; includes both qualitative and quantitative benefits but tends to neglect indirect and long-term benefits
d. Equity considerations	Tends to treat shallowly without explicit decision criteria and structured analyses	Tends to distort equity considerations in favor of personal interests to the neglect of the interests of opposing parties or the common good of society
2. Risk Assessment Methods		
a. Expression mode	Quantitative	Qualitative
b. Logic mode	Computational • Risk = consequence x probability • Fault trees/event trees • Statistical correlation	Intuitive • Simplistic rationale • Media accounts
c. Learning mode	Experimental • Laboratory animals • Clinical data for humans • Engineering test equipment and simulators	Impressionistic • Personal experience/memory • Media accounts • Cultural exchange
3. Basis for Trusting Information		
a. Source preference	Established institutions	Non-"establishment" sources
b. Source reliability	Qualifications of experts	Limited ability to judge qualifications
c. Accuracy of information	Robustness/uncertainty of scientific knowledge	Minimal understanding of strengths and limitations of scientific knowledge
4. Risk Attribute Evaluation		
a. Low frequency risk	Objective assessment/conservatisms	Tends to exaggerate or ignore risk
b. Newness of risk	Broad range of high and low estimates	Tends to exaggerate or ignore risk
c. Catastrophic vs. dispersed deaths	Gives equal weight[b]	Gives greater weight to catastrophic deaths
d. Immediate vs. delayed deaths	Diverse views over treatment of incommensurables and discount rate	Gives greater weight to immediate deaths except for known exposure to cancer-producing agents
e. Statistical vs. known deaths	Gives equal weight	Gives greater weight to known deaths
f. Dreadness of risk	Generally ignores	Gives greater weight to dreaded risk
g. Voluntary vs. involuntary risk	Gives equal weight	Gives greater weight to involuntary risk
5. Technological Considerations		
a. Murphy's Law (If anything can go wrong, it will.)	Stimulus for redundancy and defense-in-depth in systems design and operating procedures; margins of conservatism in design; quality assurance programs	Stimulus for "what-if" syndromes and distrust of technologies and technocrats; source of exaggerated views on risk levels using worst case assumptions
b. Reports of technological failures/accidents	Valued source of data for technological fixes and prioritizing research; increased attention to consequence mitigation	Confirms validity of Murphy's Law; increased distrust of technocrats

a/ Some of the descriptors in this table unintentionally reflect the image that the "experts are always right." Experts, of course, are not without emotions and sources of bias. Indeed, experts could benefit from improved information and scientific advances in reducing uncertainties in assessing technologies and their societal impacts as well as a wider appreciation of public attitudes and changing social values.

b/ For an exception, see the safety goal report of the Advisory Committee on Reactor Safeguards.[5]

Source: H. R. Denton (Ref. 1).

interdisciplinary basis involving different scientific specializations from the physical, biological and social sciences, including economics, law, and a wide range of other areas of special knowledge such as medicine, psychology, communications and information theory, to name only a few.(9)

However, it is readily observable that the stated NEPA requirements for interdisciplinary analysis and the frequent exhortations regarding its desirability rarely lead to its successful practice. It is important to understand the underlying problems serving as impediments in order that solutions can be developed. One such basic problem is the manner in which specialized fields of study, or scientific disciplines are structured. Most, it seems, have a rather narrowly defined span of knowledge about natural or human phenomena they aspire to encompass in order to permit development of the strengths of in-depth knowledge, or expertise. These strengths are, by the very same token, a major source of weakness for interdisciplinary analysis. Each discipline develops its own spans of information, its own special concepts and jargon, and its own hierarchy of preferences for scientific methodologies that seem best suited to their limited fields of inquiry of work-related responsibilities. Putting professionals from different disciplines together to perform an integrated <u>interdisciplinary</u> analysis of the complex issues inherent in the risks, costs, and benefits of technological options too often results instead in the foibles, frustrations, -- and even, at times, counterproductiveness -- of <u>multi-disciplinary</u> analysis. It is noted that interdisciplinary analysis and multi-disciplinary analysis are alike in covering the scope of scientific knowledge and behavioral insight of two or more disciplines. However, unlike multidisciplinary analysis (which is analogous to mounting additional patches to the quiltwork of analytical effort), interdisciplinary analysis involves a form of hybridization or blending of the incorporated disciplines in which a fully integrated process is sought in a <u>systems analytic framework</u> that encompasses the <u>interacting</u> behavioral and value-productive relationships <u>between</u> causal factors covered by the performing disciplines. Classic examples of hybridization include physical chemistry and social psychology.

