Towards a Global Environmental Risk Management Framework

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Abstract

This paper suggests a framework for global risk management that takes into account the complexities of the global context: large-scale and long-term impacts, inadequate data, uncertainties and unknowns, non-linearities and surprises. This framework is based on a growing consensus among risk researchers that risk estimates of complex phenomena are not only highly uncertain, but also not fully separable from value considerations. We advocate the adoption of an analytic-deliberative process recently put forth by the U.S. National Research Council, and we argue that this process is relevant for setting priorities on global environmental risks. The distinguishing feature of this framework is the early involvement of the interested and affected parties, which in a national debate on climate change issues, would involve those concerned with the local consequences and costs. We point to projects in Europe, where researchers are implementing this process in the global change arena. Finally, we discuss recent IIASA research on global change and catastrophic risk research and its place in the analytic-deliberative framework.

1. Introduction

Global changes, including those with regard to land use, population migration and the earth's climate, are imposing serious risks to human health and ecosystems. There is mounting evidence that climate change of the scale currently projected would have pervasive adverse impacts on human health due to heat stress, worsened air pollution, and increased incidence of vector-borne infectious diseases such as malaria, schistosomiasis and dengue, diseases related to water supply and sanitation, and food-borne illnesses.[2] Ecologists also warn of the effects of global change, especially climate change, to ecosystems. During rapid climate change, disturbances like fires, floods, erosion, droughts, and storms may increase with adverse effects on ecosystem functions as important as water

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[1] Seconded from the European Commission - Joint Research Centre - Institute for Systems, Informatics and Safety - I -21020 Ispra (VA), Italy

[2] International Physicians' Letter on Global Climate Change & Human Health - June 23, 1997.

supply, soil fertility and carbon sequestration. Changes in global land use, together with climate change, will likely lead to habitat disruption and possibly to steep declines in worldwide biodiversity.[3]

Climate change may also result in sea level rise, which should be a particular concern to low-lying island communities, causing beach erosion and threatening coastal marshes and mangrove forests. Onshore human development will further hamper new establishment of coastal natural areas with a loss of habitat for a substantial number of species of birds, fish, shellfish, microorganisms and animals. Marshes and mangroves protect shorelines from storms and high tides and act as filters for pollutants such as sewage and other effluents. Their loss would lead to increased erosion and degradation of onshore human development.

Global social and environmental changes, such as shifts in land use, population and migration, energy use and climate warming, will likely increase the social costs of natural and technological disasters and raise the potential for more severe, mega-catastrophes. Climate change may be implicated in the observation that extreme atmospheric events have accounted for a large proportion of the increasing losses from natural disasters, including hurricanes, windstorms, mud slides, draughts, fires, hail storms and other weather- related disasters.[4] Another global-change phenomenon is more directly implicated. The migration of people to large urban areas or mega-cities at unprecedented rates is increasing the concentration and vulnerability of the world's population to natural and technological disasters as well as to acts of sabotage and terrorism. This also unavoidably results in a poorer social ecology that may enhance acts of sabotage and terrorism. According to IIASA projections, the proportion of people living in urban areas has increased dramatically in the last decades and is expected to rise to nearly 60 per cent by 2025.[5] The 1995 Kobe earthquake in Japan demonstrated the potential for extreme disasters to devastate densely populated areas.[6] Moreover, terrorist acts in Tokyo, New York, Oklahoma City, Manchester and London have raised concerns about deliberate disasters in urban areas. Finally, a new dimension of vulnerability has been created by the complex networks of interdependencies (e.g. computer systems).[7]

From the recent Kyoto Protocol on Climate Change, it appears that, at least for climate change, an international consensus has emerged on how to manage the risks - on how much to reduce greenhouse gases and how to spread the costs of this reduction. The protocol requires a reduction in GHG emissions by about 5.2 percent from 1990 levels on the part of 38 industrialized countries to be achieved in the commitment period 2008 to 2012. The responsibility for taking action is thus squarely on the shoulders of the industrialized

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[3] Ecological Society of America, released on May 21, 1997.

