RISK MANAGEMENT AND EIA: RESEARCH NEEDS AND OPPORTUNITIES

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FOREWORD

The Canadian Environmental Assessment Research Council (CEARC) was established on January 30, 1984 by the Federal Minister of the Environment to advise government, industry and universities on ways to improve the scientific, technical and procedural basis for environmental impact assessment (EIA) in Canada.

CEARC is currently in the process of establishing research programmes related to improving the practice of environmental assessment. The Council has identified "Risk Assessment and Management" as one of the priority research areas and plans to publish a research prospectus dealing with this subject by the end of 1986.

The purpose of commissioning this paper, and indeed of all the other CEARC-sponsored background documents, is to provide relevant information and to stimulate discussion on the topics of interest to the EIA community. The opinions expressed, however, are strictly the authors' own and do not necessarily reflect the views of the members of the Council or its Secretariat,

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PREFACE AND ACKNOWLEDGEMENTS

The purpose of environmental impact assessment (EIA) is to predict in a systematic manner the consequences of proposed major projects such as airports, nuclear power plants and exploration for hydrocarbons in the Arctic, or changes in policy or regulatory procedures such as planning acts. For this reasons, much of the work carried out in EIA already involves risk analysis. One critical question that faces society is how it should intervene to reduce or mitigate risk arising out of such activities. This is a challenge faced particularly by proponents, assessors, intervenors and panel members in EIA. However, EIA and risk assessment as emerging research fields and management strategies have hitherto developed in parallel. We may have reached the stage when risk assessment should be incorporated more formally into EIA. In late 1984 the Canadian Environmental Assessment Research Council (CEARC) identified this topic as one of its priorities for discussion and review.

This paper builds on the results of a Workshop on Risk Assessment and EIA held in April 1985 at Seneca College, King City, Ontario, and a preliminary meeting in March at the Institute for Environmental Studies (IES), University of Toronto. In May 1985, CEARC asked IES to prepare a report that would aid in setting priorities for research relevant to the application of risk assessment principles in EIA. In responding to this request, we have used our collective judgment, research and teaching experience to identify the salient research needs and opportunities in this field. We have deliberately avoided the two familiar options of a literature review and detailed research proposals. We have interpreted our terms of reference broadly. For example, our discussion could apply to risks that are not currently subject to EIA but which may be in the future (e.g. forest spraying).

The leading light of much work on risk assessment and EIA was unavoidably unavailable as a member of the writing team; however, Ted Munn helped to implant the idea for the project, and his moral support is much appreciated. We also thank the fifty participants and the authors of the papers presented at the Workshop on Risk Management and EIA in April 1985 and the participants at the meeting at IES in March 1985. A subsequent workshop on Information Needs for Risk Management in September 1985 also contributed to our research and discussions. The workshops on Risk Management were supported by Health and Welfare Canada, Environment Canada, the Federal Environmental Assessment Review Office, SCOPE (Scientific Committee on Problems of the Environment) Canada/National Research Council and Ontario Hydro.

The financial support of CEARC for this project and the encouragement of Dr. Husain Sadar and Dr. Gordon Beanlands are very much appreciated. We thank the members of CEARC, for their thoughtful questions and suggestions. We are particularly grateful to Dr. J. O'Riordan and Prof. Audrey Armour who reviewed an earlier draft and provided us with many insightful questions and constructive comments. We also thank Miss J. Retel who typed numerous drafts of the report and Mrs. Gail Rania who provided administrative support for the project.

EXECUTIVE SUMMARY

How should society intervene to reduce or mitigate risk? This is one challenge that proponents, assessors, intervenors and panel members in EIA have to face; and because of this much of the work carried out in EIA already involves risk analysis. In this study we focus on two questions: Would the more explicit treatment of risk in EIA improve, codify or extend aspects of the EIA process; and what research needs, opportunities and priorities would emerge as a result?

We start in Section 1 by providing working definitions of *risk* (a judgment about the measure of probability and severity of harm to human health and the environment) and the various stages of risk assessment and management. *Technical risk analysis* is the identification of risk and the estimation (usually by statistical procedures) of the likelihood of an event and its subsequent impacts. *Risk evaluation* or *risk assessment* is the consideration of the importance of risks and associated social, economic and environmental impacts in order to identify and compare a range of management options. *Risk management* is the overall term to include analysis, evaluation, implementation and monitoring of a preferred course of action.

Although proponents, assessors and intervenors all share a common interest in risk (e.g. economic risks, environmental hazards, accident insurance), their language, perspectives and techniques are quite different. We believe that the first beneficial effect of the application of risk to EIA would be to infuse the whole process with the risk philosophy, i.e. outright rejection of the dichotomy of safe and *unsafe* with its implied certainties. While in time we may arrive at a decision about a level of "acceptable risk", we are always dealing with a range of probabilities. We also recognize that universal acceptability is as unattainable as iron-clad certainty. In brief, the use of risk assessment in EIA would:

- focus attention on the question of uncertainty — both scientific and societal — and
- clarify the need to solicit a range of societal opinions and judgments to arrive at some consensus among conflicting values and interests.

In Section 2 we examine technical risk analysis which is the first stage of risk assessment. This demands a great deal of data; however, even when comprehensive and accurate estimation cannot be carried out, risk analysis provides a framework for data collection and the identification of gaps in understanding. Research is required into the sufficiency of data and into the confidence and the reliability of data. The use of worst-case analysis often means that a lot of time and effort is spent on examining highly implausible risks; the use of "worst-plausible-case" analysis may be a more productive alternative. Another issue is whether non-specialists find mathematical risk analysis useful; if not, what else could be used? Research is needed to develop an appropriate language for presenting risk analysis to non-specialists without oversimplifying.

The integration of the concerns of the public in risk assessment and management is a clear priority area in order to ensure the acceptability of the EIA process and of the results of that process. The integration of the attitudes and concerns of the public about risk are important research areas examined in Section 3. Of particular interest is the gap between objective risks and perceived risks, Another question is how to obtain and handle public input: timing, organization, type of forum, etc. It is critical to separate differences of opinion over the competence of technical analysis from differences over the implications of the analysis.

Differences over the consequences of various risks are part of the evaluation and assessment of risk in EIA, i.e. the point when conflicting values and interests are explicitly factored into the risk problem. We examine this in Section 4. This is the phase where professional judgment, accountability and responsibility are paramount. We need research into developing the best and most manageable guidelines for identifying the full range of possible alternatives and their risks and benefits; and it is here that we need to learn from past experience, particularly good experience. There are several assessment methods (risk-benefit analysis, cost-effectiveness analysis) that attempt to clarify the trade-offs between risks and benefits. We need to use these methods consistently, and explore their usefulness in the real world. We also need more focussed research into the way that the public values and evaluates its own concerns, lifestyle and other elements of its well-being; and into the question of equity-in brief, into what is or is not "acceptable risk".

The EIA process is a significant institutional arrangement in its own right for monitoring, reducing or containing risk. In Section 5 we address four issues that cut across the analysis-evaluation-assessment phases or have very broad implications for the content and scope of EIA. First, data about the costs (and effectiveness) of risk mitigation across a range of risks would provide the public and decision makers with a framework to guide decisions about further expenditures on risk mitigation. Second, it would be useful to do research into the relative merits of proposed ways to improve the management of expertise in adversarial contexts e.g. "sciences courts", advisory panels, independent commissions. Third, research into innovative institutional instruments is likely to prove useful (e.g. comparative studies of institutions in Canada, Europe and United States focussing on legal liability, insurance, "bubbles" and "offsets"). Fourth, the integration of economic risks into the risk framework is of great importance, but requires substantial research before it can be handled appropriately.