A fitting paradigm of multidisciplinary analysis is the behavior of the fabled blind men of Indostan, who focused on analyzing their own special part of the elephant with results as described in the last verse of John Saxe's poem, "The Blind Men and the Elephant": [4]

"And so these men of Indostan
Disputed loud and long,
Each in his own opinion
Exceeding stiff and strong,
Though each was partly in the right,
And all were in the wrong!"

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[4] For insight into the problems, frustrations, and delays of the (multidisciplinary/interdisciplinary) analyses of the 4-year CONAES study (Ref. 10) on <u>Energy in Transition, 1985-2010</u>, see Handler's candid transmittal letter to the Secretary of Energy (pp. v-xi) and also Boulding's sensitive comments on disagreements, found in Appendix A (pp. 613-618).

Another barrier to attaining the objectives of interdisciplinary analysis is the tendency of different kinds of professionals, when assembled as a team, to jostle for favored positions in a hen-pecking order,[5] rather than to adopt the more humble, conciliatory process of learning from each other that is so essential to converting multidisciplinary analysis into the more productive mode of interdisciplinary analysis. Kenneth Boulding, who has done more than anyone I know to advance the cause and practice of interdisciplinary analysis, describes this need in his book Beyond Economics:(11)

> "Economics has a certain reputation - not, I think, wholly undeserved - for being the most scientific of the social sciences, it does possess, I think, a larger body of analytical propositions that are widely accepted by competent persons than either sociology or political science. It also exhibits the marks of the history of a true science, in that it exhibits an orderly development toward greater and greater generality. The older theories - i.e., of the classical economists - can easily be formulated as special cases of the more general modern theory. This very internal consistency and success, however, has developed in some economists a certain spiritual pride which has injured the development of social science as a whole, and I think the profession is coming to realize more and more the necessity for trade among the various disciplines if further specialization is to be fruitful. We are reaching out on all sides today toward a unified social science - a regional federation, as it were, which must be accomplished before we can proceed to that great federation of all knowledge that is the ultimate task of the inquiring spirit. All the social sciences have much to learn from one another, and the same might be said of sciences of any kind."

Another impediment to interdisciplinary analysis is the limitation of scientific method to provide reliable estimates or forecasts of technological effects that appear focal to various disciplines. This difficulty is compounded, as noted by Cumming,(12) whenever trans-scientific elements are encountered that can be asked within the framework of science, but which are beyond the capacity of science to answer. Sometimes, of course, the limitations of science to provide reliable answers to relevant questions are the more mechanical limitations of human, financial or time resources. The greater the limitations of science, for whatever reasons, to provide reliable answers, the greater is the need for wisdom to carry the burdens of analysis and translate the resulting balance of knowledge, judgment, and uncertainty into a meaningful form for decisionmaking. Wisdom, it should be observed, encompasses the bounds of scientific learning but also is built upon a creative and metaphysical imagination that discerns inner qualities and relationships. Each scientific discipline develops its own conventional wisdom patterned after its recognized leaders and which may, if not properly directed, clash with the conventional wisdom of other disciplines, thus leading to the foibles of multidisciplinary analysis described above. Perhaps it is not too strong a presumption to state that the best chances for

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[5]As described by Joseph Coates at a 1971 meeting on Technology Assessment in Andover, New Hampshire sponsored by the Engineering Foundation.

successful interdisciplinary analysis exists if the participants fully understand and accept that the team effort is one of pursuing various forms of unconventional wisdom.

Nevertheless, the imaginative aspects of unconventional wisdom, subject as they may be to personal bias and loss of worldly reality, hold their own perils. This danger has been recognized by Boulding:(11)

> "The noble concept of the unification of science has always attracted the imaginative thinker. It is a concept, however, which has proved disappointing, and perhaps even positively dangerous in practice. It has led either to grandiose overall systems like those of Bacon and Comte, which remain empty because the bulging and slatternly corpus of knowledge obstinately refuses to fit the neat corsets of the system builders, or it has led to something much more dangerous - pseudo-systems which have been satisfying to the mind without being sufficiently true to reality. The Aristotelian system was one such. In the social sciences there are the Marxian system and also that of Veblen. Both these represent premature syntheses in social science - integrations of bad economics, bad sociology and anthropology, bad political science. Nevertheless, because they are syntheses they exert remarkable power over the minds of men, to the ultimate detriment of intellectual progress. They are comfortable mental inns on the long dark road of knowledge; it is little wonder that men seek their warmth and shelter, and that they settle down in them and refuse to continue their journey."