[4] Munich Re. (1998). Public Publications Press, http\www.munichre.com, Jan. 27, p.1 of 2.

[5] Lutz, W. (1994). *The Future Population of the World: What Can We Assume Today?* Earthscan: London.

[6] European Commission (1996). Communication to the Commission on Earthquakes, EUR 16993 EN, Doc. ((96)3772/2/ 17.12.96).

[7] Haimes, Yacov, Y. (1997) Sustainable Operation of Threatened Infrastructures, *Journal of Infrastructure Systems*, forthcoming.

nations with a commitment to achieving the committed GHG reductions at the lowest cost through the use of market mechanisms.

However, from the perspective of reducing concentrations of greenhouse gases in the atmosphere and reducing the risks of global warming, the treaty is only a first step forward. The significance of Kyoto is that it begins to build an international legal framework for significantly reducing carbon emissions over the long run. The Kyoto conference is a first step toward the introduction of policies such as carbon trading and a clean energy fund to achieve specific reduction targets. If not undermined by the U.S. Congress, Kyoto could send an important signal to investors and industries about the opportunities to introduce technologies that reduce carbon emissions.

Even if the goals of Kyoto are met, however, a total of 140 billion tons of carbon will be added to the atmosphere from 1990 to 2010, increasing atmospheric concentrations by eight percent. Clearly, much more will need to be done to manage the risks of climate warming. The post-Kyoto world, therefore, will need to continue to address questions of how much to reduce greenhouse gases, at what cost, and at what burden to which countries? Similarly hard decisions will have to be made with regard to other types of global changes, including population policy, migration, land use, and material use.

2. Characterizing Risks

Risk research addresses the identification and management of situations which might result in losses or harms, immediate or delayed, to individuals, groups, or even to whole communities or ecosystems, often as a result of the interaction of (alternative) human activities with natural processes. The purpose of risk research is to inform policy decisions, which is a difficult task since:

a) the physical 'human activity - natural process' interaction is often very complex and non-linear; and
b) the social context in which decisions are to be taken and implemented is characterized by multiple subjects, bringing different *values*, *knowledge* and *interests* to bear.

Despite the difficulties, however, resources for reducing or mitigating risks are limited, and therefore priorities need to be assigned. For this purpose, early deliberations on risk advocated a three-stage approach; establish the probability and magnitude of the hazards respecting the inherent scientific uncertainties (a technical process), evaluate the benefits and costs (a social process), and set priorities in such a way that the greatest social benefits are achieved at the lowest cost.[8]

This three-stage process is the basis of past and recent studies of comparative risk analyses to set priorities on reducing risks across disparate risk contexts. Most analysts now recognize that priorities cannot be set simply by expressing risk in terms of expected harm and choosing to reduce those risks for which the most lives can be saved (or damages

[8] National Research Council, 1982. *Risk and Decision Making: Perspectives and Research*. Washington, DC: National Academy Press.

reduced) for the least cost. Extensive work on risk perception shows that communities are far more concerned, for example, with reducing high-consequence risks than low-consequence risks, with reducing involuntary risks over voluntary ones, with reducing risks which affect future generations, and so forth.[9] Therefore, recent comparative studies of risk have attempted to factor in the public's concerns about the nature and context of the risks. These comparative studies, however, have not questioned the fundamental distinction between facts (such as expected life losses in car accidents, expectancy of rare technological accidents, etc.) and values.

According to Rayner, et.al. (1997), rejecting this distinction undermines the three-stage process in setting risk-policy priorities for at least two reasons: First, the selection of issues for the attention of technical analysis, as well as the selection of methods for their analysis, embodies value commitments. Second, reducing risk decisions to be based only on probabilities and magnitudes fails to reflect concerns about trust, liability and consent to activities that are inherent components of the risk management process.

