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# RESEARCH IMPLICATIONS OF SCIENCE-INFORMED, VALUE-BASED DECISION MAKING

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**Abstract.** In 'Hard' science, scientists correctly operate as the 'guardians of certainty', using hypothesis testing formulations and value judgements about error rates and time discounting that make classical inferential methods appropriate. But these methods can neither generate most of the inputs needed by decision makers in their time frame, nor generate them in a form that allows them to be integrated into the decision in an analytically coherent and transparent way. The need for transparent accountability in public decision making under uncertainty and value conflict means the analytical coherence provided by the stochastic Bayesian decision analytic approach, drawing on the outputs of Bayesian science, is needed. If scientific researchers are to play the role they should be playing in informing value-based decision making, they need to see themselves also as 'guardians of uncertainty', ensuring that the best possible current posterior distributions on relevant parameters are made available for decision making, irrespective of the state of the certainty-seeking research. The paper distinguishes the actors employing different technologies in terms of the focus of the technology (knowledge, values, choice); the 'home base' mode of their activity on the cognitive continuum of varying analysis-to-intuition ratios; and the underlying value judgements of the activity (especially error loss functions and time discount rates). Those who propose any principle of decision making other than the banal 'Best Principle', including the 'Precautionary Principle', are properly interpreted as advocates seeking to have their own value judgements and preferences regarding mode location apply. The task for accountable decision makers, and their supporting technologists, is to determine the best course of action under the universal conditions of uncertainty and value difference/conflict.

**Key words:**

Decision technology, Decision analysis, Bayesian science, Cognitive continuum, Best Principle

## INTRODUCTION

Scientific researchers are often tempted to collude with policy makers' desire – reflecting the dreams of their constituents – to be seen as offering 'science-based' decisions and policies. However, value judgements are the logically necessary basis for all decisions, so, irrespective of the amount of certainty and uncertainty in the scientific evidence, the most that scientists can do is inform value-based decision making. Putting it this way is not intended to diminish the vital importance of this role, but it is a preliminary to arguing that, at the moment, scientists are not performing this 'informing' task appropriately – or efficiently, taking into account the societal resources involved

– and policy makers are not asking for it to be performed appropriately. This reflects a long-standing and partly self-serving confusion in both groups between the methodologies and criteria appropriate for knowledge generation and evaluation on the one hand and for decision and policy making on the other. In the former, scientists correctly operate as the 'guardians of certainty', using hypothesis testing formulations and value judgements about error rates and time discounting that make classical inferential methods entirely appropriate. But this approach and these methods can neither generate most of the inputs needed by decision makers in their time frame, nor generate them in a form that allows them to be integrated into the deci-

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sion in an analytically coherent and transparent way. Both the nature of public decisions and the need for transparent accountability in public decision making under uncertainty and amid value conflict mean that the analytical coherence provided by the stochastic Bayesian decision analytic approach, drawing on the outputs of Bayesian science, is needed. Hence, if scientific researchers are to play the role they should be playing in informing value-based decision making, they need to see themselves also as 'guardians of uncertainty', contributing to optimal decision making, by ensuring that their current posterior distributions on relevant parameters are made available for decision making, irrespective of the state (or results) of the knowledge-generating (certainty-seeking) research. So long as the fundamental distinction between Classical 'Hard' Science and Bayesian Science is strictly maintained, and always publicly stressed, both functions can be performed well by the same person or group – and what ought to be complementary aspects of scientific careers thereby safeguarded.

In developing its theme, the paper distinguishes the actors employing different technologies in terms of the focus of the technology (knowledge, values, choice); the 'home base' mode of their activity on the cognitive continuum of varying analysis-to-intuition ratios; and the underlying value judgements of the activity (e.g., error loss functions and time discount rates). It is argued that those who pro-

pose any principle of decision making other than the banal 'Best Principle', for example the 'Precautionary Principle', are properly interpreted as advocates seeking to have their own value judgements and their own preferences regarding mode location apply. Thus they are fully entitled to do, like all of us, but only as advocates. The task for accountable decision makers, and their supporting technologists, must be to determine the best course of action under the universal conditions of uncertainty and value difference/conflict.