The salient point being made by Boulding is not that integrative, interdisciplinary analysis should be abandoned because of these hazards. The continuing conflict of the conventional wisdoms of the various scientific disciplines also poses danger for our society which is urgently pressing for solutions to the interrelated problems of non-renewable resources and inflation as well as other limits to growth or the attainment or sustaining of the "good life". Rather, a watchword of caution is needed for our adventurous travels in the world of interdisciplinary analysis which seeks quite ambitiously and somewhat gropingly to integrate the contributive wisdom of the various disciplines so that the whole is greater (and not less) than the sum of its parts.

3. INTERDISCIPLINARY ISSUES IN THE DESIGN AND USE OF RISK PERCEPTION RESEARCH

Minus the disillusioned, escapist tone of Otway's article,(6) I find many points of essential agreement with the perspective he provides bearing on the present status or needs of risk perception research:[6]

(1) That risk (and its perception) is only one of many aspects that determine the social acceptability of risk-bearing technologies.

(2) That risk perceptions vary from technology to technology, are a function of situational and institutional contexts, and differ for different social groups--and all this is time dependent.

(3) That it is difficult to see primary (or direct) uses for psychometric studies of risk perception in policy decisions. (I would add to this: as presently designed.)

(4) That technical experts tend to view the "risk perceptions" of the lay public as often exaggerated "misperceptions." (Indeed, if segments of the public perceive risks "realistically," i.e., as the experts feel they assess these risks, there is a disappearance of conflict and sense of problem.)

(5) That the present technical risk literature abounds with confusion over descriptive and prescriptive (or normative) models. The latter, in my view, is the more relevant to policy decisions, which must accommodate, to some degree, ethical and equity considerations in the distribution between interest groups of risks, costs, and benefits of technological options over space and time.(13)

(6) That personal attitudes is a preferred key to the measurement of risk perception as a function of its salient determinants, or beliefs, and the values assigned to their attributes.[7]

(7) That these lay attitudes are based upon more than statistical risk information and, for nuclear power, might be associated with such nuclear power attributes as nuclear weapons, unlimited energy supplies, or technocratic elitism.

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[6] These points have been selectively paraphrased in the interests of brevity and, in some instances, modified somewhat or reinterpreted to make them more descriptive of the author's own views. To the extent there are any serious departures from Otway's views, the author apologizes for assuming that a rough equivalency exists.

[7] I have suggested in Ref. (14) that treatment of attitudes should be organized in a closely related or patterned sense identifiable as "syndromes." A syndrome may be viewed as a set of concurrent concepts including related emotions and decision or action predispositions that form an identifiable attitudinal pattern (Webster's New Collegiate Dictionary).

(8) That greater attention needs to be directed toward what determines people's risk judgments, the number of dimensions needed to describe these judgments, and what are the correlates of these dimensions (such as the syndromes described in Ref. 14).

(9) That it is important to study what benefits mean to people and the components or characteristics of such benefits; benefit perception should receive as much attention as risk perception.

(10) That the role of considerations of equity and other social norms needs to be understood as determinants of people's (and I would add, expert's) judgments of acceptable risk.

(11) That technological acceptability needs to be understood in the context of the public's concern for the legitimacy of regulating institutions and their (analytical and decision) procedures.

(12) That psychometric studies can help understand the dimensions of the acceptance problem for particular cases. However, unlike Otway, I feel that more restricted, but still useful, insights can be gleaned from appropriately designed psychometric studies for generic policy development.

(13) That more attention needs to be directed in acceptability research to real world situations in which acceptability is negotiated among special interests groups in a highly political context, including differential research on attitudes of politically active groups (both for and against the technology options).

(14) That psychometric research (if it is to be of greater value to policy makers) must broaden its approach beyond the conceptual framework of the "flat earthers" (i.e., the present distorted perspective of the lay public as seen in the eyes of the experts). This is not to say that technical experts do not also have distorted perspectives in certain attributes to the question of the social acceptability of technologies that are also deserving of attention as an issue in interdisciplinary analysis. This includes what Otway denotes as unilateral decisions of technical experts based on the hard "facts" of risk and benefit--to the exclusions of those possessing other relevant, but soft, information.

(15) That attitudes toward policy options can be measured as a function of underlying beliefs and values, but in view of the large number of attitude objects, and the perishable nature of the results, such studies can provide useful information to the regulator but are not (generally) sufficient as a firm policy basis.

(16) That policy makers, if only guided by opinion or attitude surveys (and thus bound to select the most popular option) will have betrayed the (broader, long-term) societal interests as presently protected by our special form of (representative) democracy.