A new perspective to risk analysis is thus emerging and is elaborated in a recent publication of the U.S. National Research Council, titled *Understanding RISK - Informing Decisions in a Democratic Society.*[10] The distinguishing feature of this new approach is that it sets out an *analytic-deliberative* process that builds on the notion that value judgements are an inherent feature of expert approaches to risk assessment. The *analysis* of risk situations involves the systematic application of specific theories and methods from the natural and social sciences for the purpose of increasing the understanding of the substantive qualities of the risk situation, including the seriousness, likelihood, and conditions of a hazard or risks and of the options for managing it. *Deliberation* is any process for communication and for raising and collectively considering risk/policy issues. Deliberations about risk include discussions of the role, subjects, methods, and results of analysis. The important point is that the process of risk management – and setting priorities for research and policy action – is an interactive process involving both analysis and deliberation.

A purpose of the analytic-deliberative process is to provide a synthesis and summary of information about a hazard that addresses the needs and interests of policy makers and of interested and affected parties. This is referred to as *risk characterization.* The success of risk characterization

> *depends critically on systematic analysis that is appropriate to the problem, responds to the needs of the interested and affected parties, and treats uncertainties of importance to the decision problem in a comprehensible way. Success also depends on deliberations that formulate the decision problem, guide analysis to improve decision participants' understanding, seek the meaning of analytical findings and*

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[9] Slovic, Paul (1987). Perception of Risk, *Science 236:280-285*.

[10] Stern P.C. and Fineberg H.V.(eds). 1996 *Understanding Risk - Informing Decision in a Democratic Society.* National Research Council. National Academy Press. Washington, D.C.

uncertainties, and improve the ability of interested and affected parties to participate effectively in the risk decision process. (P.3)

This calls for a participatory procedure, in which the different stakeholders are involved early in the risk analysis process to "characterize" risks, even before they are given a formal assessment. The proposed procedure does not diminish the role of modeling and quantification, but is aimed at eliciting the "values" and the perspectives of the community involved so that the multiple dimensions of risk can be taken into account early on in the assessment. With this procedure, tacit recognition is given to the notion that the expert risk estimates are influenced by the context of the risk, that the experts cannot generate "facts", even probabilistic measures, that are void of values. Too many times, risk assessment, even when committed by a public administration, has been considered unsatisfactory by the community which attributed different values to dimensions not assumed in the analysis.

Table I shows an example of the multiple dimensions of the risk connected with uncontrolled releases of chemical substances (chemical accident). In particular it shows the indicators that have been selected to characterize the severity of chemical accidents by the competent regulatory authorities in the European Union.[11] The indicators express in some case incommensurable values, or at least values that many people feel cannot be transformed into a one-dimensional utility scalar.

In the past, comparative risk assessments have tended to reduce many dimensions of risk to one in order for the risks to be comparable. This technique necessarily simplifies the risk situations and requires value choices among the various dimensions of risk, and these value judgements have too often been left implicit in the analyses. However, comparative risk assessment can be explicitly embedded in an analytic-deliberative process and, as such, can be an important and useful input to the policy process. Recent work at Carnegie-Melon University is experimenting with the notion that the public can rank risks and pass these rankings on to the policy community. The analytic-deliberative process is thus mutual and recursive:

Analysis and deliberation are complementary and must be integrated throughout the process leading to risk characterization: deliberation frames analysis, analysis informs deliberation. (Stern and Fineberg, p.6)

One possible objection to the analytic-deliberative procedure is that it might appear to violate the policy makers' needs to make decisions in a reasonable time frame.[12] Also it cannot be extrapolated to social realities different from that in which the analysis was performed. However its basic message holds true: if risk research contributes to inform socially implementable decisions, the interested and affected parties must be involved at an early stage.

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[11] Amendola A., F. Francocci, M. Chaugny (1994). *Gravity Scales for Classifying Chemical Accidents.* ESReDA Seminar on Accident Analysis. EC-JRC, Ispra, Italy, October 13 –14.