**TECHNOLOGIES**

Technologies are ways of doing things. If we want to do something, we have to use a technology. If we want to increase our knowledge or represent the current state of our knowledge and uncertainty, we have to use a Knowledge Technology (KT). If we want to establish our values, we have to use a Valuation Technology (VT). If we want to make a decision – and this will require somehow integrating the current state of our knowledge and our values - we have to use a Decision Technology (DT). Finally, though of relatively little concern here, if we want to communicate information about anything (knowledge, values, decisions), we have to use an Information Technology (IT). All these tasks can be – and are in practice – tackled at most modes on the Cognitive Continuum of changing

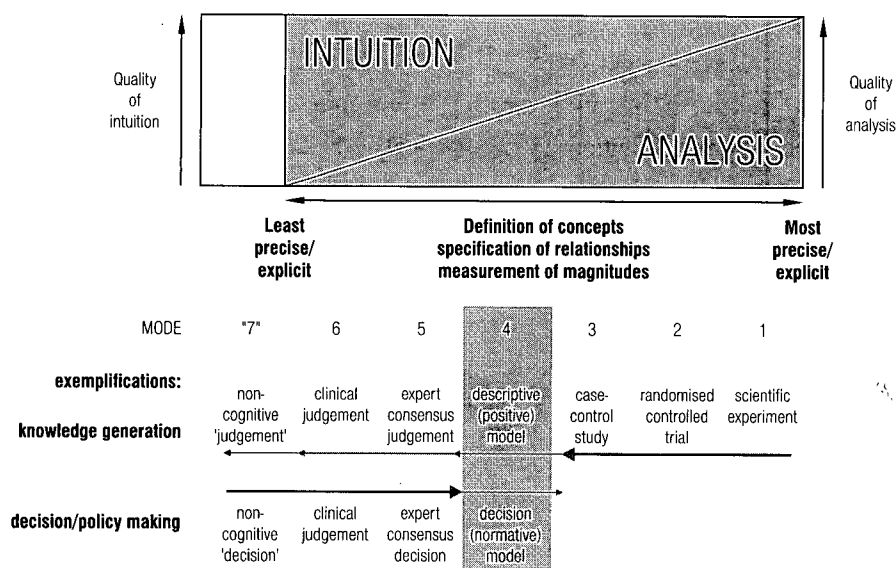


Fig. 1. The Cognitive Continuum with exemplifications.

Analysis-to-Intuition (A-I) ratios (Fig. 1). But obviously very strong views are held about where they should be tackled, especially in relation to Decision Technologies when the decisions are either public/societal (as in public health) or agent-involving (as in clinical medicine) [1].

Very briefly, Cognitive Continuum theory suggests that we have two basic types of cognition available to us – analysis and intuition. Contrary to thinkers who see these as binary and exclusive, Hammond [2] suggests that we think of them as being combined, and combinable, in different ratios along a continuum running from highly intuitive at one extreme to highly analytical at the other. Broadly speaking, as we increase the A-I ratio, the definition of concepts, the specification of relationships and the measurement of magnitudes becomes more explicit and precise – and ‘transparent’ in current parlance. While the continuum is indeed a continuum, broad ranges can be conceptualised as relatively distinct modes of cognition. Six seem sufficient to locate the main types of inquiry and practice. It is important to emphasise that there is no implication that the higher the A-I ratio the better, nor the reverse, so that the numbering scheme and orientation in the diagram has no significance in this respect. The quality dimension emphasises that both analysis and intuition may vary in quality in any particular instantiation.

## KNOWLEDGE TECHNOLOGIES

We have two ultimate aims involving knowledge – possessing it and using it. We want to know ‘the truth’ and we want to make good decisions. While different definitions follow from these different aims, in both cases we are interested in the nature of states of the world (both biophysical and human), the processes that link them (especially ‘causal’ links) and the events that change either the nature of the states or the linking processes.

In pursuit of the former, Truth-Focused, aim we define knowledge as ‘the certain truth’ - and only the certain truth. This is the aim of the activity we will refer to as ‘Hard’ Science and suggest it usefully characterised as a Truth-Focused Certainty-Seeking Knowledge Technology. It seeks to increase the stock of knowledge by

removing the uncertainties we have, especially about causation. Only when all uncertainty is removed, and certainty achieved, is knowledge increased. There can be no justification for compromising on standards for external instrumental reasons (such as decision making). For this reason ‘Hard’ Science has a zero time discount rate, as indeed should all Truth-Focused technologies.

