VALUES AND RISKS

A Research Proposal for IIASA

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FOREWORD

The issue of risk has been a focus of attention in the last few years, in particular in fields where new technologies were introduced, with great promises of reward but also involving hazards that society has sometimes shown some reluctance to accept. Policy-making in the public sector, for those domains where risks have to be balanced with economic costs or benefits, implicitly or explicitly involves a system of values.

IIASA has been concerned with and involved with these problems for some time. A substantial amount of work was done in the Energy Program in conjunction with IAEA. The Management and Technology Area has been involved in these studies, and is currently engaged on a major project concerning the management of high-risk technological situations (oil blow-outs, nuclear reactors, LNG plants). The S.D.S. area is concerned with methodological aspects, and every Area and program is tackling problems of a risk-like structure. Accordingly, serious consideration is being given to the possibility of expanding and coordinating these interests to form an IIASA program.

This paper therefore represents a stage in the process of developing such a program. It has been prepared by Professor

Marie-Elisabeth Paté, a visiting scholar to IIASA, jointly within the MMT and SDS Areas. It is a proposal for a large IIASA study aimed at exploring the relation between values and risks; comparing risks and policies in different sectors, looking into the problems of risk valuation and eventually comparing different solutions of risk management, those are the goals of this proposal. In this paper the issues that could be addressed in the IIASA framework are identified and research directions suggested.

At the time of preparing this Foreword the formulation process has gone a stage further with the preparation of a further document, (incorporating much of Professor Pate's ideas), for consideration by the IIASA Council.

ACKNOWLEDGEMENTS

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Special thanks are due to Rolfe Tomlinson who introduced the author to IIASA in the Management and Technology Area.

This paper does not include a list of references. It was not feasible in the available time and is left for the preparation of a more complete document.

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PRINCIPLES

The following program, proposed for IIASA on the issues of "Values and Risk" relies on a few principles that I would like to clarify first.

1. Risk

What is understood here by "risk" is a characterization of the effects of a hazard, both in terms of possibility of occurrence--probabilistic description if feasible--and magnitude of the consequences of a dangerous event.

2. Risk Analysis

Risk analysis is a tool for policy analysis, that is a decision tool for public measures, such as regulation, licensing, investment in research. It can possibly be a design tool for those systems whose reliability is essential, whatever their nature, and whose complexity does not allow intuitive perception of their critical features. It involves, anyhow, comparison of alternatives.

3. Value of Information

Risk analysis should not be used to justify a decision already made. The public has shown skepticism with respect to risk analysis results and in some cases, rightly so. Obvious biases and unstated assumptions have helped neither the different fields of application nor the credibility of the tool itself. They only alter the value of information that risk analysis provides. If one wants to make risk analysis results credible in the future, and risk analysis usable at all, that credibility has to be assured. The first thing is thus to set goals and standards for risk analysis itself. Separating analysis and value judgment,

clearly stating risk comparability criteria and integrating conflicting expert opinions represents the first step. This, of course, means understanding public opinion rather than trying to manipulate it. In the long term, it is the only valid--and the least naive--course of action. From any ethical and even strategic point of view, it is the only justifiable one.

4. Standard Setting in Uncertainty

A clear and coherent policy of the state as regards risk management would be quite beneficial for the economic sectors involved. But overconfidence in risk estimates can lead to dubious results. Public policy should be flexible enough to allow protection of the people in the frequent cases where later experience provides additional information for risk assessment. One of the goals here is thus to explore what sort of coherence is desirable among the standards set in the different sectors. This would avoid interminable and costly delays. But at the same time, it is essential to be aware of the limits of knowledge and to allow for updating and decisions.

5. Risk Management and Institutions

The study of the institutional framework of risk management is important: the results should lead to implementable policies. But no risk evaluation, acceptance or regulation should be irrevocably bound to existing institutions. The results of a risk analysis should indeed allow determination of whether or not a modification of that framework might be desirable, provided all its other implications are considered.

6. The Nuclear Experience

The risk issues in the nuclear field are loaded with so many political passions that it seems vital, at the beginning of such a program, to back away from it, without forgetting the lessons provided by such studies as WASH 1400. The nuclear problem represents only one aspect of the societal risk with its own specificities and difficulties.

7. War as a Potential Outcome or as an External Factor

The most dreadful risk that modern society faces is war. Yet, it is often ignored--as too painful to face--in risk assessments, that is, as a possible outcome of some decisions, or as an external factor capable of worsening an existing risk. The issue cannot and should not be ignored, in particular in the international setting of IIASA.

8. Research Direction

A choice has to be made in the general direction of research between three alternatives:

-- studying first the general framework of risk analysis and comparability of risk, then examining the specific problems of various fields of application;

-- or the reverse, that is conducting first several practical studies in specific fields of research, then observing and guiding the emergence of a general methodology;

-- conducting and coordinating at the same time methodological studies and application to specific fields.