[12] Macilwain, Colin (1996). US panel backs new approach to risk, *Nature* 381:638.

Finally, it is important to emphasize the role of the analyst in this process. To be policy relevant, risk characterization must be accurate, balanced and informative, which requires "getting the science right and the right science". Those responsible for a risk characterization should begin thus by developing a "*provisional diagnosis of the decision situation*" (p.7). The agency responsible for risk characterization begins with a diagnosis that include ideas about the nature of the hazard, the purpose of the characterization, and the kinds of information that will probably be needed. Such a diagnosis can be formal or informal, involving quantitative and qualitative methods. As we will discuss in a later section, models can also be useful for this initial stage.

3. Characterizing Global Risks

How is global risk management different from managing risks on the national, regional or local levels, and are the new analytic-deliberative procedures for risk analysis relevant to global risks? Certainly, risks at the global level exhibit many, if not all, of the characteristics that increasingly plague more local risks, including:

- complex, non-linear cause-effect relationships;
- incomplete knowledge, even scientific ignorance, about the physical interactions;
- potential for surprise effects;
- disagreements among scientists;
- multiple affected and interested parties with different values and interests;

and,

- in many countries, a lack of trust on the part of the public in the "risk decision-makers".

Risks from global environmental change, thus, do not differ from many domestic risk issues in their scientific intractability, or in what Funtowicz and Ravetz (1991) have referred to as their deviations from "traditional science". Global risks have long-term impacts, data are generally inadequate and the phenomena are complex and not well understood. Funtowicz and Ravetz point out that the limitations of traditional problem-solving strategies in dealing with global environmental risks arise because decisions depend on evaluations of future states of the natural environment, resources and human society, all of which are unknown and unknowable. A new methodology is therefore required that should rely on "extended peer communities" because quality assurance requires participants outside the usual peer communities of experts.[13]

Superimposed on this intricate science/policy risk landscape, global risks embody even further complications in their management. First and most obviously, there are no global risk managing organizations with powers of enforcement. Therefore, decisions have to be negotiated and agreed by a collective` in the global arena. As demonstrated in the latest

[13] Funtowicz, S.O. and J.R. Ravetz (1991) A new scientific methodology for global environmental issues. In, R. Costanza (ed.), *Ecological Economics: The Science and Management of Sustainability.* Columbia University Press, New York.

negotiating rounds of the Kyoto Protocol, this process is cumbersome and time consuming, but is developing in such a way that the affected and interested parties (the NGOs) are becoming increasingly involved.

This involvement appears to be critical for the implementation stage of environmental agreements. Based on a rich set of case studies, a recent IIASA study shows the importance of several factors in the implementation process.[14] The first is broad participation of the target groups in the treaty negotiation and implementation process. While some argue that inclusion of industrial groups and regulated parties can lead to "regulatory capture" and a weakening of commitments, decisions made through participatory processes are likely to be more stable and effective.

The analytic-deliberative process may, therefore, be useful, even crucial, for international treaty making on global risk issues. Not only is it important to involve the interested and affected parties in the risk analysis process leading to a country's position on global change issues but also to continue to involve the parties in the implementation stages.

4. An Example of a Deliberative Process

The analysis by Clark (1990), calling for the *adaptive management* of global climatic change is still a very lucid one, and can be applied to other global risk issues as well. In Clark's words:

> *"We need to think ahead of time about how new pieces of scientific evidence should rationally alter our willingness to undertake specific actions..."*[15]

In this perspective not only new scientific evidence, but even decisions taken may constitute a branching point in a research agenda. Before Kyoto, the risk agenda was to generate scenarios *"to undertake specific actions now postponed on the grounds of uncertainties..."* Should the Kyoto Protocol be ratified by the relevant countries, the national research institutes will necessarily turn (1) to issues of its implementation and (2) to analyzing future global agreements on climate change.