In pursuit of the latter, Decision-Focused, aim we define knowledge as the extent to which we are not uncertain about something at this (decisional) point in time. The aim, and only aim, of the activity we will refer to as Bayesian Science (a Decision-Focused Uncertainty Representing Knowledge Technology) is to represent that certainty/uncertainty in the way that will best help make the best decision now. Time limitation, dictated by the decision focus, is central to this activity and means that it will almost always be necessary to accept only limited fulfillment of ‘scientific standards’.

The best decision will obviously incorporate any relevant certainties established by Truth-Focused Certainty-Seeking Knowledge Technology, but these will invariably be insufficient to determine a public decision, even if we were to leave aside (as we can’t) the necessary value inputs. Moreover, the format of the output from a Truth-Focused Certainty-Seeking Knowledge Technology will typically be inappropriate for decision makers using an analytic Decision Technology.

In terms of the cognitive continuum, ‘Hard’ Science as a Truth-Focused Certainty-Seeking Knowledge Technology is undertaken at mode 1 in relation to physical and biological objects and at mode 2 in relation to human beings as assemblies of physical and biological elements (as in most RCTs). Whether or not some relaxation of these downward cut-offs is permitted in practice, there are clear cut-offs in principle, not least to ensure that conventional scientific standards have been met at the most rigorous and transparent level – and hence be replicable.

On the contrary, Bayesian Science as an Decision-Focused Uncertainty-Representing Knowledge Technology can have no cut-off on the continuum since the best possible representation of our current uncertainty in a particular case may be generated at any mode. Bayesian Science is

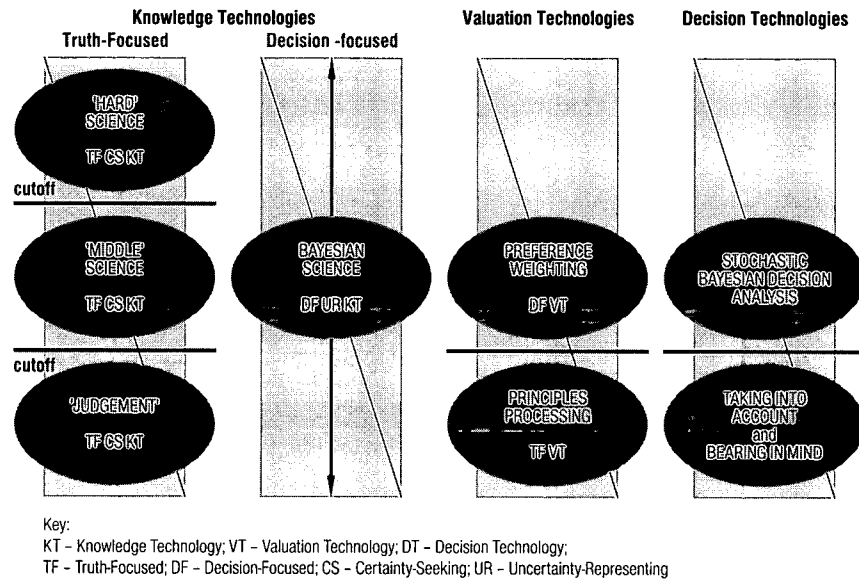


Fig. 2. Locating knowledge, valuation and decision technologies.

generally disposed to respect the 'hierarchy of evidence', subject to this being extended to modes below mode 2 and any cut-off being eschewed. But there is no assumption that scientific standards can be fully met within the relevant time window and indeed the Truth-Focus implies irrelevant value judgements about error costs. The 'home base' of Bayesian Science is the middle (modes 3 and 4) of the cognitive continuum.

So far, for expositional convenience in contrasting 'Hard' Science and Bayesian Science, we have talked as if the former is the only Truth-Focused Certainty-Seeking Knowledge Technology. But of course many within Western cultures, as well as many non-Western ones, believe there are other valid ways of truth seeking, especially in relation to human beings and the human world.

Within what we will call 'the Humanities', the term 'understanding' may be used as often as, or instead of, 'knowledge', but in terms of our framework we are still dealing with Truth-Focused Certainty-Seeking Knowledge Technologies. These, however, are ones located at modes 5 and 6 - or even the non-cognitive mode 7 - at the opposite end of the Cognitive Continuum to 'Hard' Science. Proponents of such ways of truth-seeking tend to employ an upward cut-off, paralleling the downward cut-off of 'Hard' Science. The implication is that, above a certain Analysis-to-Intuition ratio, and particularly in respect to concep-

tual precision and quantification, one cannot obtain 'true' understanding or knowledge about people as people (as distinct from biophysical entities) and the meanings they attach to things (life, art, relationships, the self ...).