In Section 6 we select some of those research needs and opportunities which we feel have the highest priority.

1. INTRODUCTION

1.1 Risk and EIA

People everywhere have always attempted to avoid unduly high risks to their safety, health, property and other valued aspects of their lives and environment. As a species we have survived and adapted to an often uncertain and turbulent environment; and in this perspective much of our world can be seen as having been shaped through various responses to risk. In our routine day-to-day decisions we are constantly and often unconsciously assessing the risks and benefits of our varied activities. Professionals in medicine, law, and emergency services are called upon to make explicit and responsible decisions about risks for the benefit of other individuals and for the community as a whole. Society, in turn, makes similar choices through government and other institutional mechanisms in attempting to standardize procedures, set priorities, and otherwise evaluate concerns over risk; these choices are reflected in legislation, regulations, codes of professional practice, mandatory testing and so on. There is, therefore, nothing new in the recognition of risk, nor are we inexperienced in avoiding, mitigating and managing many of them.

What is new is the more general recognition of risk as a specific concept, subject to formal analysis and disciplined study that can contribute directly to the rationalization of our sometimes contradictory, ineffective and unnecessarily costly attempts to minimize certain risks. Rigorous risk analysis has, of course, been going on for many years in such areas as actuarial science; but the current enthusiasm for the study and discussion of the nature, analysis, assessment and management of risks — particularly environmental risks — is of fairly recent origin. In fact, its history runs parallel to that of environmental impact assessment (EIA), and some of the factors responsible for the new interest in risk are similar to those which influenced the initiation of EIA (Wolf 1983).

EIA as we know it today originated in 1969 with the National Environmental Policy Act (NEPA) in the United States. The formalization of the process in Canada took place in 1973 with the initiation of the Environmental Assessment and Review Process (EARP) and the establishment of the Federal Environmental Assessment Review Office (FEARO). Provincial governments soon followed with their own legislation and procedures for EIA beginning in 1973 (Couch et *a/*. 1983). Since then the literature and the volume of environmental impact statements have grown rapidly.

During the same period interest in risk concepts also grew apace. The substantial work on technical risk analysis that was characteristic of the period up to the 1970s began to be coupled with epidemiological and natural hazards research, and also with the more general recognition that the risk analyses of the potential failure of complex technical facilities should be expanded to cope with the consequences of those failures — that is, a "risk context" was now needed in addition to risk quantification. Important stimuli came from the writings of Starr (1972), Tversky and Kahneman (1974), Rowe (1977), Lawless (1977), Lowrance (1976) as well as the literature on risks ranging from natural hazards (Burton, Kates and White 1978), risks to health and safety, and risks to ecosystem structure and function (Burton, Fowle and McCullough 1982). More recently, interdisciplinary symposia have reflected the growing recognition of the potential for cross-sectoral application of risk concepts and of the many factors which frustrate our attempts to cope with risks (Warner 1982; Rogers and Bates 1983).

Even more than these theoretical and scholarly papers, however, the main driving force behind the increasing interest in "risk" has been the growing social and political concern over the management and mismanagement of a bewildering array of potentially hazardous systems, products, projects and technologies. Many of these "hazards" are already subject to risk analyses e.g. tests on new drugs, fault-tree analyses for nuclear reactors — and the extension of risk analysis methodologies to more general "risk assessments" is a natural development in the application of risk theory.

The imposition of legislative requirements for EIA in the early 1970s severely taxed the abilities of assessors to carry out good quality assessments. Regulatory agencies were inexperienced in preparing guidelines, and assessors were often faced with the impossible task of providing scientific assessments in the absence of appropriate information and under time constraints which precluded the collection of adequate data. The consequence was general dissatisfaction with most EIAs (Munn 1975; Beanlands and Duinker 1983; Whitney and Maclaren 1985; PADC (Project Appraisal for Development Control) (1983).

Recently, however, a number of steps have been taken to foster more consistent and rigorous approaches to EIAs in Canada. For example one could point to the publication of "An Ecological Framework for Environmental Impact Assessment in Canada" (Beanlands and Duinker 1983) and to the proceedings of a workshop edited by Whitney and Maclaren (1985). Another step was the establishment of the Canadian Environmental Assessment Research Council (CEARC) to promote research designed to improve EIA in Canada.

Given these circumstances, the time is perhaps ripe to inquire whether or not the fields of risk assessment and environmental impact assessment can be mutually supportive or cross-pollinating; both fields have much in common and have evolved to the point where their different pathways towards an appropriate mix of scientific rigour, social concern and political judgment may be on the verge of meeting. In particular we ask in this paper whether the more explicit treatment of risk in EIA would assist in codifying, improving and extending some aspects of the EIA process.

1.2. Objectives and Scope of the Study

This paper is a product of a CEARC initiative, and follows a planning meeting at IES in March 1985. In April 1985, IES organized a workshop on risk management and EIA sponsored by Environment Canada, Ontario Hydro, Health and Welfare

Canada, the National Research Council and FEARO, at which 50 experts from both fields reviewed invited papers. While it builds on the presentations and discussions at the workshop, this paper is intended as a further, specific attempt to improve EIAs by exploring the research needs and opportunities presented by the application of risk concepts to EIA. In order to provide arguments and rationales for the research we believe ought to be done, however, we consider it necessary to outline both our approach to the topic of risk management, and also some of the difficult (and intriguing) issues related to the application of risk concepts in EIA.

In the next subsection we provide working definitions of various aspects of risk management (i.e. risk analysis, evaluation and assessment). Research issues in technical risk analysis revolve around data requirements, the concern for uncertainties in estimation and interpretation, and the presentation of the results of the analysis (Section 2). Much of the risk literature is technical in nature; this makes public involvement a particularly controversial and difficult issue (Section 3). Research issues in risk evaluation divide into improving the input of information into the evaluative process, specific evaluative techniques, and final decisions about acceptable risk (Section 4). In Section 5, we examine four issues that cut across the analysis-evaluation phases and that have very broad implications for the scope and content of EIA. The concluding section highlights research priorities (Section 6).

Most of the risk literature deals with risks to human health, and risk impacts are generally measured in terms of mortality, premature death and morbidity. We have, however, also included environmental risks such as impacts on ecosystem structure and function, on amenity and heritage values and on economic well-being. It should further be kept in mind that not all impacts in EIA are related to risk; many impacts can be measured with a very high degree of confidence. Hence when they are relevant, the application of risk concepts is not a panacea for all the problems of EIA; risk assessment is one more tool to be utilized where appropriate.

One question that runs through this study is whether the more explicit treatment of risk would improve the quality of EIAs. There are two aspects to this question:

- Would risk assessment improve the technical basis for decision making?
- Would risk assessment result in better decisions?

It is difficult to give categorical answers largely because these are not purely analytical questions; the answers would need to be formulated in the relevant context on a case-by-case basis.

On the whole, the data and understanding required for risk analysis and assessment should be expected to improve the technical basis for decision making, even though we do argue throughout this study that there are still many inadequacies and point out research needs and opportunities. Risk analysis and assessment could provide the stimulus to ask explicit questions about acceptable risk in order to obtain and organize information that could lead to better informed decisions. This type of reasoning was one of the spurs for the rapid adoption of EIA a decade ago with respect to environmental impacts.