I recommend the third solution for the following reason: a framework of analysis, coherent across the different fields of application, has to be developed to allow comparison of results and policies. But methodological problems are easier to grasp on concrete examples. Coordination will thus be the key point, to make sure that everyone benefits from the different methodologies used by each group. But it should be kept in mind that one of the most critical problems posed by risk analysis is the use that can be made of its results. After an in-depth literature survey, and while studying the particularities of specific risks, I think that it is essential to examine the different forms that can be given to the results, their comparability, and the implication of using different criteria for the assessment of public policies. In particular, it is important to make explicit the values that are at stake in the acceptance of policies involving risk. Those values determine the limits of decision power between the state and the citizen (e.g., individual freedom, social justice and equity) and the resolution of conflicts of objectives between different groups and individuals. There is a political component in the risk management question; it has to be faced at that early stage.

BACKGROUND

1. The Risk Issue

The issue of risk, in particular the risk attached to a new technology, has received increased attention in the last twenty years. There are different reasons for that. Some are attached to the reality of new scale of man-made hazards--power of technological means, complexity of the systems that they affect, large scale of the effects. Some are attached to the growing wealth of some regions of the world and the fact that means of mitigation have been technically developed and become economically accessible --one can "afford" to invest in protection against earthquakes. Some are attached to the perception of the risk: the mass media have made the information about accidents and catastrophes accessible. Some have little to do with risk itself, but the issue of risk becomes a point of crystallization of a deeper disenchantment with respect to technical progress vs. quality of life.

In any case, real or perceived, the question of risk cannot be regarded as a mere fantasy of the public opinion. There is a need for risk mitigation measures, and a need for coherence among those measures.

2. Risk Analysis and Decision Analysis

The border line is very thin between the two disciplines

The results of risk analysis can be considered as a piece of information to be provided to the decision-maker or to the public and introduced into the institutional channel, "free" of value judgment; or the results of risk analysis may include those value judgments and lead to more complete recommendations regarding the decision.

The decision analysis methodology as developed, in particular in the U.S., relies on four phases of study:

-- A deterministic phase, which involves structuration of the problem, deep study of causalities and identification of alternatives;

-- A probabilistic phase, which involves encoding the probabilities of critical variables and deriving the probabilities of the possible outcomes;

-- An information phase, which may lead to the decision to gather more information; and

-- A valuation process in which the decision-maker's risk attitude and value system are made explicit, in order to evaluate the consequences of each outcome.

There are roughly two schools of thought as far as the valuation question is concerned--both within the framework of utility theory: the "single attribute" method (Howard), where a single objective function is designed, thus assuming a uniform risk attitude for all the attributes, and the "multi attribute" method (Raiffa, Keeney), that keeps the different elements of the outcomes separate--e.g., time vs. money--and defines the valuation function over the set of those attributes.

That decision analysis method is more particularly suited for single decision problems. It does not explicitly involve a phase of risk management per se, and for instance, the dynamic aspect of sequential or corrected decisions.

The Eastern European approach relates rather to the techniques of cooperative games and to control theory, as regards in particular the problems of dynamic implementation, with possible modification of goals as new experience and information are gathered.

When the decision belongs to a single person, utility functions can be constructed that reflect the individuals preferences and the single decision problem is solved. When it comes to public decisions the valuation question relies on a basic set of political, ethical and philosophical principles and also on the way the institutions are designed to deal with collective decisions. It is the whole question of risk management in the proposed study.

Including risk in a decision of the public sector thus involves at least three elements:

-- risk assessment, that includes a deterministic and a probabilistic analysis of the question;

-- risk evaluation, that involves the introduction of value judgments, risk attitude, political principles,

tradeoffs among the different attributes of the decision and conflicting policy goals, and

-- risk management, which means the choice and the implementation of public policies or strategies that appear most suitable to deal with the issue (regulation, incentives, ... etc.).

The main difference that could be emphasized between the two methods--risk analysis and decision analysis--is that decision analysis is better designed for a specific decision and an identified decision-maker--e.g., the decision to build a plant at a given site. In contrast, risk analysis gives one of the elements of a much broader policy problem. The question there is to set general goals, principles and shapes of institutions, to include and balance the various risks involved, and possibly modify the initial goals and institutions in the light of the results of the analysis. Risk analysis should allow comparison of alternatives but does not require a priori that all alternative courses of action be identified.

3. Risk and decision analysis as described above are powerful tools, but leave essential questions unresolved as regards policy-making in the public sector. Those questions pertain to the analysis of specific risks as well as the general methodology, some of those are mentioned below.

One problem to be addressed is that of the uncertainty that analysis cannot grasp, unknown outcomes and probabilities of occurrence. It becomes a question of risk valuation, of risk management and of adaptability of the institutions to allow for flexibility and robustness of proposed solutions.