Looking at the left hand column of Fig. 2, we now have a picture in which the two dominant Truth-Focused Certainty-Seeking Knowledge Technologies of our times ('Hard' Science and 'Judgement') are located at the extremes of the continuum. This leaves the middle modes as the location of what we will call (for want of a better term and to avoid 'Soft') 'Middle' Science. This embraces such activities as 'observational' as opposed to 'interventional' studies in the health sciences, descriptive 'modelling' in various disciplines, and most of the empirical 'social sciences'. Each of the three, for its own reasons, operates a cut-off in relation to its neighbours, 'Middle' Science being subject to cut-offs from each direction and often suffering disparagement simultaneously from those in 'Hard' sciences and the typically qualitative judgemental disciplines. However, its inhabitants often themselves affirm these boundaries by stressing the importance of avoiding both the Scylla of 'objectivity' (upwards in our diagram) and the Charybdis of 'subjectivity' (downwards) (in academic terms it is obvious that inter-disciplinary disputes are often essentially about cut-off infractions, but perhaps not so obvious that many intra-disciplinary fights

in subjects such as economics and psychology are also about where the discipline should be located in relation to these boundaries).

The dominant Decision-Focused Uncertainty-Representing Knowledge Technology, Bayesian Science, also has these middle modes as its home base, but has no cut-off either upwards or downwards and draws from all depending on the case (see second column from left in Fig. 2).

### VALUATION TECHNOLOGIES

In contrast to knowledge, it does not make sense to say that we want to 'increase' Values, but there is much interest in establishing the 'one true' set of values. Through the centuries many individuals and groups have claimed to have discovered 'the truth' in this respect and much of the world's misery has followed from such 'discoveries'.

From our decisional point of view, however, the key issue is the way the Value inputs are established at decision time. Here we identify the dominant types of Valuation Technology as Truth-Focused Principles Processing and Decision-Focused Preference Weighting (see third column of Fig. 2).

In Truth-Focused Principles Processing values are held in the form of general principles, usually a mixture of both the deontological (rights and duties) and the utilitarian (both act and rule), with the processing of these involving a judicious discursive qualitative weaving – 'artful moral dodging' in Morreim's [3] complimentary term. No formal, explicit ranking or rating of principles is established in this discourse, let alone any abstract quantitative trade-off of one with another. The 'home base' of Truth-Focused Principles Processing is therefore modes 5 and 6 – and in many cases, it would seem, the non-cognitive mode 7.

In Decision-Focused Preference Weighting these principles are translated/transformed into the aspirationally coherent and quantitatively ranked and rated preferences necessary for analytical decision making. Such preferences necessarily reflect the trading-off of the competing claims arising from different ethical principles and moral claims and, in essence, involve the commutation of all the principles into a single metric. Note that, for decision making,

it is not a question of whether this commutation is done, but how it is done. It can be done non-transparently at the largely intuitively modes (5 and 6), or much more transparently at the analysis-to-intuition ratios that characterise the middle modes (3 and 4).

### DECISION TECHNOLOGIES

We are now in a position to compare the two basic types of Decision Technologies available.

The currently dominant DT used in public decision making is located at modes 5 and 6. It is referred to here as Taking Into Account and Bearing In Mind (TIABIM), because these phrases are characteristic of the way their decision process is described by those involved. Stereotypically TIABIM involves taking into account and bearing in mind the outputs of Truth-Focused KT's ('Hard' Science at modes 1 and 2, 'Judgement' at modes 5 and 6 and, with distinctly less enthusiasm, 'Middle' Science at modes 3 and 4) together with the outputs of Truth-Focused Principles Processing at modes 5 and 6. To accomplish the cognitive 'sleight of mind' involved in such cross-technology and cross-mode integration Taking Into Account and Bearing In Mind requires the use of concepts that are non-operational and implicitly confound knowledge and values. 'Risk', when used, as it typically is in TIABIM discourse, other than as a simple synonym for probability or disutility, is a leading example. 'Safe' and 'dangerous' and their various cognates are others. We have argued at length elsewhere why the 'Risk Approach' is incompatible with analytically coherent public decision making and should be replaced by the Decision Analytic one [4].