Japan has already taken extensive measures for the restriction of GHG emissions by means of increasing the energy efficiency of the economy. The challenge now is to implement further reductions of GHGs that are both efficient in terms of their costs and acceptable to the affected parties. In this regard, public involvement can be an important aspect of climate risk management and crucial for setting the post-Kyoto priorities. Kyoto has thus changed the context in which a research agenda should be developed.

How can the public be involved in setting local and regional priorities for reducing GHGs and thus contribute to a research agenda for climate change? A recent project is investigating the use of focus groups, or groups of randomly chosen citizens, for involving

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[14] Victor, David G., Kal Raustiala, and Eugene B. Skolnikoff (1997) Introduction, *The Implementation and Effectiveness of International Environmental Commitments*, Cambridge: MIT Press.

[15] Clark C. William (1990). *Usable Knowledge for Managing Global Climatic Change: The Problem of Assessment.* in "Usable Knowledge for Managing Global Climatic Change". Clark C. William (ed.). The Stockholm Environment Institute.

the public in regional priority setting in the face of climate change.[16] The ULYSSES (Urban LifestYles, SuStainability and Integrated Environmental ASsessment) project, funded by the European Commission (DG XII), is designing and testing a procedure to allow informed citizens to express their judgements on climate policy. The particular approach taken is to use so-called "IA Focus Groups" and to use some tools of Integrated Assessment (IA) to stimulate the discussion in these groups. The focus groups are conducted in seven urban regions throughout Europe: Barcelona, Venice, Athens, Zurich, Frankfurt (Rhine/Main), Manchester and Stockholm.

In a focus group small groups of citizens share a moderated discussion on climate risks and options for climate policy. Each focus group meets for five individual sessions or for two consecutive days. In the first session environmental problems and climate change are discussed in a general way. In the second session global issues are addressed using an Integrated Assessment model to stimulate and inform the discussion, and based on this model, the group focuses on regional and local policy issues. Finally, the participants produce a "citizens report" on the basis of the discussions in all sessions.

The interesting feature of this process is that it combines analysis and deliberation. A number of Integrated Assessment Models have been used in the pilot and first phases of the ULYSSES project, including IMAGE, TARGETS and PoleStar. Early results show that in many of these groups the participants find the interactive computer model understandable and useful for their joint assessments. Ideally, these deliberations should also lead to improvements in the analyses, that is, in the Integrated Assessment Models.

This means that research organizations, while continuing to cooperate with the international research community to calibrate models and to upgrade "measurements" and "predictions", should focus research on the regional risk consequences of post-Kyoto measures. In close collaboration with the affected public, consequences common to the whole region and local effects should be analyzed, including the social-economical issues. In this regard, it is also important to consider the *equity issues*.[17] Equity issues can arise across countries and/or in a same country when consequences have impacts of different severity for different social groups or communities. These may severely affect further global risk issues, like population pressure across countries or movements within a country.

5. The Analytic-Deliberative Process: Global Change and Catastrophic Risk

An issue of particular concern in setting national and global research priorities is the publics' aversion to catastrophic risks that affect present or future generations. Indeed, the non-linear effects of climate change, the potential surprises, involving large-scale negative

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[16] Kasemir, Bernd et.al. (1997). *Focus Groups in Integrated Assessment: The ULYSSES Pilot Experience*, ULYSSES: Urban Life styles, Sustainability and Integrated Environmental Assessment, WP-97-4, Darmstadt University of Technology.

[17] Linnerooth-Bayer, Joanne (forthcoming). Fairness and Climate Change, *Equity in Integrated Assessment Models* (tentative title), London: Earthscan.

consequences appear to be of great concern to the public. Already evidence is cumulating that intensifying, weather-related, "natural" disasters may be a result of climate change.