(17) That psychometric studies should not be used by the regulator as a basis for attitude change programs.

In particular, the last point of agreement deserves a fuller explanation of the author's views, especially as these relate to the interaction of information and attitude change and the need to focus risk perception research on this interaction. I believe that the interests of democratic procedures (as opposed to autocratic elitism in the social management of technology) will be served best by a dynamic interchange of information between the regulator and those affected by the decision outcomes of regulation and this may, of course, cause attitude changes on both parts. There are numerous channels for accomplishing this, but none is, alas, without serious deficiencies if only because of the limited resources that can be afforded for such processes. Emotional barriers to effective communication might also intervene whenever polarized views are held that lead to cognitive dissonance and the tendency not to be open-minded regarding disconfirming information [see Refs. (8), (13)]. Among these communication modes are direct information exchanges at public hearings or workshops, or with community leaders and officials on site visits.

The most significant indirect methods of information exchange are published information sources available to the lay public and technical experts such as:

(1) Publications of the Nuclear Regulatory Commission (Safety Analysis Reports and Environmental Impact Statements related to individual licensing actions; published reports on technological or generic policy issues or review procedures; Federal Register notifications of regulatory matters, some inviting public input; and speeches or articles by agency officials or staff).

(2) Articles, books, Congressional hearings, speeches, lectures, and seminars by educators, professional researchers, and other thought leaders representing various special interest groups or the common weal.

(3) Media reporting on technological events or issues regarded as "newsworthy."

Knowledge of these types of direct and indirect information is relatively commonplace, but its listing serves to remind us of the inordinate complexity and diversity of information sources which, at one and the same time, may serve to enlighten and also to distort and fuel controversy among experts as well as the lay public over technological issues. Moreover, it illustrates how much we all suffer from information overload and how limited a body of the available information we are able or desire to access. Presumably, technical experts are able to tap a larger fraction of the relevant body of information than the lay public or its political representatives, who may spread their attention over a wider range of public issues than those involved in a more limited field of technological options. Nevertheless, the mono-disciplinary orientation and interests of most experts, as discussed above, contributes to an unbalanced and biased perspective of technological issues and their socially desirable solutions. This in turn biases the perspective in the speeches, articles, or reports they write, their selection of written materials or other communication channels for personal consumption, and the all-important interpretation or analysis of the information inputs as received.

The generalists, who also contribute to the body of relevant information, suffer from different sorts of biases that are due to lack of in-depth knowledge on key aspects of technological issues. In a Congressional report(15) that highlights the relative strengths and weaknesses of specialists and generalists, the following observation was provided by Senator Henry M. Jackson in the Foreword:

> "Modern-day specialists can make important contributions in decision-making; but there is no substitute in government for the wise generalist with skill and shrewdness in judging the competence of specialists and in determining the operational feasibility and political acceptability of any plan of action. It is a skill that can come when a specialist widens his interests and takes on assignments presenting broadened challenges--particularly the challenges of dealing with people in a range of different situations at home and overseas."

As a policy analyst in a regulatory agency committed to the interdisciplinary analysis of the risks, costs, and benefits of technological options, I appreciate very much the information provided by public opinion polls and public perception research. These provide important insights regarding the profile of current values, attitudes, and opinions of various segments of the public and the information premises (including forecast assumptions) that serve as a basis for these. As public servants, we cannot in good conscience assume that our own set of values are the most appropriate values to serve the best interests of society in both the short and long term. Nor can we assume that society has a homogeneous and fully consistent set of values. Attention of public decision-makers to the diversity and conflict of values within single individuals as well as between different interest groups is essential if principles of equity and distributive justice are to be served.

Yet I do not believe that the best interests of society will be served by taking at face value the current opinions of the public as obtained by the polls and surveys regarding technological acceptance issues. Not only must public decision makers act as surrogates for the interests of future generations (who, of course, cannot be polled). They must also seek to understand how the longer term interests of the present generation will shift with changing circumstances resulting from the implementation of plans and programs--or, alternatively, as forecasted with different scenario assumptions that cover a reasonable range of possible happenings for events or outcomes not subject to the control (or the full control) of society.

Other troubling aspects of taking at face value the surveyed opinions of the lay public are the observable deficiencies of information and logic which interact with the more rudimentary values of individuals in determining their option preferences. For example, suppose a physician found that a patient's initial perception of the risks, costs and benefits of a proposed operation led to a rejection of the operation when it was quite obvious that the patient was poorly informed on certain of these decision attributes. Moreover, on further dicsussion the physician found that the patient had given little or no thought to the risks, costs, and benefits of having no operation or pursuing other forms of treatment--options which in the best professional judgment of the physician hold a clearly inferior risk-benefit prognosis. Would the physician's practice be an ethical one if he accepted the initial poorly informed views of the patient as a final determinant of the patient's best interests? I think not. At the very least he should provide additional information based on the most reliable scientific sources available including the counsel of other experienced practitioners regarding the most reasonable set of options.