The contrast with the main alternative DT, Stochastic Bayesian Decision Analysis, could not be starker. Mode 5/6-based TIABIM reluctantly makes some use of Truth-Focused inputs from the middle modes ('Middle' Science) but relatively little use of Decision-Focused inputs from Bayesian Science based in the 'middle modes' (in the UK the National Institute for Clinical Excellence is taking the first faltering steps towards greater use of such inputs within its increasingly analytic decision technology). On the contrary, Stochastic Bayesian Decision

Analysis is not only based in the middle modes itself, but achieves its coherence by using, as its inputs, the outputs of a middle mode-based Decision-Focused Uncertainty-Representing KT (such as the probabilities generated by Bayesian Science) and a middle mode-based Decision-Focused Preference Weighting VT (such as utilities and QALYs).

To many scientists and large numbers of the public, 'Hard' Science is the only valid Truth-focused Certainty-seeking KT. The problem with this position is that when it comes to decision making the results (or lack of results) obtained by 'Hard' Science can be incorporated into decision making only when the DT is located at mode 5 or 6. And in fact the same applies to the outputs of all types of Truth-Focused KT – they can only be used within a TIABIM-type DT. Because it is Decision-Focused, Bayesian Science is the only appropriate KT if we wish to adopt a middle mode DT.

It is, of course, no part of the role of the analyst, as analyst, to influence the decision maker's mode of decision making. But the responsible and accountable, and indeed ethical, public decision maker would be well advised not to assume that they are able (in TIABIM mode) to outperform the recommendations emerging from a modelling exercise (e.g., a SBDA) merely because they can point to flaws and limitations in the model. Especially not when they are making a totally irrelevant comparison with the output of a Truth-Focused Certainty-Seeking Knowledge Technology. It hardly needs pointing out that there is a considerable evidence that the implicit decision models of the human decision makers involved in TIABIM – usually committees of some sort – have flaws and limitations. The real issue is accordingly the comparative imperfection of these alternative decision technologies. Failure to recognise and accept this leads to the endemic phenomena of 'double standards' and the 'nirvana trap', which involve applying standards of perfection to DTs, particularly middle mode ones like Stochastic Bayesian Decision Analysis, that one has no intention of applying to oneself (at mode 6) or in collaboration with one's fellow decision makers (at mode 5). While it is socially acceptable and almost mandatory to stress that it is es-

sentia that the contents of a model are robust enough to withstand critical scrutiny, it is much less acceptable to suggest the same rigorous examination of the contents of a decision maker.

The Decision-Focused inhabitants of the middle modes, whether Bayesian Scientists, Preference Weighters or Stochastic Bayesian Decision Analysts suffer the twin socio-professional perils of 'living in the middle' of the continuum and insisting that decision making inputs should be derived from Decision-Focused not Truth-Focused technologies. Historically, the universal desire for certainty has led to the privileging of the two poles of the A-I continuum, i.e., mode 1, where it was felt we could trust the process of objective science, and mode 6, where it was felt we could trust the personal authority of the individual expert. Recently, growing disaffection with, and distrust of, these extreme modes has led to greater willingness to move inwards at both ends, to high quality mode 2 scientific research processed by expert groups at mode 5 ('Evidence-based ...' is the adjective now commonly applied to this TIABIM-type DT, still making only slow advance relative to the traditional mode 6 DT of 'clinical/professional judgement'). But there is still formidable reluctance and hostility to any move further inwards to the middle modes (4 and 3) that represent the most equal balancing of analysis and intuition.

Why this reluctance? We suggest that, apart from massive vested material interests, it is because in the middle of the continuum one actually maximises what we really – psychologically and socio-psychologically – do not want to know. In the middle we maximise uncertainty by exposing all its sources as completely as possible and insisting that all the uncertainties be dealt with explicitly, transparently and quantitatively, rather than denied or dealt with implicitly, covertly and qualitatively, as is still substantially the case at mode 5 (albeit less so than at mode 6). Equally, in the middle we maximise the extent to which we are confronted by the existence of incoherent values within individuals and groups and value differences and conflicts between individuals and groups (such as over uncertainty preferences and time discount rates). In the middle we are denied our denials.