Whether the application of risk principles in EIA would result in better decisions would depend in part on the technical adequacy of the analysis, and in part on the degree to which the decision itself is amenable to technical analysis. This qualifaction is particularly relevant to our study because it applies to EIA too. We view risk management and EIA primarily as planning tools or techniques for sorting out data and information. The decisions that follow would depend primarily on both the political context (i.e. which interests wield more power) and on the societal commitment to such considerations as environmental quality, distributional ethics, cultural integrity and intergenerational equity. In this regard risk assessment and management could be useful in EIA because they emphasize the inextricably risk-laden lives we lead with or without formal assessment!

In brief, the risk concept is useful in pointing out both the limits of science (scientific uncertainty) and the limits of public consensus. However, we do not subscribe to the view that risk management — or EIA — is designed to force a shift in public attitudes towards the environment or towards more equitable allocations of resources. Like other techniques of policy analysis in the past (e.g. EIA, benefit-cost analysis, location-allocation analysis), risk management is largely an analytical tool and could be used by different interests to further their purposes. Risk management is not expected to resolve value questions but to clarify the implications of alternative decisions for value groups.* To us, that is a powerful argument for the more specific treatment of risk.

1.3 Working Definitions

We start from the premise that risk and EIA have potentially much in common, since, after all, the purpose of an EIA is to predict the consequences of a planned action, whether it be the construction of an airport, coal-fired power station, nuclear plant, electrical transmission line or perhaps even changes in land tax legislation, planning acts or some other change in environmental policy (e.g. the decision to build a central facility for hazardous waste management in Ontario).

Much of the work carried out in current EIAs is risk analysis in everything but name. We argued above that the explicit treatment of risk concepts in EIAs would help to clarify and codify some of the existing aspects of the process and would also point the way to new developments in the existing process. As a preliminary step, it is necessary to explain what we mean by risk assessment and management and how they relate to EIA. The definitions in the literature vary considerably; however, we assume that as long as we are reasonably clear about what we mean, and the definitions we offer are relatively free from ambiguity, we need not become involved in a semantic debate.

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* We thank Audrey Armour, Jon O'Riordan and other members of CEARC for their stimulating and thoughtful comments on the role of risk concepts in EIA. We should add that no analytical tool is entirely value-neutral. This is another reason to insist on the explicit treatment of risk in EIA.

We define **risk,** after Lowrance (1976:8) as [a judgment about the] measure of probability and severity of harm to human health [and the health of human ecosystems, broadly defined] .

Risk analysis is the measurement of the likelihood and severity of harm. Risk analysis is usually made up of risk *identification* and *risk estimation;* the latter is the attempt to estimate scientifically, mathematically, statistically, or by some other rigorous procedure the probabilities of an event and the consequences associated with it. Generally, risk analysis is the most time-consuming, costly and technically difficult part of risk management, requiring data collection and analysis, in areas where needed data often do not exist and where analysis of these data is more of an art than a science. Because risk analysis often involves probabilities, statistics and epidemiological data, it may be difficult to convey the results of an analysis to the public and to non-specialists.

Next comes **risk evaluation.** In this volume we use **risk assessment** interchangeably with the term risk evaluation. It is at this stage that values and judgments enter the process explicitly or implicitly by including consideration of the importance of the assessed risks and the associated social, environmental and economic consequences in order to identify a range of alternatives for managing the risks, and to consider whether or not the proposed change as a whole is acceptable. Evaluation requires the determination of the trade-offs between the various beneficial and adverse impacts and for this reason the views of various interest or value groups need to be solicited and considered.

We use risk **risk management** as the overall term to include the identification and quantification of risks associated with a proposal/action, the evaluation of alternative strategies and designs that mitigate these risks or their consequences, and the decision and implementation of a preferred course of action. Risk management includes the entire range of methods of coping with risk rationally and systematically.

Having read the foregoing pages, the practitioner of EIA might very well say: "That's all very well and good. You describe quite well the sorts of things we already do. Potential impacts are identified, their magnitude estimated, and various scenarios are constructed to show how impacts change as alternatives are proposed in the EIA. Guidelines usually require explicit statements regarding lack of data and other sources of uncertainty. And we consult with interested public(s). We already do much of what you describe. What can "risk" do for us? What are its advantages? Why should we be concerned about risk?"

In the rest of this introduction, we want to discuss our underlying rationale for the use of "risk" in EIA and point out how the use of risk focusses attention on one of the fundamental issues of making predictions — the question of uncertainty, scientific and societal.

1.4 Underlying Rationale: The Question of Uncertainty

We believe that the first beneficial effect of the application of risk to EIA would be to infuse the whole process with the risk philosophy. That is to say, we would reject the dichotomy of *safe* and *unsafe* with its implied certainties, and explicitly recognize that we are always dealing with a range of risks, and that while it is true that by a combination of scientific and societal judgments we may arrive at a level of "acceptable risk", we are constantly dealing with some range of probability and consensus and not iron-clad certainty or universal acceptability. *

1.4.1 Scientific Uncertainty

Practitioners of EIA have constantly to deal with two perspectives on scientific uncertainty relative to impacts: uncertainty as perceived by scientists, and uncertainty as perceived by laymen (i.e. non-specialists and the public and sometimes by scientists who do not share the same mindset). Uncertainty is a fundamental component of the scientific method; questioning, doubt, criticism and clarification are basic functions of good science. The progress of their discipline depends upon scientists constantly attempting to undermine — and go beyond — their most cherished laws and paradigms. However, this intrinsic uncertainty often comes across to the public as a lack of control, or a lack of understanding.

This presents the authors of EIAs with a familiar dilemma. If they make categorical statements or definitive pronouncements without qualification, they are open to criticism by their peers. If they make qualified interpretations, they are open to attack for being "wishy-washy", "non-committal", or "buck-passing" since the pressure is on making the "right" decision, free from uncertainty as to the consequences.

In order to reduce these difficulties, it is important to keep in mind, first of all, that there is a range of kinds of scientific uncertainty. In an EIA context we need to distinguish among several of these:

- There are many complex processes and interactions in nature about which virtually all scientists and engineers are in agreement and for which predictions are quite certain. We can make very exact predictions when we have a reliable data base, robust scientific understanding and well-defined hypotheses: the outcome of chemical reactions, the motion of the planets, and-the curative power of certain drugs are all predictions of this sort. But even here, scientists remain sceptical, and focus their attention on the interesting uncertainties and rough edges of theory, always striving for that next important clarification — and that next important paper.

- At the other end of the spectrum, there are situations of uncertainty which confront us because we lack data and a robust hypothesis. For example, we cannot yet predict the

* In this section we focus on uncertainty; the societal judgments and range of consensus (or conflict) are discussed in Sections 3 and 4 below.

incidence of AIDS. even though we are now confident that we understand something of the mechanisms by which the disease spreads.

In an EIA context those predictions about which there is general agreement do not require extensive risk analysis before mitigative measures are considered; of course, there may or may not be as much general agreement about which mitigative measures are best (e.g. building a dam to reduce floods versus land use zoning). Those predictions about which there are no robust hypotheses or data would benefit from risk assessment only to the extent that risk analysis would provide an organizing framework for looking for data and testable relationships. Meanwhile only subjective analysis is possible.

In between the two extremes, there are several intermediate kinds of scientific uncertainty. For example:

- There are events of low probability and high consequences (LOPHIC) such as those at Seveso and Bhopal. Mitigative measures for LOPHIC risks tend to be very costly — as in the case of nuclear plants and hazardous waste disposal facilities — while the data are limited and subject to various interpretations. In these cases risk assessment, even in the absence of historical data, provides a useful organizing framework. for conducting rational discourse.