According to figures published by Munich Re., in the last decade the number of major natural catastrophes (e.g., floods, hurricanes, earthquakes, wildfires, avalanches, sea surges, hail storms and volcanic eruptions) is three times as great, and cost the world's economies eight times as much as the decade of the 1960's.[18] In 1997, a year with exceptionally few natural catastrophes, the burdens concentrated in populated, developing countries resulting in relatively more losses in lives (13,000 lives lost world wide compared with 12,000 in the previous year) but relatively lower overall economic losses (approaching $30 billion compared to $60 billion in 1996). The most frequent natural catastrophes were windstorms and floods, which accounted for 82% of the economic losses and no less that 97% of the insured losses. Floods devastated large areas of China, Latin America, Somalia, and the United States. The major event for Europe was, as in 1996, a flood in Central Europe, where the heaviest precipitation ever recorded inundated areas in Poland, Germany and the Czech Republic.[19]

Global social and environmental changes, such as shifts in land use, population and migration, energy use and climate warming, will likely increase the social costs of natural and technological disasters and raise the potential for more severe, mega-catastrophes. The observation that extreme atmospheric events have accounted for a large proportion of the increasing losses raises concerns that climate change may be an important influencing factor[20] and already insurance representatives are taking action to influence global policy on climate change (as in Kyoto). Another global-change phenomenon is more directly implicated. The migration of people to large urban areas or mega-cities at unprecedented rates is increasing the concentration and vulnerability of the world's population to natural and technological disasters as well as to acts of sabotage and terrorism. The 1995 Kobe earthquake in Japan demonstrated the potential for extreme disasters to devastate densely populated areas, and illustrated that even the losses from earthquakes are directly related to global change phenomena in the sense that populations continue to migrate to densely populated areas, and complexity of infrastructures is continuously increasing. Moreover, industries are also clustering in certain areas, making them more vulnerable to natural and technological catastrophes.

The Kobe earthquake resulted in 6300 lives lost and around $100 billion in property damage (about 3% of GDP), of which only about $3 billion of losses was insured. Japan is also vulnerable to many types of weather-related catastrophes, including typhoons and tsunamis. Some limited types of catastrophic insurance, e.g. for earthquake risks are available in Japan, but it is generally prohibitively expensive for most households and small enterprises. The burdens from the Kobe earthquake were thus spread locally through family and other social institutions and nationally through government aid and compensation. The Japanese, themselves, thus absorbed the full costs of this earthquake.

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[18] Munich Re (1998). Public Publications Press, http\www.munichre.com, Jan. 27, p.1 of 2.

[19] Munich Re, *ibid.*, p.1 of 2.

[20] Munich Re, *op cit* 1,. p.1 of 2.

Given the risks of a major earthquake in Tokyo and other disaster scenarios, limited private insurance on the part of individuals, households, firms and municipalities may be a serious problem. In addition the high concentration of certain types of industries, e.g., computer manufacturing, are factors contributing to Japan's vulnerability to catastrophic risks. An important policy issue is reducing this vulnerability through prudent risk management strategies, including siting decisions to avoid industry clustering, building codes and other mitigation measures, and financial diversification through insurance. These are issues for risk analysis, and, as such, they can benefit from the insights provided by the analytic-deliberative process.

Scientific analysis is crucial for this process. A particular concern throughout the world is that storms, floods and other weather-related catastrophes may not be the rare and independent events that they were once thought to be. Recent research at IIASA shows that these events display certain tendency patterns and appear to be clustering in time, which is evidence that they may be dependent on outside factors. The relationship of the world climate to ocean anomalies, such as the *El Ninos,* is widely recognized.[21] It is also recognized that the North Atlantic Oscillation determines the strength of the westerly winds across Europe and affects storm tracks, patterns of rainfall and temperature. If, as some recent studies suggest,[22] the strength of these oscillations is related to sea surface temperatures (that seem to have orderly patterns), then windstorms, ocean surges, floods and other weather-related disasters may not be independent events.[23] Establishing the dependencies of natural disasters on geo-physical phenomena that are affected by global change can improve assessments of their risks. A similar temporal clustering of earthquakes along certain faults (i.e., the time between earthquakes is decreasing) has also been observed.

