increased productivity. Supporting texts made it clear that much of the "new" regulation-including health, safety, and environmental standards-was implicated.

mines.

Another result has been renewed interest in the study of the distortions which occur in individual perceptions of low probability events carrying risks of highly unfavorable consequences. One such study, a joint project of the International Atomic Energy Agency and IIASA, was directed explicitly at the consequences for societal decisions related to large-scale technology. Other work on analytical methods for possible improvement in public decisions involving risk was discussed at the 1977 Denver meetings of the American Academy for the Advancement of Science, and has recently been reported in a publication in its Symposium Series under the title, "Judgment and Decision in Public Policy Formation". Both of these efforts will be discussed further below.

The purpose of this article is to reflect briefly on the issues raised in all this literature, and the implications for our present institutions. (For those interested, footnotes and detailed references-which would be out of place in this context-have been collected in a separate note available from the writer.)

More importantly, however, the purpose is to call attention to the need for discussion of this topic, with this magazine being one forum for the purpose. Canada has supported IIASA as one of the founding members; utilization of the work done by that body in the area of risk assessment is one of the ways in which that investment might have direct national payoff. For this purpose, a major conference following up the Denver meeting and attempting a synthesis of the lessons from the IIASA work and related European studies is planned for next year.

Indeed, amongst the major programs of the Institute from which Canada has derived significant benefit is the work on ecological systems initiated by Buzz Holling and his co-workers at IIASA, and now carried on at U.B.C. Some of their ideas on "resilience" and "hazard management" deserve to be debated in these pages as crucial questions of social policy.

Thus, this present article is really a call for a debate on appropriate compromises in the ancient tension between analysis and politics in government-between "scientific" thinking and "strategic" thinking in handling public decisions. It seems clear that in matters of risk assessment and standard-setting, we are increasingly heading down the road of partisan analysis, of advisers as advocates, of the competition of ideas in formal or informal "science courts".

Must we do so? Is it necessary that we live with the fact that people do not seem to deal with risky situations as "logic" dictates they should, or are the participants in social decisions "educable" on these matters? If individual perceptions of risk deviate from consistency, must collective decisions be equally idiosyncratic? What role can analysis play in such decisions?

As an aside, it is interesting that there seem to be some particular difficulties in the handling of uncertainty. Conventional wisdom in the operations research literature suggests that experience teaches pretty good solutions to optimization problems: trial and error, and rules of thumb, seem to lead close to optimal solutions to many of the very complex optimization problems that arise in industry. And, despite some recent disenchantment, it is fascinating that industrial societies have evolved market mechanisms to provide precisely the information and the incentives leading to such solutions of both static and dynamic optimization problems.

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But in the presence of uncertainty, these results seem to collapse: people do not seem to be intuitively very good decision analysts, and, with few exceptions, appropriate market mechanisms for pooling risks have not evolved. How effective "good" analysts might be in arriving at "good" decisions is a question explored a little further below.

"Responsible Regulation", the interim report of the Economic Council of Canada's regulation reference, makes it very clear that the "new" regulation will prove, in the end, an unlikely candidate for deregulation. Inextricably associated with the setting of standards-for health, or safety, or fairness-such regulation is opposed by many businessmen as both costly and arbitrary. Yet strong pressures exist to retain such regulatory authorities, even though little is known about the consequences, the alternatives, or procedures to establish appropriate levels for standards in any of these areas.

Present procedures do not appear to achieve anything close to a rational allocation of society's resources amongst lifesaving and other competing social objectives, or even among different ways to achieve the goal of reducing risks of life. Examples abound: investments in highway engineering appear to promise a reduction in highway deaths at a cost of only $20,000 to $80.000 per life saved; decisions on standards for air travel imply a value of at least ten times that amount. It has been suggested that some regulatory decisions in the nuclear power industry imply a cost per life saved of around six billion dollars.

One cannot quarrel directly, perhaps, with any of these numbers, although the Economist of March 22, 1980, took to task the estimates of the U.K.'s National Radiological Protection Board which had just published a resources in n clear

sex has a lesson for analysts.

Simple calculation shows that if an hour of jogging per day will extend the life of an eighteen-year old by only two years (from 70 to 72, say) the time for living (net of jogging) is still reduced. Before jogging fans rise in anger, it should be added that if jogging is also counted as living, then no problem2,

events must depend upon how much of the veil of uncertainty has been lifted thus far, and what has been revealed.

The problem boils down to the appropriate point of departure or origin of events. Pierre Simon, Marquis de Laplace, put it well almost two hundred years ago:

> *When a number in the lottery of France has not been drawn for a long time, the crowd is*

suggests that otherwise intelligent and "rational" individuals may not have valid perceptions of the frequency of the hazardous events to which they might be exposed. Their assignment of probabilities to various possible outcomes may be subject to systematic distortion or illusion.

In particular, there appears to be a tendency to overestimate the probability of highly memorable or easily imagined events. Professor A. Tversky of the Hebrew University of Jerusalem, who for the past decade has been conducting a research program into the principles that govern human judgment under conditions of uncertainty, refers to this as the principle of availability. "In this heuristic, one judges the probability of an event, or the frequency of a class, by the ease with which an event can be imagined, or by the ease with which instances of the class can be brought to mind." Sensational media coverage of some classes of events obviously may contribute to this weighting of risks.