- Another intermediate type of uncertainty is where a probability of occurrence and magnitude for both event and consequence are available (e.g. earthquakes, frequency of severe storms, pipeline explosions) but prediction in terms of time and place are almost impossible. In such cases risk assessment is useful in order to improve policy. For example, it would be impracticable to make every home plane-crash proof but one could use risk data to zone land uses around airfields.

1.4.2 Uncertainty about Societal Futures

The search for certainty — and its frustration — is particularly relevant to the assessors and appraisers of EIA. It is well to recall that EIAs are a device for ensuring that the future will not be catastrophically surprising as a result of some new endeavour.

Tomorrow's society is shaped by today's decisions. Although an EIA is specifically related to some particular project or area, it is also worth keeping in mind that an EIA is a lightning rod for a whole range of social concerns, simply by virtue of its attempting to discuss the future systematically. Similarly, "risk" is a polarizing word, since, like a strong magnet, it sets up fields of concern within which people orient. themselves to protect against or firmly espouse the kind of future that .is perceived to follow a decision. However, because it is polarizing, risk perhaps gives us the chance to find out exactly what is at stake in a proposed project, and gives us a way of determining what will allay certain concerns. Part of the answer is to better understand societal uncertainty, i.e. the degree of consensus regarding societal futures including the kind of economy and institutions we want or are likely to have in the future (e.g. a more centralized, "Big Brother" society versus a more loosely knit economic system). For example, some of the controversy in EIAs revolves around whether certain technologies favour the evolution of more centralized institutions and whether such institutions are desirable.

In any case, the future evolution of economies and institutions — and the attached uncertainty — are relevant to EIAs. Societal uncertainty derives from the obvious truth that, as Marshall McLuhan used to say, we are driving into the future by looking through the rear-view mirror. This apparent inconsistency is endemic to human life, and society itself is an attempt to cope with, and sometimes benefit from the fact that life is not totally predictable — or risk-free.

In earlier times, traditions, myths, religions, were widely shared and this gave regularity and meaning to many of our activities. Much of that regularity and meaning remains, but it is often expressed only fragmentarily in small social groups such as the community, or the family, or in times of national crisis. By and large, modern communities do not share much of a consensus about societal futures and, therefore, predictions about future institutions and economies are not likely to prove persuasive. We would like to make it clear that the issue is a political one and is more amenable to dialogue among value groups than to technical information exchanges (cf. public hearings). However, the implications of project development on institutional structures should be part of EIA. In addition, some of the potential mitigative measures may be changes in institutional structures (e.g. compulsory, non-subsidized insurance for automobiles; or establishing a Crown corporation to manage hazardous waste) (See Section 5.4).

One way of coping with this situation, as we have said, is to take both public concerns about societal uncertainty and scientific uncertainty into account; to take them equally seriously in terms of future research on how to improve EIAs. Having given up the search for false absolutes, we can use the perspective of risk to explore the different ways in which the debate over the probabilities and consequences of events is carried out, and also the ways in which the burden of uncertainty is shifted and minimized. In terms of social impacts, we are not just referring to alterations in the perception of various risks, but also to such issues as:

- Given the range of risks that people already face, are additional risks worth taking on?
- How will they fit into the overall spectrum of risk?
- Regarding the question of equity, who is to be saddled with what risks, for how long, and for what benefits?
- And regarding the question of acceptability, what is an acceptable risk, and what is an acceptable process for coming to that determination?

In the following sections, we look at the research that may assist in answering these and other questions we have raised in our introduction.

2. TECHNICAL RISK ANALYSIS

2.1 Introduction

We have divided technical risk analysis into three categories as possible areas for further research: information needs, uncertainties in estimation and interpretation, and presentation of technical information.

One of the characteristics of risk assessment is its attempt to conduct rigorous risk analyses, wherever possible. This kind of analysis is information intensive and technical in nature, leading ultimately to *objective risk estimates.* Several mathematical and scientific techniques are available and in relatively wide use, including fault-tree analysis for estimating probabilities, epidemiological surveys, toxicological experimentation, and systems modelling. Problems for the risk analyst revolve around which technique is appropriate for each occasion, considering both the adequacy of the available data, and the relevance of any results.

To conduct a competent risk analysis, there must be an adequate information base. The most interesting and controversial EIAs often deal with projects that require the installation of the latest technology (e.g. high temperature incinerators); that propose to move into previously forbidding territory (e.g. Arctic, offshore); or that otherwise go beyond existing practice (e.g. final disposal of radioactive waste). Analysis is, therefore, plagued with having to work with information collected originally for other purposes, to cope with disparate quantities and qualities of available data, and to consider the need to extrapolate beyond the range of observations. For some risks, one may be reduced to arguing from analogy. It is no wonder that truly reliable and objective analyses are rare. Even in those cases where formal risk analysis is not possible, we suggest that the procedure for risk analysis provides a useful framework for sorting out available data and identifying gaps in understanding.

2.2 Information Needs

We would like to distinguish between two types of information in risk analysis:

- data required by scientists and technical analysts in order to make their rigorous risk estimations; and
- the results of these analyses for use by panel members, the various public groups and the decision makers (see Section 2.4 below).

In the latter type, the methods of presentation and interpretation tend to involve more subjectivity than in the former.

One of the criteria for judging the quality of a risk analysis is the extent to which existing information has been utilized. Sometimes information is available, but unusable in its present form, i.e. needs to be interpreted (e.g. traffic accidents); or is available but somehow unobtainable (e.g. proprietary information); or is simply unavailable (e.g. risks from new technologies). Research in these areas should focus on improving the utility and availability of data. As one of the reviewers of this report pointed out, there is a lot of information relevant to risk analysis that is both available and usable. Research should be directed at developing information systems appropriate for risk analysis of projects subject to EIA.

Improving the utility of information implies that although information is available, it is either deficient in quality or in quantity. We need to examine ways to improve the gathering of data for risk analysis, in order to make appropriate comparisons between different types of risks. One important objective is to ensure that data gathered for one assessment adds to the general stock of risk information (i.e. an information system), and need not be replicated at some later data. Are risk data sufficiently generic as to be widely applicable in different studies? Can we devise criteria for the "generic" quality of data?

Because of the continuing problem of using information gathered for one purpose in order to perform risk analyses for another purpose, the establishment of "translation criteria" and standards is crucial in ensuring the adequacy of risk assessment. The first of these criteria would be an explicit understanding about the confidence bars to be assigned to analyses. The second criterion would help define those cases where a risk analysis would perhaps be ruled out, since the information available was of insufficient quality or quantity to make an analysis worthwhile. Can we devise criteria for sufficiency of quality of information?

The unavailability of information due to lack of research, proprietary considerations, or other factors brings into play issues such as the level of information on potential risks to be required from a proponent through EIA guidelines. What is a risk assessor to do when the concerns of the public over certain risks are clearly not worth expending valuable research budgets, or when the public's concerns cannot be resolved by any amount of research (e.g. into very low-level radiation effects)? The assignment of research priorities ultimately should reflect the need for relevant information on the part of the assessors to make their decisions. In the meantime, guidelines calling for risk analyses and evaluations need to include criteria on when the data and scientific understanding are deemed adequate; and include suggestions on what to do when these criteria cannot be met.