A frequent problem in the use of explanatory analogies is that there may be important differences as well as parallelisms. The above analogy is certainly no exception. It is simply not practicable to make technological or regulatory decisions--especially for high technologies involving complex societal "good" and "bad" effects--where some individuals would not regard themselves as losers in the decision options and others, winners. The ethical principle of "informed consent " and the one-to-one exchange of information between physician and patient is not a real world situation in the social management of such technologies. Regulators will always be confronted with the difficult decisions of exercising, within their legally defined responsibilities and authorities, their best judgment of equitable compromises between different interest groups.

Notwithstanding these differences with the medical risk analogy, I feel it would provide superior insight to the regulatory decision maker to have public perception research that goes beyond a mere provision of a "photographic snapshot" of the current values and attitudes, and the information premises affecting these for different interest groups of our society. In my view such research should explore in the manner of sensitivity analyses the heuristic shifts of values and attitudes of the public as related to variations in informational premises of the form: If attribute "X_i (or attributes X_i, Y_j, etc.) were actually the realized outcome(s) of certain technological/regulatory options, then what would be your valued preferences?

The choice of the X_i or Y_j outcomes to serve as a basis for these sensitivity analyses should, in my view, be based on the high, low or medium estimates (or forecasted outcomes) reflecting a reasonable range of uncertainty among experts. This would supply at least some of the beneficial insight to the regulator as is achieved in the information exchanges between physician and patient in which the information supplied by the physician is his or her expert knowledge of the expected range of outcomes of treatment options and the patient provided information of his or her sense of values as related to these outcomes. This, I believe, would provide a more effective method of assimilating societal values into technological decisionmaking than the present survey methods that basically reflect what societal values and preferences are when based upon a distorted perspective of information premises relative to that which regulators use as a basis for their decisions.

Note that such a use of this heuristic approach to an improved understanding of public perception of the values inherent in more realistic expectations of decision outcomes has nothing to do, in and of itself, with changing peoples attitudes. However, in my view perception research along these lines would also potentially hold considerable benefit to educators in various fields and especially to political leaders in their important role of conflict resolution. As stated by Burns,(16) the quality of interplay between leadership and followership is highly important:

> "Leadership is a process of morality to the degree that leaders engage with followers on the basis of shared motives and values and goals--on the basis, that is, of the followers' "true" needs as well as those of leaders: psychological, economic, safety, spiritual, sexual, aesthetic, or physical. Friends, relatives, teachers, officials, politicians, ministers, and others will supply a variety of initiatives, but only the followers themselves can ultimately define their own true needs. And they can do so only when they have been exposed to the competing diagnoses, claims, and values of would-be leaders, only when the followers can make an informed choice among competing "prescriptions," only when--in the political area at least--followers have had full opportunity to perceive, comprehend, evaluate, and finally experience alternatives offered by those professing to be their "true" representatives. Ultimately the moral legitimacy of transformational leadership, and to a lesser degree transactional leadership is grounded in conscious choice among real alternatives. Hence leadership assumes competition and conflict and brute power denies it."

4. TOWARD AN IMPROVED PERSPECTIVE OF NET BENEFITS

The potentiality of achieving net social benefits is the main driving force behind the development of all new technologies and their acceptability to the public. In a recent address on nuclear regulatory reform, NRC Chairman Nunzio Palladino(17) discussed actions NRC plans to take "so that nuclear regulation can work to the net benefit of the nation". Net benefits, of course, are understood to mean the summation of gross benefits of whatever kinds minus the summation of costs (both economic costs as well as adverse societal effects whose values are basically independent of market place transactions). In the case of nuclear power, an important element of cost that threatens its public acceptance is that of the associated risks to health and safety and how these are perceived by the public. Accordingly, perception research or public opinion surveys tend to focus on various kinds of risk attributes with relatively scant attention to the various kinds of benefits that prospectively would accrue to society.(18,19) Somewhat greater attention was given to benefit perception in a psychometric study of attitudes toward technological risks and benefits by Fischhoff, Slovic and Lichtenstein,(20) but even here the scope and definition of benefit attributes left much to be desired.(8)