There appears to be an overly strong tendency for beliefs to be held in the face of the evidence. The failure to incorporate new information into one's beliefs in a sufficiently responsive way leads to perseverance of initial opinions in the face of conflicting evidence longer than any "rational" information-processing model would predict. On the other hand, Tversky refers to the contrary problem in dealing with general statistical (prior) information as compared to specific "individuating" information. "Data show that, when statistical information alone is available, people use it sensibly; once individuating

may be troubled by the degree of responsibility for the weekend climber trapped on a mountain he has been warned not to attempt, as compared to that for the miner forced by economic circumstance to work miles below the surface.

Perhaps the voluntary assumption of risk for the sake of challenge or thrill should include the voluntary relinquishing of any claims for extraordinary social action in case the risks are realized?

The vexed question of the degree of social responsibility for those who bring some of the hazards upon themselves arises in other ways. Should the same social resources go into treatment of lung cancer in those who have steadfastly refused to help themselves by reducing their consumption of cigarettes as to those who have never exposed themselves in that way?

In the Treasury Board Secretariat study of exposure standards in uranium mining. the use of protective helmets as a means to reduce levels of exposure for individual uranium miners was considered. But it was argued that union officials do not like solutions to health and safety problems which require active participation and cooperation by the workers, preferring instead more general attacks on sources of damage. Under some circumstances, however, one might expect reliance on some degree of individual responsibility to be an appropriate feature of solutions to problems involving risks.

It has become common to separate the question of social choices relating to risk into two elements, as above-the problem of estimating the relevant probabilities, and the problem of appraising the acceptability of increased risk undertaken for the sake of some promised benefit.

The first problem may appear a straightforward technical matter, but we have already observed that people have real difficulties in assessing properly the risks to which they are exposed. Perceptions of risk are distorted, though this does not mean that they cannot be improved with education. Moreover, the data on which to base probability estimates are almost always absent. In any significant social decision relating to risk, judgments will have to be substituted for data in the assignment of some critical probabilities. Another way of saying essentially the same thing is that it is hard to know what is meant by the frequency of hazards associated with one-time events.

But the even more ticklish subject will be the appraisal of the outcomes, or the utilities associated with the pay-offs, or the preferences as to all the possible consequences. In estimating the social costs of projects that might increase the risk of death, or the worth of activities that might prolong life, two general lines of thought have developed.

The first, or "human capital" method, sought to value loss of life in terms of the loss in national product resulting from the increase in mortality. This notion of compensation to those affected shows up rather naturally in damage suits and court judgements, but it has been criticized, accurately, as failing to recognize the rather common personal desire not to die, even if all those around could be fully insured or compensated for the loss.

A second method has grown up to circumvent this problem, based on the idea of "willingness to pay" to avoid loss of life. A variety of approaches to assessing personal willingness to pay have been devised and discussed.

But to the extent that both of the above methods seem to be attempting to attach an explicit value to an identifiable human life, they are hotly contested as attempting to measure the unmeasurable. The fact that implicitly we do it all the time, and take for granted the necessity to do so, does not reduce the fervor of this criticism.

An alternative approach seeks to avoid asking about the "value of a life" by attempting to determine the value of a reduction in risk. Rather than evaluating the loss of a life, therefore, this method considers the price that should be paid for a reduction in the mortality curve, or an increase in the probability of survival.

The human capital method has the advantage of relying on conventional sources of data and familiar accounting or actuarial principles. Unfortunately, it is often seen as missing some essential features in the social assessment of risk. Despite this criticism, the figures so derived may be useful as lower bounds or minimum estimates for purposes of cost-benefit evaluations of proposed investments in safety.

Willingness-to-pay measures, by contrast, must rely on much less conventional data. We have, of course, some implicit evaluations or social preferences revealed by past investment decisions. We have spent, or elected not to spend, money on vast arrays of social projects having recognized impacts on lives lost or saved. Unfortunately here, too, we have noted that the record appears to show significant inconsistencies, whether one looks at implicit valuations of lives lost, or implicit valuations of reductions in risk. The Marquis de Laplace again:

The mind has its illusions as the sense of sight; and in the same manner that the sense of feeling corrects the latter, reflection and calculation correct the former. Probability based upon a daily experience, or exaggerated by fear and by hope, strikes us more than a superior probability (which) is only a simple result of calculus. Thus we do not fear in return for small advantages to expose our life to dangers much less improbable than the drawing of a quint in the lottery of France; and yet no one would wish to procure for himself the same advantages with the certainty of losing his life if this quint should be drawn.

uniform for all concerned; it is, of course, a still more difficult social problem if the odds appear to favour the poor and native over the rich and white. Even with fully equitable selection, the problem of

bathtubs pose greater risks curable at lesser costs.

One must respect the rights of individuals to say things and do things that are not consistent with the textbooks

control. We prefer to die in familiar, homely ways: we underplay the familiar risks and ascribe excessive importance to the unknown. We prefer to die in small accidents, while overstressing the risks of major catastrophe. We place infinite value on our lives cata -12 1ts, while