Another question is that of aggregating individual preferences into a collective decision process, in particular when such critical attributes as lives vs. money are at stake. The way by which those preferences are revealed and actually aggregated depends essentially on the institutions. Whether or not, eventually, basic values such as individual freedom or social justice are respected in acceptance, sharing or regulation of the risks, depends on the quality and flexibility of those institutions. It seems important to compare the risk management results currently obtained in very different public sectors, and to check them against the philosophical "norms" that seem, in principle, desirable. Such a test of the institutional framework is proposed below for some particular cases.

Other problems more specific to each field of application, arise in the use of the methodology itself. An understanding of causalities and basic mechanisms is essential to the method. Probabilities are difficult to handle in many cases and the choice of stochastic models critical. Anyhow, as is always the case with analytical tools, the results are only as good as the data, the choice of models and the understanding of the relative importance of the underlying mechanisms.

4. There is a serious question of risk management, regulation, standard setting and consistency among standards,

that is critical to good allocation of public resources. Normative models have been proposed for the optimization of that allocation under uncertainty. But the eventual trade-offs between such attributes as economics, human safety or quality of the environment, depend not only on the basic social values and individual preferences but also on the institutional framework of the decision process. There is thus always a political factor in the risk management question. How risk analysis can be used in that framework and in the light of each value system remains an important issue. Comparing risks across different sectors is unavoidable and coherence of policies is desirable. The standards for comparison remain to be defined.

5. Current Use of Probabilistic Methods for Risk Management

Statistical and probabilistic methods have been increasingly used in the last twenty years and gradually introduced in many fields of knowledge--in particular with the objective of risk assessment and decision-making under uncertainty. It would be impossible to cover the whole spectrum of those applications. But there has been much work done in that direction, in a very uneven fashion across the disciplines. There would be great benefit for each field of application in comparing, as far as risk analysis is concerned, the state of the art, the difficulties met and the experience already gathered in other domains.

A few examples can be given:

-- In economics, much work has been done concerning the financial risk in the public sector, (Arrow, Debreu et al.,), or to the value of life and human safety (Zeckhauser, Linnerooth, Arthur).

-- In engineering, probabilistic methods have developed rapidly: in electrical engineering (reliability of computer systems), in aeronautics and astronautics (risk assessment for the Apollo project), in nuclear engineering (risk assessment for nuclear reactors, Rasmussen), in chemical engineering (risk assessment for the transportation of liquefied natural gas, Elisabeth Drake), in civil engineering (probabilistic basis for setting building codes, earthquakes engineering based on seismic risk analysis, Cornell).

-- In the field of medicine and biology, statistical methods have been used for a long time to test hypotheses. It is only recently that risk analysis and decision analysis have been used (e.g., screening procedure for early cancer detection).

The tools that are classically used to structure a risk problem (decision trees, event trees, fault trees, stochastic programming) are efficient but often rely on numerous assumptions, for example, of independence of random variables. One of the major problems in using such structures, is that it is often impossible to identify all courses of events. It is left to the experts judgment to identify the most significant of those sequences. Again, the results are only as good as that

judgment. There often remains some uncertainty and it should be taken into account in the course of risk management and policy design.

Many other examples could be added to those above. The use of probabilistic methods, however, has encountered a lot of resistance. Frequentistic and bayesian approaches are often opposed. Incorporating experts judgments in a decision process, using a small data set, sometimes involve difficult technical questions. Probabilistic methods are a challenge to the cartesian mind, they are sensitive to biases, but they provide an irreplaceable piece of information: risk as can be assessed. Difficulties arise when the old notion of "safety" has to be expressed in terms of an "acceptable" risk. Implicitly or explicitly such acceptance exists; how to use the notion of residual risks in the current frameworks of policy making relies on the value problems mentioned above. It is the subject of the proposed study.

SCOPE OF THE STUDY

Goal of the Study

The goal of the proposed study is to allow incorporation of risks in a global framework of policy analysis. This requires establishing a basis for comparing risks across different sectors and setting coherent standards that satisfy basic philosophical principles.

The question is to know to what extent risk analysis techniques can be used, broadened and improved to reach that goal; how a value system can be incorporated in the institutional process; and finally, what are the risk management solutions that would satisfy that value system for the different types of risk.

The Approach

The chosen approach is to conduct at the same time applied and theoretical research. Seven case studies are proposed: they concern risks in very different areas--e.g., natural catastrophes and drug marketing--and of very different characteristics--e.g., "ill defined" technological risks with long term effects. vs. large scale consequences of a sudden catastrophe.

For each of them, methodological problems will be identified, policy issues will be raised and the framework of risk analysis will be adapted to specific characteristics.

The idea is to choose case studies that represent a good cross section of the different types of risks, so that the problem of inter-sectorial comparison can be addressed in a broad and meaningful way. The choice is also guided by IIASA experience and interests.