2.3 Uncertaintites in Estimation and Interpretation

As already mentioned, much of the uncertainty in risk analysis stems from the fact that we have a relatively brief span of data on many risks associated with new technologies (e.g. liquefied natural gas port facilities; radioactive waste disposal), new development frontiers (e.g. offshore oil drilling in the Arctic), and so on. In these cases risk analyses are often based on general prediction models, or scenarios with their well-known unreliability.

The best known problem related to uncertainty is that of low probability high consequence (LOPHIC) risk. "LOW probability" is often a euphemism for no observed occurrence, and the lack of a track record makes the prediction of the event and the consequences unreliable. Another difficulty is that in order to paint a realistic risk picture we would have to consider the cumulative and combined effects of different risks (e.g. smoking and air pollution), considerations which are difficult and may be susceptible to serious error through additive or multiplicative effects.

Reliability in estimates depends not only on the quality of information available (see previous section), but also on catching the ways in which errors creep into risk estimations, either by the additive and multiplicative process, or by heroic assumptions about such problems as human error. How reliable do estimates need to be in order to be useful for risk assessment and management?

One method of coping with technical and interpretative uncertainty is "worst-case" analysis (e.g. a full explosion of a liquefied natural gas facility given the most adverse wind conditions). This kind of analysis, while exhaustive — and often exhausting — may not however illuminate the real situation as regards risk. Rather than spending time on examining highly implausible risks, it might be worth analysing "worst plausible cases" i.e. those scenarios which are built up by technical experts, panel members, and the public in order to sketch out acceptable pictures of what the future might hold. This would, in turn, imply that research is needed into what criteria would make such scenarios faithful and believable predictions (e.g. how many scenarios would be required in order to "cover the waterfront"). Public input into developing guidelines (as in Lepreau II) could include the building of plausible scenarios. Research in this area might address the strengths and weaknesses of worst-case analysis and worst-plausible-case analysis in terms of the minimum necessary technical information, the appropriate levels of understanding by non-specialists and acceptability by interested publics.

2.4 The Presentation of Technical Information

The presentation of technical information is a great potential stumbling block in the application of risk analysis to EIA. The uncertain and probabilistic nature of much of the information provided, as well as the mathematical language often used in risk calculations, can make risk assessment threatening rather than enlightening to the layman. (Can the public understand the significance, for example, of a probability of 10^{-6} (0.000001) or its difference from a probability of 10^{-8} (O.OOOOOOOl)? This a central issue, not just for the assessors and decision makers who must make the final assessments, but also in order to make public participation meaningful and relevant. We need to know whether non-specialists find mathematical risk analysis useful. If not, what else could one use?

As the literature on the perception of risk emphasizes, the understanding of risk is a complex mix for all concerned, and there is no clear demarcation between those who respect the data and those who do not: the public — and related interest groups — are well aware of the power of science as a source of objective data, and also aware of the use of supposedly objective science as a political weapon. Often it is the interpretation, and not the rejection, of the data which is at stake in these debates. Risk enters this debate in order to clarify the arguments over possible future consequences — What should we really be concerned about? Its manner of presentation should ideally convey both what is known and what is not known about the risk in question. The usefulness of a risk analysis in the decision-making process may be expected to be enhanced if the findings are conveyed to non-specialists in clear, unambiguous and understandable terms. Research is needed into the development of an appropriate language for presenting risk analyses. We need to develop aids (e.g. maps, tables) to convey the nature of different types of risks. How can we best translate technical risk analyses into laymen's language? How do we best convey the reliability of risk estimates? What are appropriate *numeraires*, scales, and measures of risk for conveying such information to non-specialists? We need to clarify without oversimplifying. *

* A reviewer of this report suggested that one way to simplify the problem of presentation is in fact to reduce the amount of presentation required. Where the impacts are routine, the regulatory process in place should deal with the project approval. This would allow the EIA process to concentrate on those risks with costly consequences and/or poorly defined management options. Research is required on how to shift as many impacts as possible into the "routine" category.

3. PUBLIC INVOLVEMENT

3.1 Introduction

The integration of the concerns of the public in risk assessment is a clear priority area in order to ensure the acceptability of the EIA process, and the results of that process. The difficulty, as we have noted elsewhere (e.g. Grima 1985; Timmerman 1984), is to make those concerns felt in a timely, equitable, efficient and useful fashion.

By public involvement we mean the whole range of public inputs into the assessment process, including the public concern with "risk" and "uncertainty". Specifically, we would like to include the attitudes and concerns of the public (i.e. "public perception"), the involvement of the public in the preparation of guidelines and in the hearing and assessment process (i.e. "public participation"), and the question of equity — all of which lead towards the articulation of what is or is not "acceptable risk". Our view is that one vital part of making any form of risk acceptable is that the process by which the decision to assume (or impose) a burden of new risk is made should itself be acceptable. This process is a very important research area.

In this section we discuss the research needs relating to the participation of the public in the debate over risk. We divide our discussion into the perception of risk and public participation.

3.2 The Perception of Risk

In recent years, difference between what is considered expert opinion and the views of the public on matters of risk (e.g. the nuclear power debate) have created a substantial literature, much of which is referred to as "the perception of risk" (Tversky and Kahneman 1973; Otway and Pahner 1976; Kahneman et *al* 1982; Timmerman 1985). Controversial issues, especially ones which pose potential threats to human health and well-being, tend to polarize the various players in the evaluative process, and bring to the surface many different views, not just on the specific risks being evaluated, but also on the implications of those risks, on the levels of responsibility and accountability of elected and non-elected public representatives, and sometimes on the whole future of society and institutions (cf. some of the presentations to the Porter Commission on Electrical Power Planning in Ontario).

These concerns are much broader than the term "perception of risk" would lead one to believe; and, in fact, the term carries with it the slightly pejorative view that the public has "perceptions" which are mostly illusory and emotionally based, while scientists and other experts have a monopoly on objective reality. It would perhaps be better if we spoke about different "conceptions of risk" held by different stakeholders, which would remind us that people's perceptions of risk are often a function of their experiences and conceptions of life; however, the term "perception of risk" is now almost standard in the literature, and will be used throughout this section.

What the "perception of risk" literature shows is that human beings have, over millenia, learnt to use "judgment" in dealing with risk. They have developed largely intuitive methods of scanning and simplifying the vast array of incoming stimuli and information in order to concentrate on those phenomena which are adaptively significant; methods which can sometimes be systematically misleading. This is especially true in an era such as our own, where we are bombarded by disconnected bits of information from all sides, information that we have little or no time to evaluate critically, and where the operating rules-of-thumb which mankind has developed to avoid and adapt to risks and uncertainties often do not apply (e.g. urea formaldehyde, asbestos and cigarette smoking hazards). The literature suggests that we prefer risks we are acquainted with ("better the devil you know"... e.g. smoking cigarettes); and that we are more frightened by low probability high consequence risks (e.g. plane crashes) (Fishhoff et *al*. 1981). These are sensible strategies when we have little or no information to go on — as was the case for most of human history — but now that we do have a great deal of systematic information on many hazardous activities, and can compare risks with some accuracy, these strategies no longer appear sensible to the statistician, scientist, or other expert.

This human conservatism in the face of uncertainty used to be referred to as "wisdom", and since wisdom is not a quality much in abundance these days, we should be careful about dismissing it out of hand. In a broader perspective, the public mistrust of expert assessments of risk has to do with, among other things, people's loss of a sense of stability or control over their own lives. In addition there have been occasions when science and expertise have increased, rather than decreased the risks with which some sectors of society have to live (e.g. Love Canal residents and Bhopal victims). Finally, a large segment of the public has a healthy scepticism for the quantitative approach to qualitative issues (e.g. the high priority that personal health and the care of children have in both household and government budget making).