Indeed, the neglect of a sound interdisciplinary approach to assessing benefits along with risks is rather widespread. Table 2 summarizes the presence or absence of risk-cost-benefit considerations in seven institutional studies on nuclear power and alternative energy sources in a review by Sponsler.(21) While all seven studies provided cost comparisons of energy alternatives, only two compared benefits. One of the justifications sometimes used for the neglect of benefits in the comparison of nuclear power with alternative sources of

Table 2. -- Summary of Selected Review Aspects Related to Risk Assessment and Safety Goal Formulation as Found in Seven Institutional Studies on Nuclear Power and Alternative Sources of Energy

REVIEW ASPECT ↓ / STUDY REVIEWED (Short Title) →	1. Nuclear Moratorium (IEA/ORAU)	2. Issues & Choices (MITRE)	3. The Next 20 Years (RfF)	4. America's Future (RfF)	5. Energy in Transition (NRC/NAS)	6. Energy Future (Harvard)	7. Jobs & Energy (CEP)
1. Risk† Definition							
a. Explicit	--	--	--	--	X	--	--
b. Implicit	X	X	X	X	--	X	X
2. Fuel Cycle Coverage							
a. All elements	X	X	--	--	X	--	--
b. Power generation	X	X	X	X	X	X	--
c. Some other elements	--	--	X	X	--	X	X
3. Risk Assessments							
a. Nuclear	QN	QN	QL	QL	QN	QL	QL
b. Coal	QN	QN	QL	QL	QN	QL	QL
c. Other fossil	QN	--	QL	QL	QN	QL	--
d. Solar, hydro & other	QL	--	--	QL	QL	QL	QL
4. Risk Assessment Methodology							
a. Mathematical models	X	--	X	--	X	--	--
b. Judgmental assessments							
(i) by explicit rationale	X	X	X	X	X	X	--
(ii) by assertion	--	X	--	--	--	X	X
5. Safety Goal Treatment							
a. Explicit goals and forms*	X	--	--	--	X	--	--
b. Only indirect information	--	X	X	X	--	X	--
6. Goal Formulation Criteria**							
a. Direct information	X	--	--	X	X	--	--
b. Indirect information							
(i) Safety improvement possibilities	--	X	--	--	X	--	--
(ii) Social acceptance issues	X	X	X	X	X	X	--
(iii) Other	X	X	X	X	X	X	--
7. Risk-Cost-Benefit Considerations†† in Comparing Energy Options							
a. Risk comparisons	X	X	--	X	X	--	--
b. Cost comparisons	X	X	X	X	X	X	X
c. Benefit comparisons	--	--	--	--	X	--	X
d. Tradeoff considerations							
(i) Risk-cost tradeoffs	--	--	X	--	X	X	--
(ii) Risk-cost-benefit tradeoffs	--	--	--	X	X	--	--

†The treatment of "risk" may include social, economic and other environmental values at risk as well as safety and health effects.

††Costs and benefits include more than dollar impacts; regarding societal interests, costs are any adverse impacts and benefits are any desirable impacts.

*With attention to goal forms proposed by Mattson et al. (22)

**With attention to decision criteria for evaluating alternative goal formulations proposed by Mattson et al. (op. cit., pp. 5-10).

LEGEND:

X Denotes information present for the review aspect.

-- Denotes information absent or insubstantial for the review aspect.

QN Quantitative risk assessment.

QL Qualitative risk assessment.

NOTE: When many risk assessments were made, the authors generally used both quantitative and qualitative modes; accordingly, the tabular notations, QN or QL, denote the reviewer's impression of the more dominant mode.

energy for generating electricity is that in their view the principal benefit of the competing technologies is the quantity of kilowatt-hours of electricity generated. Since power plants can be built to provide equal outputs of electricity, then the benefits are, following this logic, the same regardless of fuel source. Still another simplistic view is that the primary benefit of nuclear energy is its potentially lower costs, and hence, lower consumer rates. In several Harris polls, by hypothecating the cost advantage of nuclear power over other types of power to range from -20% to +50%, the overall swing of positive response in the general public was +60% (i.e., from a low of 24% acceptance with a 20% negative cost comparison to 84% acceptance with a 50% cost advantage).(19)

Another benefit sometimes used in comparing energy options is the number of jobs related to the technology.(23) While job creation has obvious attractions for the local economies thus benefitting, the net job creation in the national economy could be either negative or positive, since jobs created by the favored technology may be more or less offset by the job losses in the displaced technologies. Other indirect impacts of employment must also be considered due to related effects occasioned by subsidies, productivity gains or losses, etc. It should be noted that a large number of jobs associated with a prospective technology may price it out of viable competition and that a major contributing factor to the productive and competitive strengths of the American economy historically has been the introduction of labor-saving innovations.