The proposed cases are the following:

-- in agriculture: the risk of drought;

-- in climatology: risk of climatic change from accumulation of CO_2 (the greenhouse effect);

-- in civil engineering: the question of safety of dams and the risk of dam failure;

-- natural catastrophes: the risk of floods;

-- energy questions and chemical industry:

  (1) the risk of nuclear accident

  (2) the risk of transportation of hazardous chemicals, specifically transportation of liquefied natural gas;

-- in the medical field: risk of marketing new drugs.

The methodological problems met in each of those cases should be addressed by a group of theoreticians and feed-back should be provided to all groups of applied studies. Each group could then benefit from the experience and the progress of the other research areas.

At the same time general methodology questions should be addressed by a group of specialists of decision sciences:

-- the valuation problem which concerns the risk attitude and value system of a group of individuals facing a decision with multiple objectives and attributes (for example, questions of human lives), including the possible variations in time of preferences, goals and objectives.

-- the question of risk management and policy design where different risks are integrated and balanced against economic factors, and where different kinds of public policies can be adopted at different times according, for example, to the state of knowledge.

Those two aspects of the risk issue--valuation and management--are closely related and concern all fields of application. The question of comparability of risks, values and public policy can thus be addressed in a much broader perspective than if methodological research were kept at a theoretical level.

Communications between the groups and organization of the research team are key points in the success of this approach. The interest of the proposed program would be greatly diminished if each group worked independently from the others.

Articulation

After a common literature survey and a preliminary agreement on basic methodologies, the seven cases should be studied simultaneously by different applied research groups. Each problem should be structured in a risk analysis framework by a collaboration of specialists of risk analysis and probabilistic methods and experts of each field of application.

Meanwhile general methodological studies on risk valuation and management should be carried out. Each case study should

cast a new light on the meaning of different risk indicators, for example. The theoretical team should, in turn, benefit from the experience of the applied research groups.

In a second phase, the methodological problems met in each field of application could become the point of focus and be studied in depth from a theoretical point of view. The question of human error for example could be approached from a statistical and probabilistic point of view, in different work environments, under different psychological conditions; the the question of how human error intervenes in each type of risk would be addressed for the case studies (wrong choice of crops based on ten wet years in a dry country for instance, as well as pilot error for the LNG vessel).

The proposed organization thus has the structure of a matrix, based on fields of application and methodological problems. That structure is developed below after examination of the problems specific to each domain of application.

TASKS

The tasks, as proposed here, are possibly smaller than traditional IIASA tasks. They have been divided among different types of risks and can be grouped into broader domains of interest if it is desirable.

Literature Survey and Critical Evaluation of Traditional Risk Research

The first task is to examine the classical frameworks of risk analysis (including the "non-quantitative" ones); then to agree on a starting point of risk methodology, to be used to begin the study of the proposed cases and to be improved in the light of the results. This implies, at least temporarily, an agreement about the adoption of a numerical and probabilistic method of risk assessment providing comparable results, to the extent that it is feasible, in the different fields of application. This task is preliminary to the case studies and does not require at that stage an effort of risk valuation.

The following tasks can (and should) be undertaken simultaneously. What is suggested here are directions of investigation. The framework of research is set up to allow for final intersectorial comparison of risks (methodologies and results). But these tasks will have to be more completely defined by the work teams, according to their interests, priorities and previous experience. There is probably more suggested here than can be done by a relatively limited group. The following directions are to be completed by specialists of the fields of application.

Tasks 2 to 8 will include structuration and risk assessment for each case study and suggest valuation and management issues to be addressed in a global way in tasks 9 and 10.

Climatic Issues: The Risk of Drought

The structuration of the problem in the form of a risk analysis study requires first an identification of causalities between several factors: climatic variations, human settlements and migrations in different regions of the globe, choice of crops given previous climatic experience, quality of the soil and economic needs. Methods of statistical inference could be used and expanded in that domain.

The next question is the assessment of the consequences of droughts of different duration and severity, which includes economic implications, health effects--and possibly famines--human displacement and environmental effects. The dynamics of spreading of aridity can also be considered at that stage.

The probabilistic approach to the question of drought relies on the frequencies observed in the past, but also on more general climatic and ecological causalities. Questions of dependences and system memory can be addressed there.

For a given region, with a given population, climate, agriculture and more generally economic structure, one could then assess probabilities of annual losses. How could the results of risk analysis help to define policies is then the major question: choice of crops, water resources management, incentives (or not) to human settlement, for example. The policy choice depends on possibilities of trade in case of drought and on the general structure of the society and the economy.

What are the relevant risk indicators, and how they relate to various policies would be interesting to explore.

IIASA Reference: Memo of Professor Vasiliev of the IIASA Task on Climate and Society. The risk of drought issue would be a good opportunity for interaction between two IIASA major projects with different methodologies.

Climatic Issues: Risk Due to the Accumulation of CO_2 in the Atmosphere and Greenhouse Effects

This is typically an "ill defined" problem where the kind of structuration that risk analysis calls for can be of great help. Difficult as they are to obtain, probabilities, even when spread over a wide range, could bring here an information of great value: if policies are to be implemented, they will require an extraordinary international cooperation. Whereas that cooperation can perhaps be achieved if probabilities and scale of losses are shown to be important, it is doubtful that anything will be done if the risk is felt to be low or if the risk assessment remains at a purely descriptive level.