Further research into the "perception of risk" needs to take into account the interweaving of the political and the psychological in the EIA process if "risks" is to become a worthwhile addition to the overall mix. The literature on risk perception has not been codified to any great extent. While this research can explain certain phenomena at public hearings and elsewhere — why the public focusses on certain words, issues, and images — and can assist in the better presentation of data, it has yet to be applied systematically in any long-range risk issues, nor has it been applied to any great extent to community and group interactions involving environmental issues.

3.3 Public Participation

As noted in Section 3.1, the acceptability of the process itself is an integral part of the acceptability of the results of the process. The due process of EIA is one of the best ways of ensuring that risks and benefits are acknowledged. We preface our remarks by noting that public involvement in EIA has

already progressed far and some of the issues we raise in this section may already be addressed, at least in some EIAs. However, the use of risk assessment techniques and concepts assists in this by ensuring that uncertainties about future consequences are not ignored, but are specifically considered, clarified and communicated to the stakeholders.

The most important initial question about the involvement of the public in the debate over various risks is whether or not the complex and sophisticated terminology of much of risk analysis can be easily and correctly translated, or whether another layer of frustration is about to be added to the public participation process. As we noted in the section on technical risk analysis, presentation of data in compelling and clear forms is a fundamental research priority if risk assessment is to be of use in a public choice context.

A second question is how public input on issues involving risk is to be handled. One major advantage of risk as a concept is that it can be used to concentrate the minds of panelists, proponents, and the public on the relative importance of various concerns, by explicitly focussing on probabilities and potential consequences, and identifying the major gaps in our understanding that would be required to be filled before this could be done properly. Research is needed into when, during the process, the explicit public focus on risk should take place. It is reasonably clear that two main types of public participation are necessary: first, public scrutiny of the adequacy of the technical risk analyses: and, second, public forums at which the public and its representatives can articulate their own priorities and concerns. In order that both of these types of public participation can be used to maximum effectiveness in the EIA process, the practice of having public input before the guidelines for the EIS are promulgated is to be encouraged. This helps to ensure that some parts of the public concern are potentially resolvable without having to undertake new studies in mid-process, and with luck, can help to ensure that many potentially serious arguments do not revolve around mutual unresolvable ignorance as to the real — or perceived — nature of the risk.

A longer term question is how to institute meaningful comparisons between different types of risk. Public participation allows for the articulation and expression of different concerns over risk. Participation must be handled so that differences of opinion over the competence of technical analysis are separated from differences of opinion over the nature of the risks involved. The crucial importance of this is that failure to provide adequate or compelling rationales for certain aspects of risk analysis suggests that predictive competence over what will happen in the future is less than adequate, which very rapidly translates into a loss of confidence in the overall status of the EIA process. On the other hand, differences over the nature of the risks involved are to be considered as part of the usual political process where different interest and value groups compete for power and influence.

4. RISK EVALUATION AND ASSESSMENT

4.1 Introduction

The evaluation of alternative designs, strategies, and policies for mitigating risks comes at that point in the process when conflicting interests and values begin to be explicitly factored into the risk equation. We emphasized in the previous sections that the technical analysis of risk may involve subjective judgments at various points, but one of the main attributes of technical or scientific analysis is the continual striving to keep subjectivity to a minimum. In the evaluation and assessment of risks, personal subjectivity is still minimized, but the recognition that evaluation is now being undertaken supersedes any simple subjective/objective split. We now enter the realm of professional judgment, accountability and responsibility, i.e. assessment of a number of potentially incommensurable factors for the purposes of decision making.

Under ideal circumstances, the correct decision may just emerge as a result of the carrying out of proper procedures. For this to happen — or indeed for any evaluation or assessment to work smoothly — there must be confidence on the part of all stakeholders that this work has been done properly, that "all bases have been covered", and that the array of evidence before the decision maker is adequate for some decision to be made. This confidence is not there if assessors are continually having to make decisions on the basis of inadequate information, gaps in the knowledge base, and best guesses. It is here that we need research into developing the best and most manageable guidelines for identifying the full range of possible risks and benefits, and then evaluating and assessing their significance. And it is here that we need to learn from past experience, particularly good experience (see Section 6 below).

4.2 Evaluation

"Risk" theoretically unites a whole range of uncertainties within one conceptual framework: there is economic risk, health risk, risk of technical failure, environmental risk and psychological fear of uncertainty. The basic question here is whether this conceptual unity is spurious (i.e. due to similarities of terminology), or whether it might have practical significance, particularly when we come to the phase of an EIA when it is time to weigh and assess alternatives.

There are several methodologies and approaches (benefit-cost analysis, risk-benefit analysis, multi-attribute utility analysis, mediation, etc.) that attempt to clarify the trade-offs among risks, costs, and benefits (Dooley and Byer 1982; Fischoff et *a/* 1981). Should the guidelines for EIA ask that the proponent and assessors attempt to generate and present data on "willingness to pay" or "willingness to receive compensation" in order to exemplify the necessary trade-offs? These methods are really ways of ordering and organizing information about risks and values. Which methods are most appropriate for which problems? Should they be used on a consistent basis in risk evaluation and EIA? How does one obtain accurate but quick estimates of public acceptability and guarantees? The information is required not only as part of public participation but, more importantly, as part of evaluation and assessment.

4.3 Equity and the Question of "Acceptable Risk"

The decision makers have eventually to balance off the various concerns and presented information and decide if the risks associated with going ahead on a project are acceptable, given everything else. "Given everything else" and "on balance" are alternative ways of saying that some form of weighting is eventually carried out, however much one may dislike comparing apples and oranges. An additional complication is that the distribution of the burden of risks, and of the benefits accruing from those risks is, in part, an ethical concern.

One advantage of risk as a concept is that it puts the issue of future uncertainty squarely in the forefront of concern. A working definition of acceptable risk might be:

> An *acceptable risk* is a risk whose probability of occurrence is so small, whose consequences are so slight, or whose benefits (perceived or real) are so great that a person, group, or society is willing to take that risk (Munn, personal communication).

The difficulty, of course, is that the combination of elements outlined above rarely occurs in the situations that need to be assessed; since when they do, assessment becomes simple. Much more usual are those risks where some combinations are positive, and some are negative: for example, the probability may be low, the consequences high, and the benefits high. In such a case, the issue may come down to a value judgment about whether probabilities, consequences, or benefits are to count for more in the weighting.

Even more complex are those often recurring situations where the persons put at risk are likely to receive some level of benefits, but the bulk of the benefits are to go to a larger group of others, or to some specific beneficiary. Particularly intractable are those cases where the assumed increase in risk to one group is arbitrary, even though the benefits are widespread and substantial (e.g. hazardous waste facility siting) (Timmerman 1984; Singer 1979; Hare 198 1).

Faced with cases like this, the ability to weigh risks and benefits may be essential to determining such alternatives as compensation to a potentially affected community; and yet such weighing may fall victim to the constant tendency to underrate qualitative factors in favour of quantitative factors. Specifically, one may find oneself in a position where the open-ended burden of future uncertainty is to be compensated for by lump-sum payments. It is important that research be carried out into the ethical consequences of economic models using (for example) high discount rates on future value, and "willingness to pay" criteria (Schultze and Kneese 1981).