Thus, if psychometric or other public opinion surveys are to achieve a better balance in the examination of attitudes and values regarding the full gamut of risks and net benefits of technological options, it is clear that we need a truly interdisciplinary approach which defines the full scope of potential benefits. This approach must also take into account equity considerations including the conflicts between net benefits at the individual or special interest group level and the net benefits for our nation.[8]

According to Ricci and Molton,(24) judicial reviews by the higher courts regarding the balanced treatment of benefits and risks in regulatory decisions have been quite varied; but whether the mandate of Congress in the governing laws is carefully observed by the agency is the key criterion of the courts. In both the cases of the NEPA and the Energy Reorganization Act of 1974, as amended, that govern the responsibilities of the NRC, a wide scope of benefits is required to be examined. The kinds of benefits the Congress had in mind in passing the latter act are found in Sec. 2(a) under "Declaration of Purpose":

"The Congress hereby declares that the general welfare and the common defense and security require effective action to develop,

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[8]This focus on national level effects does not imply a neglect of effects of technologies on other nations, since the benefits of international cooperation, the quality of foreign relations, etc. may be regarded as integral to our national interests. The acid rain problem and the nuclear proliferation problem are cases in point.

and increase the efficiency and reliability of use of, all energy sources to meet the needs of present and future generations, to increase the productivity of the national economy and strengthen its position in regard to international trade, to make the Nation self-sufficient in energy, to advance the goals of restoring, protecting, and enhancing environmental quality, and to assure public health and safety.

These benefits, although wide-ranging in scope, require more definitive interpretation and analysis. A composite list of potential net benefits to the nation from the nuclear power option would include:

(1) The expected net saving of lives as well as possible disease reduction from the use of nuclear as opposed to alternative viable energy sources for generating electricity.

(2) The expected net saving of substantial consumer costs of electricity for present and future generations. This is principally due to nuclear fuel costs projected to remain lower than coal fuel costs as well as an enhanced nuclear-coal fuel mix relieving inflationary pressures on coal prices versus the closing out of the nuclear growth option.

(3) The saving of coal resources for possibly more valuable uses of future generations (and perhaps in our own lifetimes) such as liquid fuel conversion, syngas manufacture, or as substitutes for petrochemicals in the manufacture of plastics, fertilizers, etc.

(4) Increased national security and fuel reliability by a reduced dependency on oil for the generation of electricity or the encouragement of electricity uses in place of oil consumption for space heating through the possibly induced lower electricity costs of the nuclear option. (A shared benefit with the use of coal.)

(5) Reduced risk of acid rain and greenhouse effects on property values and income losses versus the possibly lesser increased risk of property value and income losses attaining to the nuclear option.

(6) The possible net reduction of future anxiety (or psychic) costs over limits to growth and other energy-related fears during the period of transition from dependency on depletable energy resources to renewable or ubiquitous energy resources.(8)

Several observations are in order concerning the above formulation of potential net benefits from nuclear power. First of all, what is a cost assessment in an absolute sense (e.g., risk to lives, dollar costs of electricity, etc.) is converted to a net benefit for a technological option if these costs in a comparative mode are less than for optional technologies. For example, regarding item (2) above, if the projected total generating costs using nuclear energy in the Midwest for two 1200 MWe units is correct at $10.6 billion for operation from 1990-2020 versus a projected $13.4 billion for coal-fired units of equivalent electrical output, then the net benefit of these nuclear units to the consumers of the region (and hence, to the nation) is \$2.8 billion.(25) For different regions of the United States the projected net benefits of this kind for the nuclear option are greater or lesser since the cost of coal transportation enters significantly into these projections.

Regarding net safety benefits (see item 1), Table 3 reveals that the mean estimated excess mortality per year for a 1000 MWe nuclear plant is either 1.0 or 2.9 depending on scenario assumptions. For a 30-year operating life this means that 30 to 87 excess deaths will result for a nuclear plant versus 1260 deaths (30 x 42) for an equivalent coal-fired plant.(25) If these estimates are correct, then a net benefit of 1173 to 1230 lives per nuclear plant will have been saved.[9] For 100 nuclear plants the estimated saving of lives would be around 120,000. The estimated mean excess deaths to the general public downwind from coal-fired electric generating facility (due to air pollution) is 17.3 deaths per year per 1000 MWe plant, or over six times greater than the estimated rate of 2.8 deaths per year from occupational accidents and disease associated with the mining of coal to supply such a unit.(25) These estimates contradict the popular belief that the major source of total loss of life from the use of coal to generate electricity is the occupational deaths of coal mining (a voluntary activity) rather than the (involuntary) risks to the general public from air pollution effects of coal combustion.