Identification of the causes of the greenhouse effect seems the only way to implement fundamental policies--rather than policies dealing with the effects. Understanding of consequences of the greenhouse effect will allow one to obtain an order of magnitude of losses that can be expected. The risk then can be

divided among several lines according to the type of consequences. One example will be the risk of a break of the ice of the antarctic sheet followed by a significant rise of the sea level.

Causalities, probabilities both of time factor (when could it occur) and of the scale of the phenomenon, evaluation of social and economic consequences, are critical to the adoption of a policy. It is the sort of long term, ill-perceived, low probability, very high consequence risk, for which the relation between risk assessment, valuation and management has to be approached at an international level, that is the most complex and puzzling one.

IIASA Reference: IIASA proposed task on Climate and Society. It seems important to add the policy issue to the scope of that study; it will help identify the critical variables which have to be examined in priority. It is a typical case where the inter-relation between policy analysis and risk analysis is the most fruitful and the least obvious. It is also a case where the time factor seems critical.

Civil Engineering: Safety of Dams

This is the case of a man-made low probability, high consequence risk, for which the policies available are essentially to build or not to build a dam at a given design level. But in a broad risk analysis, the decision to build a dam cannot be isolated from expected benefits and potential alternatives (in particular as far as energy production is concerned). The current method, in the US for example, is to use cost-benefit analysis for the acceptance of a dam construction project.

The introduction of risk in such decisions can be done in a crude way by adding expected losses to the costs and by balancing risks and benefits obtained in that way. This in turn raises the following question: what better criterion, what risk calculation should be used for such a decision?

Another critical issue is how to assess the probability of failure of a given dam. This is a basic methodological question: one can approach the problem from a frequentist point of view and observe past failures in different categories of dams; or one can try to consider each individual case of dam and aim at a probabilistic analysis of the basic mechanisms of dam failure--over-topping, foundation and geological problems, earthquakes including induced seismicity, piping, etc.

For the hydrological part of the phenomenon, probabilities are relatively easy to obtain: the precipitations are relatively known. The issue becomes the following: for what flood frequency should a dam be designed. For the geotechnical and structural causes of failure, the basic mechanisms themselves remain to be explored. This raises basic questions of risk management: what to do and what policy to adopt before acquisition of knowledge that will take a long time to gather.

Another question that can be addressed here, and extended to other types of structures, is the comparison of the

traditional methods--use of safety factors--and of probabilistic methods--use of risk based design parameters. There is an effort in the US to harmonize the safety coefficients of building codes, for example, on the basis of probabilities of different failure modes. This, on one hand, finally brings the problem to the puzzling "acceptable risk" concept. The method, on the other hand, allows better allocation of resources for the strengthening of a structure by decreasing the probability of occurrence of dominant failure modes.

In the light of that case, one can raise another question: how appropriate are the methods of risk analysis as a design tool, to the extent that they reveal the "weak points" of a system, as opposed to a regulation tool providing a global probability of failure. A similar problem is met in the nuclear field.

IIASA Reference: Professor Vasiliev, Dynamics of the wave in case of dam failure; risk and safety factor. Elisabeth Paté, Introducing the risk in the cost-benefit analysis of dam projects.

Natural Catastrophes: Floods

The risk assessment of floods--probability of floods and evaluation of the losses--is not theoretically extremely complex. The most interesting questions there are those of causalities and risk management. What attracts human settlements in flood plains, is it more desirable to build flood control structures or to discourage the development of those plains, raise all sorts of policy problems that could be investigated. What would be the effects of regulations, of economic incentives such as disaster relief, of the mechanisms of insurance market, those are basic issues. The risk is either left to the individual, or shared through insurance or supported by all tax payers.

The problem takes another scale in developing populated areas where the possibilities of policies are much more limited and where enormous resources would have to be mobilized for flood control. Also, floods may be one of the causes of fertility of the earth. The effects of floods on the ecosystem and on the social structure have to be investigated before a balance is found between risks, costs and benefits of flood control, according to a social value system.

Another aspect of flood effects mitigation is flood warnings and alerts. What are the effects of flood warnings, how can they be improved, those are questions of crisis management. They can be extended to other sorts of warnings, against natural catastrophes--hurricanes, potentially earthquakes--or technical accidents such as failure of a dam or failure of a nuclear reactor.

Energy: Risk Associated with the Use of Nuclear Power for Electrical Energy Production.

In order to make meaningful comparisons of risks, it is appropriate to consider the whole of the nuclear fuel cycle--nuclear fuel extraction, enrichment, transportation, storage,

processing in reactors, storage and disposal of wastes--and to base future risk research on a better understanding of public reaction to nuclear energy.

