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A novel approach to the appraisal of technological risk: a multicriteria mapping study of a genetically modified crop

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Abstract. The recent controversy over genetically modified (GM) foods amply demonstrates the general difficulties encountered in the social appraisal of technological risk. Existing procedures for regulatory appraisal neglect many possible forms of impact and routinely exclude important cultural and social dimensions of risk. A narrow, expert, 'science-based' approach is now widely acknowledged to be insufficient. There is a need for new approaches that are more broadly based, transparent, pluralistic and ready to acknowledge uncertainty as well as being practically feasible and robust. The authors investigate the potential for a novel 'multicriteria mapping' (MCM) method as one such possible tool. Drawing on a variety of perspectives in the current UK debate, a range of agricultural strategies for the production of oilseed rape, including both GM and non-GM options were explored in this MCM pilot exercise. The results demonstrate the general feasibility and positive potential of this type of approach, with specific findings providing modest insights for policymaking in this difficult area.

Introduction

Managing technologies in the 'risk society'

Technological risk is becoming a dominant ordering principle in late modern societies. Under the 'risk society' analysis, risk is seen increasingly as a structuring force in social and institutional relations—to some extent replacing monetary wealth and cultural privilege as the focus of distributional tensions and political conflict (for example, Beck, 1992; Giddens, 1990; Lash et al, 1996; Luhmann, 1991). Policy discourses over climate change, stratospheric ozone depletion, urban smog, nuclear waste and proliferation, pesticides, endocrine-disrupting chemicals, BSE, and genetically modified food provide obvious examples of arenas in which the new politics of risk are played out.

With mounting institutional and economic commitments to global technological infrastructures, the stakes are high and growing ever higher. Once a particular industrial strategy or technological path has been chosen, a host of self-reinforcing mechanisms come into play (Arthur, 1989; Cowan, 1991; Hughes, 1983; Winner, 1977; 1980). The enormous investments of human resources, financial capital, and institutional reputation can render technological trajectories effectively irreversible once adopted.

Against this background, the business of risk assessment and technology appraisal takes place across sectors such as energy, chemicals, transport, information, communication, and food production. In all these fields, it is increasingly recognised that the old 'scientistic', expert-centred approaches are not enough (Adam et al, 1999; Gilbert et al, 1997; HoL, 2000; NRC, 1996; RCEP, 1998a). Complexities in the characterising, prioritising, and distribution of risks, their ethical and cultural implications, and the way they are communicated and understood all transcend the narrow clinical notions of conventional risk assessment (Fischoff, 1995; Fischoff et al, 1981; Jasanoff, 1996;

O'Brien, 2000; Otway and Wynne, 1989; Renn, 1998; Slovic, 1993; Wynne, 1987). Even the most ostensibly 'technical' citadels of the analytic approach—the quantification of probabilities and the measurement of harm—remain fundamentally context dependent, subjective, and thence political in character (Funtowicz and Ravetz, 1990; Loasby, 1976; Smithson, 1989; Stirling, 1998; Wynne, 1992). Although the traditional 'expert institutions' of risk assessment wield undoubted specialist knowledge in their respective circumscribed fields, they remain no better equipped (or mandated) to decide upon the profound general questions of values and interests that 'frame' their analysis, than are other assemblages of citizens and interest groups (GEC, 1999; Sclove, 1995).

Official expert reports now only rarely assert the exclusive sufficiency of 'sound science' or frame the issues as a problem of 'public irrationality'. Efforts are being made to open up the procedures of regulatory appraisal to a wider range of constituencies and interests and to make the process more transparent (Gilbert et al, 1997; HoL, 2000; NRC, 1996; RCEP, 1998a). Broader based 'precautionary' approaches are advanced in many quarters as substitutes for the narrow disciplines of quantitative risk assessment (Fisher and Harding, 1999; O'Riordan and Cameron, 1994; O'Riordan and Jordan, 2000; Raffensberger and Tickner, 1999; Stirling, 1999; Stirling and Mayer, 2000). Experience is accumulating with 'deliberative' and 'participatory' appraisal procedures, such as consensus conferences, focus groups, and citizens' juries (Durant and Joss, 1995; Fiorino, 1989a; 1989b; Renn et al, 1995). In some countries (such as Denmark and the Netherlands), these trends have progressed to the point where such approaches have become a statutory part of the regulatory process. Despite important recent initiatives (Clark et al, 1998; Grove-White et al, 1997; MacNaghten et al, 1995; Science Museum, 1994; UKCEED, 1999; Wakeford, 1999), greater experience has been gained in some other countries (such as Germany and parts of the USA) than in the United Kingdom.

Of course, the new 'precautionary', 'deliberative', and 'participatory' approaches are not without their own ambiguities. Serious questions remain over the best means to integrate such processes with the more conventional 'scientific' elements of appraisal, and with wider provisions for accountability (Levidow, 1999; Stirling, 1999). There are no simple panaceas for the intractabilities and sensitivities encountered in the regulatory appraisal of technological risk. Indeed, there can be no foregone conclusion that such approaches offer a way out of the current risk impasse. In this light, the crucial task is to evaluate the strengths and weaknesses of the new approaches in comparison with the old.