The complexity of the physical phenomena and the complexity of the social and financial institutions have led to an increased reliance on computer models to aid public and private managers in their response to catastrophic risks. At IIASA, computer models have been developed to simulate energy futures and their implications for the global environment, and to better understand population, land-use and other global changes. The insurance industry is also embracing computer models to aid their strategies for dealing with catastrophic risks by improving the insurability of rare events (with dependent claims) and reducing the vulnerability of the insurance industry to insolvencies. In this regard, IIASA has recently developed a Model for Catastrophic Risk Management, which applies sophisticated optimization techniques developed at IIASA to improve industry-wide decisions on diversification, contracts and other decision variables. It also can improve regulatory decisions on catastrophe management by suggesting and analyzing options for

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[21] See, for instance, publications of the World Meteorological Association, Geneva, Switzerland.

[22] Sutton, R.T. and M.R. Allen (1997). Decadal predictability of North Atlantic sea surface temperature and climate, *Nature* 386:563-566.

[23] That is, once a flood occurs, the occurrence of a second flood is not an independent event, but the probability in a specified time might be greater or less than the occurrence of the first flood depending on the physical dependencies.

the public authorities in providing regulations (building codes, for example), emergency preparedness and response, and national insurance.

What should the role of the IIASA and other models be in setting priorities for catastrophic risk management, and indirectly thus for setting priorities on global risk research? Within the deliberative-analytic framework discussed above, these models provide a provisional diagnosis of the decision situation. The models do not provide "hard facts" on the risks or the "optimal response" strategies for private firms or the public authorities. Rather, they provide an early representation of the risk situation. Any application of the model must be, if it is to be effective, combined with a deliberative process. As a case study, IIASA, together with collaborating partners throughout Europe, is proposing such a process for the characterization of earthquake risks in taking as case studies earthquake-prone regions of Russia and Italy.[24] Further case studies should include other types of dysasters.

6. Conclusions

Setting priorities for research and policies to ameliorate or reduce the risks from global change is both challenging and urgent. In elaborating a process for setting these priorities it is important to recognize the limitations of expertise in estimating and evaluating the seriousness of the risks, which are, at best, highly uncertain, and, at worst, unknowable. The linear process of estimation and evaluation is increasingly viewed as unsuitable for dealing with complex risk situations, and the *process* of risk management is critical for setting priorities that are viewed as legitimate and credible by the affected and interested parties. The analytic-deliberative process described in this paper is based on the idea that citizens and analysts can provide important inputs to the priority setting process. As such, it is a good starting point for elaborating a framework for global risk management.

[24] CARISMA (CAtastrophic RISk MAnagement): A Systems Approach to Catastrophic Risk Management with Case Studies on Earthquake-prone Regions. Project proposal submitted to the EC Intas Call for tender 1997.

TABLE I. Criteria Defining the Severity of Chemical Accidents

Criteria based on data available in the short term	**Criteria based on data available in the long term**
- Quantity of dangerous substance released or exploded - Number of fatalities (within or outside the establishment) - Number of people injured / hospitalized longer than 24h - Number of people homeless or unable to work to external damages - Number of residents evacuated from home/sheltered longer than 2 h - Number of people deprived of drinking water, electricity, gas, telephone, public transport, longer than 2h	- Wild animals killed, injured, or unsuitable for human consumption - Destruction of rare/protected flora and fauna species or extinction through habitat damage - Material/Production losses in the establishment - Property/production losses outside the establishment - Volume of water polluted - Surface of soil or underground water-table subject to specific clean up or decontamination treatment - Length of shore or watercourse subject to clean up or decontamination treatment - Cost for environmental clean up / decontamination / restoration measures - Number of people subject to long term medical control - Losses to the cultural heritage