First, two lessons should be drawn:

-- the lesson of WASH 1400 and of the critiques of it that were provided, for example, by the Lewis Committee Report. Such reports can be constructively used in the whole field of risk analysis;

-- the lesson of the Harrisburg event, where a conjunction of technical failures, human error and crisis management problems could have led to a catastrophe.

Some major directions that could be taken in nuclear risk analysis research are the following:

-- a deeper study along the line of WASH 1400 that would for example include accidents that have been assumed to be negligible, therefore would allow better identification of weak points of the system. This is what is currently undertaken in West Germany by the group of Professor Birkhofer;

-- a risk study of nuclear wastes disposal, which is one of the most unknown of the aspects of nuclear risks;

-- a study of perception and public reactions to nuclear risk; an investigation about the criteria of credibility of nuclear risk studies and of studies aimed at comparing nuclear risks with the risks associated with other sources of production of energy (example: the Inhaber report).

The first two of those are large problems that would require more important teams than IIASA can gather. It is thus proposed to leave aside structural reliability and wastes issues and focus on a few important unknowns.

The first one is human error.

The question can be addressed in the following way: What are the work environments, the psychological and knowledge conditions that weaken human attention, what can be expected of human attention at its best, and what solutions can be envisioned to decrease the probability and the consequences of human error --technical redundancies, training, alert systems, etc. This would require exploration of the human error problem beyond the limited experience of the nuclear field and gathering of data on the question. A related question is how to design systems that are less susceptible to human error.

A second study, in a different perspective relates to public acceptance (or rejection) of nuclear power. The following questions could be examined: what are the criteria of credibility of nuclear risk studies and the meaning of the figures that they provide? how are the benefits of nuclear power perceived--as opposed to the benefits provided by other energy sources--what is the vulnerability of such a centralized production system to wars and sabotage? what are the effects on the

confidence of the public of the de facto polarization of opinions among "pro" and "anti" nuclear groups and how could the environmentalists' concern to be introduced in a constructive way in the decision (regulatory) process?

A third issue is that of "crisis management" and of the incorporation of new data: how flexible are the nuclear policies and regulations to allow for taking into account the experience of an event?

A fourth issue, which goes beyond the nuclear question is that of comparability of risks: how legitimate is the comparison of nuclear risk with that of natural catastrophes? are people indifferent between two situations presenting the same probability of death? what indicators can be used to measure various risks and what do they really mean (e.g., "lost days of work", maximal or average probability of death in a population, etc.)? what are the philosophical issues--freedom and equity--raised by imposing a risk on a specific group for the general benefit?

IIASA Reference: Dr. Häfele: Memo to Roger Levien on further IIASA energy studies. Rasmussen: WASH 1400. Lewis Committee Report on WASH 1400. Niehaus: comparison of energy risks.

Dr. Schnurer (Ministry of Interior of West Germany). Paper from the Berlin SMIRT conference on future developments of risk analyses for NPP's; Dr. Schnurer refers to the work of Dr. Birkhofer: Risk Analyses for nuclear reactors; project for the Federal Ministry of Research and Technology; Harry Otway: understanding public reaction to nuclear power.

Energy and Chemicals: Risk of Transportation of LNG and Other Hazardous Chemicals

This is one case in which risks that seem a priori comparable--e.g., LNG vs. chlorine transportation--have a different impact on the public opinion. What is proposed here is first a review of the risk studies previously done for LNG transportation--in particular trucking; then a study of the way by which regulations have been passed in different countries and a comparison of the LNG regulations with those concerning other hazardous chemicals--chlorine and gasoline for example. One question that can be specifically addressed is the sea transportation of hazardous chemicals (including LNG): how the economics of naval constructions--which calls for larger vessels and less maneuvering power, and the institutional and political framework of regulation--which can only follow engineering developments--contribute to the cretion of the risk, what policy options are available to reduce it, in particular in an international setting. There is a time lag between a technical development and the regulatory response that would be interesting to explore. In this case, one can compare the logics of regulation in different fields where the process of legalities meets different institutional problems.

IIASA References: David Fischer: LNG terminal siting in Norway. Elisabeth Drake: Risk analysis for LNG transportation. Nino Majone: Legalities and processes. Elisabeth Paté: Gelation for LNG for risk reduction.

Medical Field: Risks Associated with the Marketing of New Drugs

In the medical field, a classic area of risk management is the testing, licensing and monitoring of new drugs for human consumption. The central issue here is that extensive lab testing requirements prior to release of new drugs may seriously delay the availability of life-saving drugs on the market. Even then, the lab testing and small scale experimental human trials in hospitals may fail to identify dangerous side effects which appear only once a drug has been made widely available. Different countries have very different emphases regarding how much lab testing vs. how extensive post-release monitoring of actual effects, is used to manage the risk of new drugs. An extreme contrast exists between the USA, emphasizing the former strategy, and the UK, emphasizing the latter.