## RESEARCH IMPLICATIONS AND THE BEST PRINCIPLE

There are three clear research implications from the foregoing argument, which, as with the argument itself, it is only possible to present in broad outline here.

The first is that public funding for 'scientific' research should require both types of science (Truth-Focused and Decision-Focused) to be undertaken within any project in order to ensure that the work yields maximum benefits for ongoing decision making as well as for long-term knowledge accumulation. If scientific researchers are to play the role they should be playing in informing value-based decision making, they need to see themselves also as 'guardians of uncertainty', contributing to optimal decision making by ensuring that their current posterior distributions on relevant parameters are made available for decision making, irrespective of the state or results of the knowledge-generating (certainty-seeking) research. Truth-Focused Certainty Seeking and Decision-Focused Uncertainty Representation need to be accorded equal status and respect. We need to recognise that the major existing paradigms (the 'Hard' Science and the Bayesian) are complementary not competitive, but very clearly distinguish the tasks for which each is appropriate and inappropriate. We do not need a new scientific paradigm.

The second is that serious 'scientific' research into the value base of public decisions is as necessary as that into the knowledge base and should be well (i.e., much better) funded. The third, and the one on which we concentrate for the present purpose, is that no research based on, or directed towards, the 'precautionary' or any other such decision principle is required. Resort to a Truth-Focused decision principle such as the 'Precautionary Principle' represents an ultimately doomed and expensive attempt to avoid the pain of moving to the middle and dealing with the issues involved through a Decision-Focused technology located at the minimum analytical level necessary for transparent and accountable public decision making.

The 'Best Principle' is the only decisional principle we need; all others are diversions from, or deterrents to, the systematic clarification and processing of uncertainties

and value differences – including especially risk preferences and time discount rates – that will be undertaken as part of best practice Stochastic Bayesian Decision Analysis. That analysis may well show that, using the preferred inputs of some parties, the optimal course of action would be to do what the Precautionary Principle would suggest (if that can actually be determined!) – but that will be because we are following the Best Principle.

The Precautionary Principle is not to be seen as a special case of the Best Principle merely because the latter will sometimes lead to the same conclusion. The best course of action may indeed be to (for example) stop all development of some new technique or product. Or the best course of action might be to go full steam ahead with it. Or the best course of action might be to do any of the many things in between these two extremes. But this will be established by adopting the Best Principle. To see whether being 'Precautionary' is the Best course of action, we have to define operationally what being Precautionary involves – which action/s is/are in line with the principle and which isn't/aren't. In order to do that we will have to do an analysis of the various possible courses of action. It follows that we cannot decide how to be precautionary without doing the same analysis that is necessary to identify the Best course of action.

Since proponents of the Precautionary Principle are presumably suggesting that it will lead to the adoption of the Best course of action (in the circumstances where they urge its application) why do they not simply argue for the Best Principle? Why, indeed, should anyone suggest that we follow the Precautionary Principle instead of the Best Principle? The only reason seems to be that people realise that it is very difficult to set up a procedure that identifies the Best course of action without moving to a Decision-Focused DT in the middle modes. They prefer to try to evade this task by convincing themselves that a principle that can be enunciated at modes 5 and 6 is adequate. But logically no other principle can outrank the Best Principle and neither normatively nor politically can one see any authority trying to justify not following it, if asked.

The Precautionary Principle may be seen most positively if it is interpreted as a misguided attempt to overcome



the limitations and biases of the 'Risk Approach'. It is misguided because it fails to identify and address the key pathologies at the heart of that approach – the mutually supportive concepts of 'risk' and 'science-based policy'. Advocacy of the Precautionary Principle results from the confusion of Truth-Focused and Decision-Focused technologies on the one hand and of Knowledge, Valuation and Decision Technologies on the other. Despite its grounding in a highly analytical ('Hard' Science) view of what constitutes knowledge, it is, ironically, only defensible and implementable at a largely intuitive mode of decision making.

#### ACKNOWLEDGEMENTS

I am grateful to Ken Hammond for providing the original and continuing stimulation for my thinking in this area. Of course he bears no responsibility for any distortions or modifications I have introduced. This paper is drawn from a much longer manuscript [5], with a final section specifically directed at the 'Precautionary Principle'. Some

sections suffer from condensation and I apologise for that. I intend the tone to be provocative rather than offensive, but obviously each reader will come to their own judgement as to whether I have stayed on the right side of this line.

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