One solution for this type of problem is to engage the public forms of scenario construction, to evolve the type of "future story line" which appears to them to be most plausible, with various compensatory strategies attached to surprises and failures that might ensue. Another is to conduct much more focussed research into the way that the public values and evaluates its own concerns, lifestyles, and other elements of its well-being.

5. MANAGING THE PROCESS

5.1 Introduction

In this section we look at the EIA process in its own right as a significant institutional arrangement for monitoring, reducing or containing risk. We examine a few issues that either cut across the analysis-evaluation-assessment categories (e.g. the handling of expertise) or that have very broad implications for the content and scope of EIA. For example, should the assessors and panel members try — implicitly or explicitly — to equalize expenditures on mitigating risks at the margin? Should the assessors and panel members consider (or even ask for) alternative institutional mechanisms for reducing damage from hazards (e.g. non-structural adjustments to flood hazards, such as compulsory, non-su bsidized flood insurance)? These questions may not have the urgency of the bread-and-butter issues in previous sections, but we feel that they are important emerging policy issues (cf. the increasing use in the United States of "bubbles" and "offsets" to reduce air pollution at a lower cost than across-the-board regulation).

5.2 Indicators of Risk Mitigation

The U.S. NRC (1982) Committee on Risk and Decision Making noted that there is no easily available information on comparative and aggregate risks, and yet the comparative assessment of risks may be an important component of EIA (see Section 3 above). EIA is a significant institutional arrangement for identifying, monitoring, assessing and mitigating risk; as part of its administrative-educational function CEARC/FEARO could take the lead in the compilation of selected data on the public and private expenditures on reducing a broad range of risks and residual costs. Such a volume, to be published periodically, could include data on the mitigation of risks such as cancer, occupational risks, accidents in the home, risks involving children's toys, risk to ecosystem integrity (e.g. microcontaminants in the Great Lakes), and so on. Such an exercise would make the data on risk mitigation more easily accessible for assessors and reviewers of EIAs, and it would also identify gaps for departments such as Statistics Canada, Health and Welfare, Energy, Mines and Resources, Environment Canada, and Agriculture Canada. A related question is the identification and mitigation of cumulative impacts (spatially, temporally, by organism, etc.).

This type of information would provide the public and decision makers with a framework to guide decisions about further expenditures on risk mitigation and would make it possible to compare decisions in appropriate and equivalent risk-benefit frameworks. Such information would also help to examine alternatives as part of an adaptive management process.

5.3 Experts as Hired Guns

Scientists, lawyers, engineers, sociologists, economists and other experts play a major role in EIA and risk management. The NRC (1982:34) Committee on Risk and Decision Making pointed out that "While it may baffle lay people,, assessors often clash on facts". They give a long list of what experts disagree about: they may disagree on the reliability of data, their import, their interpretation, and their synthesis. Whether the issue is the biological effects of low-level radiation, the safety of food additives, the likelihood that chlorofluoromethanes diminish ozone in the stratosphere, or the health effects of different components of automobile exhaust, the process of reaching a consensus on what is known and is useful for the evaluation component of decision making is invariably difficult and often contentious (NRC 1982:34). The question is: What to do about it?

Including articulate and competent laymen on panels, stating conflicts of interest and biases, and setting up "science courts", are only some of the suggestions for increasing the orderliness and clarity of the scientific input. Adversarial proceedings have their advantages but scientific findings fall easy prey to confrontational tactics, for reasons elaborated in Section 1 above. It is, therefore, important to consider other alternatives such as advisory panels and scientific reviews (e.g. those conducted for the U.S. Academy of Sciences and the Royal Society of Canada). It would be useful to do research into the relative merits of these experiences in order to learn how to deal better with the issue of what one observer has called the mockery and prostitution of science by experts on the witness stand. Even though experts often participate with good intentions, they are often put in untenable positions by the demands of the adversarial process.

5.4 Alternative Institutional Instruments for Mitigating Risks

The critical questions facing individuals, businesses, unions, government agencies, legislatures, courts and non-governmental organizations are:

- whether to incur a risk; and
- whether to mitigate the risk.

These are the questions that EIA panels in particular have to face and decide. Adjustments and adaptations to risk include insurance (compulsory or voluntary, subsidized or not subsidized), medical care services, emergency services, educational campaigns, scientific research (e.g. epidemiological and toxicological research), policy research, and engineering and economic analyses.

However, the administrative response to acceptable-risk questions is typically much narrower. The two most common responses are legislation about liability (e.g. compulsory liability insurance for cars) and regulation (e.g. occupational health and safety regulations, compulsory car belts, emission standards, compulsory product labelling). In fact EIA has interpreted its mandate so as to enable it to enforce engineering and structural mitigation measures. In the future, EIA could very well be obliged to consider mitigation measures such as compulsory liability insurance, in particular for decisions about hazardous materials management facilities. In addition most

policy choices about acceptable risks are not mutually exclusive: compulsory insurance and health regulations complement each other (cf. workmen's compensation insurance and safety regulations).

In risk management, experimenting with innovative institutional techniques offers management the opportunity to learn from experience. There are a number of institutional contexts and instruments that address the question: "How could risks be managed in such a way as to both reduce aggregate risk and also make the choice of risks more rational and less controversial?" However, we can benefit from this learning process only if regular assessments are made of the institutional mechanisms currently in use. It would be useful:

- to compare institutional contexts and mechanisms that are already in the use in Canada, the United States, and Europe; and
- to discuss other potentially useful legal-economic mechanisms that would more effectively manage the risks associated with the hazardous facilities, hydrocarbon energy development, phases of the nuclear power cycle, etc.

The institutional-economic-legal instruments include the following:

- environmental mediation and community bargaining: experience in Washington, Virginia, Ontario, Saskatchewan, Massachusetts and other jurisdictions might be evaluated.
- compulsory insurance: ensures that funds are available to compensate those who are adversely affected and to provide an incentive to reduce leaks, spills and accidents. On the other hand, there is *prima facie* evidence that subsidized insurance encourages farmers, for example, to extend cultivation into more hazard-prone areas, this tends to increase risk rather than decrease it. There is a lot of experience in this field and the pay-off for research would be substantial even in the short term (l-3 years).
- pricing mechanisms, effluent/user charges, liability for damages: in theory these could be used to reduce the level of waste generation and the number of accidents: however, the practical applications have been few and far between. It would be useful to investigate the practical or perceived obstacles to the adaption of such legal-economic mechanisms.
- the insurance business, with its long experience of underwriting risk including environmental risks: the setting up of a working group of researchers and underwriters to explore research opportunities (e.g. to study Ontario experience of coping with the "spills bill" starting in September 1985) might be fruitful.

5.5 Assessing Economic Risk

One of the most basic questions that EIAs have to answer is whether the imposition of mitigating measures would risk the economic well-being of a firm, industry or region.

One needs to assess the effects of mandated changes on the performance of firms and market shares; the effects of regulatory uncertainty on site selection and investment decisions; the effects (positive or negative) of mandated measures on economic performance (e.g. productivity, employment, profitability, investment). We agree with the NRC (1982:60) Committee on Risk and Decision Making that "reliable economic research does not currently exist to refute or establish [various] claims". For example, Stafford (1985) argues from empirical evidence that environmental quality regulations do not rank among leading location factors of industry and are far less important than labour and market access. A literature search. and brief review would provide CEARC and FEAR0 with an initial understanding of research findings and opportunities in this somewhat neglected field. It should be pointed out that the interface between economy and environment is a major thrust of current federal activity. In addition, for EIA the impact of mandated changes in the project on local economy is nearly always important. A CEARC-sponsored working group and workshop in the next year or two could be useful in pointing out what is known and what needs to be known as well as in making appropriate recommendations.