An interesting comparative study could be done to show what kinds of costs these two approaches entail. Structuration of the problem in a risk analysis framework would raise questions about the use of statistical methods in that field, and of comparison of two policies in which human lives, public costs and industrial interests are at stake. The question of post release monitoring also involves observation of individual cases, correlation between a drug and side effects and gathering of that information. Here again, the time factor plays an important role in the efficiency of the policy, which could be interesting to investigate.

IIASA Reference: Bill Clark who recommends as references Louis Lasagna, P.B. Hutt and as an advisor Donald Kennedy ex-administrator of FDA. Philip Aspden. Brian Arthur: Implications of altering medical risks to life.

The question of medical risk is not presently one of the points of focus of IIASA research but it is an important issue and a study aimed at comparing societal risk should include medical considerations.

The following tasks concern all of the previous case studies and could be undertaken at the same time as those practical applications. They concern risk valuation and risk management.

Risk and Values

The question of values intervenes when social choices have to be made between goals and between policies involving risks. Implicitly or explicitly those values are reflected by the consensus reached in the public sector between economic factors (costs or benefits) and, for example, human safety (creation or mitigation of a risk).

The question is to:

-- understand the mechanisms of individual choices given information and perception;

-- understand the process of a collective choice starting from individual preferences and an institutional framework (a) ("descriptive model");

-- recognize the social values behind state goals (b) ("norms") and the source of a possible gap between the desirable principles and the actual result (a) vs. (b);

-- see how risk analysis can give usable information to improve the collective decision process, in particular, what form of results would be useful in that respect, given the shape of the institutions and the possibilities of modifying them (regulatory agency vs. direct vote on a regulatory issue for instance).

If one chooses to evaluate alternatives in a multi-attribute utility framework, the desired trade-offs between lives, health, environmental quality and economic factors can be gathered in a utility function which reflects the values of the person whose utilities are measured.

The notions of descriptive model--observation of the results of past decisions--versus normative models--defining principles and making public decisions according--are puzzling because of the discrepancies observed between them, which comes partially from the shape of the institutions. "Irrationalities" that are already observed at the individual level essentially mean that our models do not encompass properly human processing of information.

What is proposed here is to tackle the problem of rationality and values for individuals, then at the collective level, taking into account the role of the institutions.

The following questions can be addressed to understand better the rationale behind individual and collective choices: what are the limitations of the human mind in gathering and processing information, in particular about low probabilities, 10^{-4} or below for example? what are the norms of society--is there a trade-off between individual freedom and social justice as seems to be the case--as far as the risk issues are concerned? how do different forms of institutions, e.g., direct vote or regulatory agency, gather and process individual choices and make a collective decision? how consistent are those decisions with national goals--which could be formalized as Wierzbicki suggests by penalty function, a distance between a solution and the set of solutions that meet the normative goals?

If one chooses to compute simple indicators or incorporate the risks in public policies (expected values of economic losses, number of lost lives, maximal probability of death, etc.), the use of each of them to rank risk mitigation policies reflects a philosophical stand. What do these criteria mean with respect to freedom of choice (to accept or reject a risk for example) and equity issues (distribution of risks and benefits) is a

major question of values.

A central point of the whole risk valuation question is that of the trade-off between human safety and economic costs. One of the questions which could be addressed--since it seems clear that there is no such thing as a universal value of life--is what parameters should be taken into account in the acceptance or the rejection of a policy on the basis of a cost per life saved: probability of death, or suddenness of death or fright inspired by some horrifying hazards for example? Between two of the proposed measures of individual "value of life", i.e., willingness to pay versus human capital, which one should be aggregated (averaged for example), how could they be estimated practically, and what are the political implications of using such criteria?

Those considerations seem remote from the classical solutions provided by utility theory. The major shortcoming of that theory seems to be to ignore the role of the institutions. It would be interesting, nevertheless, to compare in each case, the insights gained to the issues raised above, to the answer that utility theory might provide.

Another critical element of the social choice, is that of time preference. It intervenes directly in the problem of management of nuclear wastes (a long term risk to be considered along with the short term risk of nuclear accident) or in the problem of climatic change (a risk presenting a large uncertainty over the time horizon of the hazard).

What "rate of discount" should be used, what balance between current economic situation (present marginal rate of transformation) and inter-generational considerations should be adopted for a national policy is a critical issue? It can probably be approached from a probabilistic point of view: what will be the technical progress between now and a given time in the future, for the reduction of the considered risk; what will be the state of the economy and even the value system which are critical factors in the time issue.

IIASA References: H. Raiffa and R. Keeney: multi-attribute decision analysis. John Lathrop: use of the utility theory for social decision-making. Joanne Linnerooth: on the value of life.

Risk Management

Two major questions arise about risk management: what are the policies available? and at what moment should they be implemented?