One of the difficulties in determining the net benefits from the use of nuclear power versus alternatives is the sizeable range of uncertainty surrounding their estimates. Indeed, most of the above items should involve forecasts of future effects since risk-reducing modifications of energy technologies and regulatory practices are likely to occur. Moreover, there are numerous causal factors, difficult of prediction, that will determine the future relative costs of generating electricity from nuclear or alternative fuels such as coal. Nevertheless, the above list of potential net benefits may provide useful starting points for the interdisciplinary analyses of the comparative risks, costs, and benefits of nuclear and alternative energy sources.

It is regrettable that limitations of space do not permit a fuller discussion in this article of the various attributes of net benefits so often neglected by analysts of energy options and public opinion researchers. It is clear that a large and possibly growing segment of the public see the major ethical issue involved in nuclear power regulation as that of licensing <u>life-taking</u> technologies. However, in a comparative analysis of nuclear power and the most probable alternative (i.e., coal-fired electricity generation), there is reason to believe that nuclear technology may actually produce the (moral) benefits of a <u>life-saving</u> technology. In my view, the real ethical issues involve (1) eliminating possible bias and reducing the range of uncertainty for the excess mortality estimates registered in Table 3 for the coal and nuclear options, and (2) determining and implementing cost-effective mitigation technologies to improve the safety performance of both nuclear and coal technologies where practicable in the best interests of society.

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[9]For a discussion of the considerations and uncertainties entering into estimates for nuclear risk, see Ref. (27).

The "best interests" of society regarding decisions on mitigative options of improved safety require the careful analysis of safety-cost tradeoff considerations as recommended by the President's Commission on the Accident at Three Mile Island.(28) For it is clear that the aggregative cost effects of a numerous sub-set of risk mitigation measures could reduce the net economic savings to society of the nuclear option without possibly justifiable compensatory gains in the aggregate net benefits of nuclear risk reduction. Indeed, if because of such cost escalations in nuclear technology the public and investors perceive the net economic benefits discussed above to have largely disappeared, then both the political and economic viability of the nuclear option will also have disappeared. Moreover, it goes without saying, that whatever the potential life-saving net benefits of nuclear technology might be (before or after further safety mitigative decisions are made), these too will have been lost to society by the closing out of the nuclear option. These ethical issues cut across the conventional wisdom of a number of disciplines already encompassed by the membership of the Society for Risk Analysis. The challenge before us -- and others who join our efforts -- is to seek the potential contributions of truly interdisciplinary analysis in bridging the gap between the technical and human sides of risk-cost-benefit assessment in a comparative mode of viewing decision options.

Table 3. - Summary of current energy source excess mortality per year per 0.8 GWy(e)

Fuel cycle	Occupational		General public		Total
	Accident	Disease	Accident	Disease	
Nuclear (U.S. population)					
All nuclear	0.22[a]	0.14[b]	0.05[c]	0.18-1.3[b]	0.59-1.7(1.0)[d]
With 100% of electricity used in the fuel cycle produced by coal power	0.24-0.25[a,e]	0.14-0.46[b,a]	0.10[c,g]	0.77-6.3[h]	1.2-6.8(2.9)
Coal (regional population)	0.35-0.65[e]	0-7[f]	1.2[g]	13-110[h]	15-120(42)
Ratio of coal to nuclear (range): (geometric means)	42 (all nuclear) 14 (with coal power)[i]				

Source: U.S. Nuclear Regulatory Commission (Ref. 26).

[a]Primarily fatal nonradiological accidents, such as falls or explosions.
[b]Primarily fatal radiogenic cancers and leukemias from normal operations at mines, mills, power plants, and reprocessing plants.
[c]Primarily fatal transportation accidents (Table S-4, 10 CFR Part 51) and serious nuclear accidents.
[d]Values in parentheses are the geometric means of the ranges ($\sqrt{ab}$).
[e]Primarily fatal mining accidents, such as cave-ins, fires, and explosions.
[f]Primarily coal workers pneumoconiosis (CWP) and related respiratory diseases leading to respiratory failure.
[g]Primarily members of the general public killed at rail crossings by coal trains.
[h]Primarily respiratory failure among the sick and elderly from combustion products from power plants, but includes deaths from waste-coal bank fires.
[i]With 100% of all electricity consumed by the nuclear fuel cycle produced by coal power; amounts to 45 MWe per 0.8 GWy(e).

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