6. RESEARCH PRIORITIES

In this section we select some of the research needs and opportunities that we think ought to be given priority. As a reading of Sections I-5 shows, this list could be much longer. These priorities are based on the arguments of the previous sections, but we have also kept in mind other considerations: what we believe would produce the best results in the shortest possible time; what we believe needs to be carried out urgently; and what we believe would be particularly important in improving EIA. Our last two more general recommendations reflect the fact that there is much more to be learned about risk from current and past experience than can be gleaned from books about the theory of risk management. Each of the other recommendations reflects the material in one or more sections above.

1. Research is needed into the presentation of technical information on risks to non-experts (Section 2.4).

One of the great stumbling blocks to the incorporation of risk assessment techniques into EIA is the mathematical nature of much of risk analysis. The presentation of these analyses is critical in developing public understanding of the strengths and limitations of analytical techniques devoted to risk estimation. In addition, misunderstandings over risk threaten to polarize future debate over the potential consequences of proposed projects to an even greater extent than is now the case.

We believe that the major responsibility for improving technical presentation — i.e. translating the results and implications of analyses — lies with the technical analyst themselves.

2. The next full-scale EIA should have associated with it a social science research component which would trace and track the various expressions of risk strategies on the part of the scientists, experts, project proponents, and the public (Sections 3 and 4).

Because of the importance of understanding the dynamics of risk perception and public acceptability in solving conflicts over risk, it is vital that competent social science be incorporated into the risk assessment process. A potentially controversial EIA would provide an ideal opportunity to investigate and evaluate the various social science models now developing in the area of risk. Not only would this provide social scientists with much-needed real-world experience of environmental controversies of this type, but the results of their research could be immediately relevant to resolution of conflict in the specific EIA chosen.

3. We need to investigate the appropriateness of including economic risk into a risk assessment (Sections 4.2 and 5.4).

The switch to an overall "risk philosophy" may present the opportunity to include the economic risks and benefits of proposed projects under the EIA process in a more comparative and integrative way than has hitherto been possible. The proponent is likely to be capable of exploring in detail the economic risks and benefits of any proposed project, while it may also become necessary to consider a package of mitigative measures, compensation and insurance for potentially adversely affected communities. A single, or broadly consistent accounting system for the risks and benefits associated with proposed projects would simplify the job of the decision makers.

However, it may be the case that the similarities are specious, and that comparing economic risk with health risk is unacceptable on other grounds, i.e. given certain moral imperatives in our society. It is in this murky area that research is most required.

4. We need to explore various methodologies for making trade-offs so as to achieve acceptable levels of risk (Sections 4.2 and 4.3).

There are a number of approaches which claim to be able to achieve some resolution of what is or is not an acceptable risk (e.g. risk/ benefit analysis, conflict resolution analysis, mediation, arbitration, and litigation). While these have garnered a substantial research literature, their usefulness in real situations is relatively untested. Research is required to see which — if any — of these techniques can effectively deal with difficulties in the messy world in which we live. We strongly recommend studies into the evaluation of mitigative measures, both physical and compensatory as components of adaptive decision making.

5. Scenario building (particularly worst-case analysis) as a method of prediction needs to be examined further (Sections 2.2 and 2.3).

Research into the risks and consequences of LOPHIC (low probability high consequence) events is particularly relevant to EIAs (e.g. on nuclear power plants, hydrocarbon exploration in the Arctic). Much of the current risk analysis work focusses on worst-case analysis, which often may be appropriate, but at other times may be a waste of valuable time and effort. One alternative might be to try and come up with "worst-plausible-case" analysis, which would focus attention on serious areas of concern. In doing this, it is essential that "plausibility" be decided upon as a result of extensive involvement by all parties in any risk assessment. In fact, this kind of scenario building would be an excellent way to enable the public to usefully express its concern about the future. Research in this area should address worst-case analysis and worst-plausible-case analysis in terms of minimum requirements of technical information, understanding by non-specialists and the potential contribution of interested publics (Section 2.3).

6. Guidelines for technical risk analyses in an EIA need to include criteria on when the data and the scientific understanding are deemed to be adequate (Sections 2.2 and 2.3).

For risk analysis to be of use to EIA, there must be an adequate information base (i.e. data and a viable technique for analysis). Analysis is often hampered with information generated for other purposes, the disparate quantities and qualities of available data, and the need to extrapolate beyond the range of observations. The guidelines for a specific EIA should include suggestions on which kind of data and functional (i.e. predictive) relationships would be considered adequate for a decision to be made. In some cases it should

be made clear to proponents, intervenors and panel members that there is not a sufficient information base for reliable risk estimation. Research into this field is required to examine cases, provide examples and explore further the dimensions of information quality.

7. **Guidelines for carrying risk assessments should be developed** (Section 2).

Each risk assessment is unique and can be complex and difficult, particularly in view of problems with lack of data, uncertainties and public involvement. Because the literature on risk assessment has expanded so rapidly in the last few years, it may be helpful to practitioners to develop guidelines on risk assessment. Such guidelines would make these assessments more consistent across EIAs. Guidelines could be developed around various difficult issues, such as when a risk assessment is necessary, what risks to consider and what information on risks should be provided, the use and admissibility of data, and how to present risk-related information in an EIA.

Though such guidelines would necessarily at first be general in nature, they could be of immediate use. Attempting to write guidelines would also help to identify gaps in practice and understanding and, of course, the guidelines would be revised as research progresses and experience in risk assessment is gained.

8. **Existing uses of risk assessment in EIA should be codified and systematized. Some environmental sectors would immediately benefit from the systematic application of risk assessment. We recommend that these be identified, and used as potential "initial experiements" for the further implementation of risk assessment in EIA.**

One way to take advantage of opportunities for improving the use of risk assessment in EIA would be to examine and codify current applications of what are risk concepts in everything but name. The interim evidence collected by Paradine (1985) suggests that risk concepts have already been applied in a limited fashion in EIAs. Research. would focus on when risk analysis is useful, whether its utility has been recognized, and **whether or** not more explicit use of risk concepts would make EIAs more comprehensive and relevant.

9. **Retrospective and comparative case studies of previous Canadian and international EIAs should be undertaken.**

One basic thrust of this paper is that the predictive nature of EIAs is often hampered by the limited experiential base for the types of risk under examination. Comparative evaluations of past analyses are probably the most cost-effective way of learning how to do better in the future. Critiques could point out omissions and inappropriate methodologies; but perhaps more importantly, they could identify "good" studies, and the features that made them stand out as successes.

Retrospective studies should preferably be selected from fields where there is considerable experience, and which are likely to be repeated in the future: e.g. hydrocarbon development in the Arctic (see priority 8 above).

Case studies from a variety of jurisdictions in Canada, the United States and other countries would be particularly illuminating, since they could suggest:

- why some risks are tolerated in some countries, cultures, and politico-economic systems rather than in others: e.g. the comparative ease of securing public acceptance or acquiescence for building nuclear power plants in France versus the opposition in the United States and other countries;
- what the different mechanisms are for coping with risk devised by different countries, cultures, or politico-economic systems.

In order for these to be more than just interesting stories, retrospective debriefings should be carried out by senior scientists, experienced panel members, and other experts working as an interdisciplinary team. We view retrospective, comparative case studies as a way to put into effect the iterative and potentially open-ended nature of the EIA process.

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