The choice of policies has to be made on the basis of both the global national effect and the redistribution effects among regions and social groups. In the public sector, the risk management issue includes two types of situation: creation of a risk for a societal benefit believed to be greater than that risk, for example building nuclear power plants or authorizing their construction; or mitigation of an existing risk, for instance the risk of earthquakes or floods or epidemics. The policies available are generally of four types: direct public investment,

e.g., in an immunization program; regulation, including licensing, standard setting, release and operation permits; economic incentives, including tax adjustments or disaster relief measures; and a more passive category of actions which is to let the market mechanisms rule the risk management issues.

The choice among these is essentially political. Again, it is proposed to explore how each political philosophy--emphasizing equity and social justice or individual freedom--guides a choice of policy, given the characteristics of the risk--voluntary or not, controllable or not. The point is to compare the results and the secondary effects of these different types of policies. Also, it would, for example, be interesting to determine the transfers that they imply, who, for instance, bears the cost of safety regulations in the industry, what share of the cost goes to the consumer, to the employer and to the employee and how this mechanism compares to a free market situation.

One of the major problems of risk management is to deal with the totally unknown situations where neither the mechanisms, the consequences, nor the probabilities of the outcomes can even be imagined and assessed. To cope with such uncertainties, the dynamics of a risk mitigation program should be modified to include the learning process. Experience will be gained as a technology is developed and used. The policy of risk management must be flexible enough to incorporate that experience. Nevertheless, initial decisions to accept or reject a technology have to be made. It would be interesting to explore how the time factor of technical progress and gain of information can be introduced in the policy decision.

Another critical issue to be considered at the time of planning is that of crisis management: how can the effectiveness of a warning system be assessed and improved? how risk analysis can be used for that purpose? what are the critical factors, communications, authority, access to the system, control and means of action that can be considered in times of crisis?. "Optimum" allocation of resources for disaster preparedness reflects a collective choice and risk attitude that is directly linked to the risk valuation question. The experience of the case studies concerning floods, LNG transportation and nuclear power should be good starting points to identify the critical elements of an effective risk management policy. The role of the institutions in the risk management issue--and in crisis situations in particular--is a very important one. Modification of institutions, and even possibly modification of goals if the risks that they imply reveal unacceptable or unmanageable, is part of a much broader issue than the risk question. All other political implications of such moves should be explored. It is proposed to examine what sort of situations suggest such deep modifications.

IIASA References: Bill Clark: on dynamic risk management. David Fischer and John Lathrop: on crisis management (Workshop on the Three Mile Island event).

CONCLUSIONS AND ORGANIZATION

It is recommended that at the end of the case studies, comparative syntheses be prepared focusing on problems that are common to several of those cases. One could choose, for example:

-- the choice of probabilistic models versus statistical inference;

-- the problems posed by incomplete data, and the consequences of that limitation for policy decisions;

-- the question of human error;

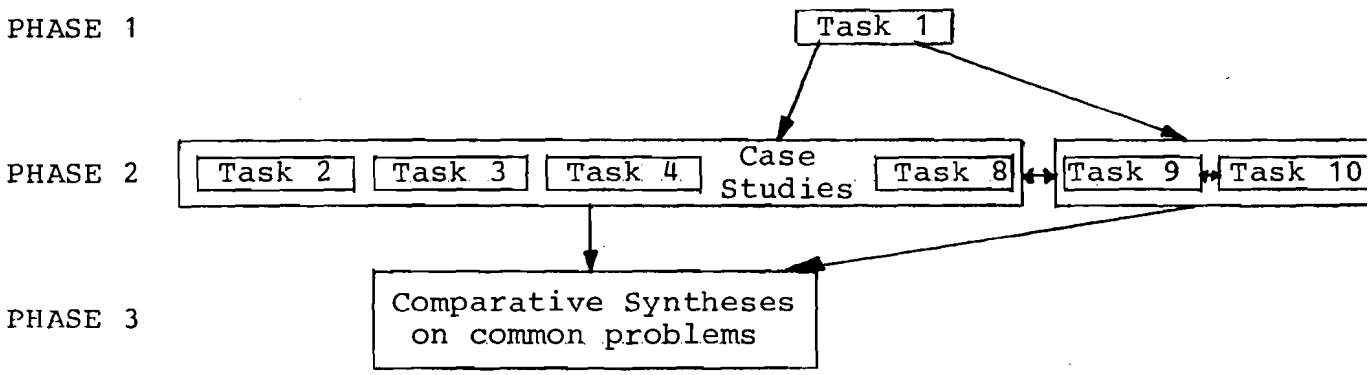
-- the question of time factor (with the uncertainties attached to it) and of time preference;

-- including potential technical progress in policy decisions;

-- crisis management for different types of risks;

and probably many other general problems that will emerge from the study.

As far as the scheduling is concerned, the organization of the work as proposed follows this pattern:



This defines a matrix organization (case studies vs. common theoretical problems) in which tasks 9 and 10 on risk valuation and risk management have a particular position: undertaken at the same time as the case studies, they should constantly relate to them. Structured in that manner, it is hoped that this study can bring people to work together in a fruitful and constructive way.