The 'market of methods' in regulatory appraisal

A wide variety of techniques have been used in the appraisal of technological risk. The more important general analytical approaches include decision and policy analysis, lifecycle analysis, and environmental impact assessment (for example, van den Berg et al, 1995), multiattribute utility theory, and multicriteria evaluation (for example, Bogetoft and Pruzan, 1991), probabilistic, comparative, and environmental risk assessment (for example, Royal Society, 1992), orthodox and 'constructive' technology assessment (for example, Rip et al, 1996), as well as the various forms of environmental cost–benefit and cost-effectiveness analysis (for example, Hanley and Spash, 1993; Pearce and Turner, 1990). Qualitative deliberation, including consensus conferences, citizens' juries, and focus groups (Bohmann, 1996; Durant and Joss, 1995; Fiorino, 1989a; 1989b; Renn et al, 1996; Sclove, 1995; Webler et al, 1995), are among the ways in which insights from the social sciences have been applied.

However, both the more traditional 'scientistic' approaches and the new 'participatory' and 'deliberative' approaches present potential difficulties. Probabilistic risk assessment and cost–benefit analysis, for example, are especially strongly emphasised

in the regulatory culture of the United Kingdom, and yet are relatively inflexible and narrow in their scope, being closed to divergent values and framing assumptions and hubristic about uncertainty. Whether explicitly or implicitly, such approaches aspire precisely to resolve individual uniquely authoritative solutions—tending to deny the essentially subjective and political aspects of the appraisal of technological risk (Foster, 1997; Stirling, 1997a; Wynne, 1987).

Under some views, however, participatory and deliberative procedures suggest concerns over the verifiability and reproducibility of results and the transparency with which they can be linked with starting assumptions. There are fears, on the one hand, that such techniques may prove to be protracted and inconclusive (Lloyd, 2000) and, on the other, that they might subvert broader democratic political processes (Levidow, 1999). Like established analytical approaches, participatory deliberation can also be used as a means to engineer artificial convergence, upholding privileged viewpoints and suppressing dissent (Rescher, 1993). All approaches—traditional and novel alike—face difficulties of feasibility, efficiency, and accountability. Against this background, appraisal methods are required which are: flexible and broad in scope; open to divergent interests and values; able to acknowledge uncertainty; whilst being systematic, transparent, verifiable, and accessible as well as practically feasible and efficient.

The structure of this paper

In the present paper we will describe one particular attempt to address these issues. First, the background and distinguishing characteristics of the novel 'multicriteria mapping' method will be described and the case study set in a broader context. Attention will then turn to the methodology, including the identification of participants and options, the conduct of interviews, and the methods of analysis. The results themselves will then be discussed, including the nature of participants' engagement, the options and criteria that they defined, the key characteristics of their appraisals, and the overall rankings and associated sensitivities. In conclusion, a series of broader implications will be explored, concerning issues of quantification, framing, and validity in an exercise such as this, as well as the more specific implications for agricultural practice and regulatory appraisal.

Methodology

The background to multicriteria mapping

One technique that has been developed with the aim of addressing the issues raised in the introduction is called 'multicriteria mapping' (MCM). The underlying approach has an unlikely origin in military logistics and operations research in the Second World War. A family of multicriteria appraisal techniques have been developed over the years in the wider field of decision analysis. In the past two decades, these have reached a stage of some maturity (Clemen, 1991; Dodgson et al, 2000). Informed by an often highly technical literature on rational choice and utility theory (Bezembinder, 1989), such techniques have tended to become increasingly complex. They are employed in many forms, to differing degrees and with varying success in fields such as transport and land-use planning, siting, energy policy, waste management, medicine, commercial decisionmaking, and sometimes technology assessment (literature cited in Stirling and Mayer, 1999). They are especially well established in a public policy context in northern European countries such as Denmark and the Netherlands (Bogetoft and Pruzan, 1991; Janssen, 1994; Nijkamp et al, 1990; Voogd, 1983), but—outside of the field of management science—seem considerably less frequently used in the United Kingdom (DETR, 1998; Dodgson et al, 2000; ILGRA, 1997).

Multicriteria procedures are often employed in a similar fashion to those of orthodox cost–benefit or risk analysis—as an attempt to impose a single 'right' answer to an intractable decision problem. One recent example of their unsuccessful use in this regard in the United Kingdom is provided by the site-selection procedure for a national radioactive waste repository undertaken by the nuclear industry in the late 1980s (NIREX, 1995; Stirling, 1996). However, the techniques of multicriteria appraisal do offer the potential for a radically more flexible decision-aiding tool. Instead of being used in the narrow and often counterproductive fashion of an 'analytical fix', they can be used instead as a 'heuristic'—a way of exploring the main dimensions of a risk issue and establishing their key characteristics, relationships, and relative importance.

An explicit (and, as will be seen, somewhat contrived) working distinction between the ostensibly 'technical' concept of performance 'scores' and the more openly subjective notion of criteria 'weightings' is an idea common to all multicriteria approaches. This offers an especially important feature in exploring the relationship between scientific and sociopolitical factors in appraisal. The explicit attention thereby focused on such issues also provides a model for the treatment of other tricky aspects of appraisal. Factors such as the scope of analysis, the framing of crucial assumptions, and the treatment of uncertainties can all be handled in multicriteria appraisal alongside 'performance scores' and 'criteria weights' in a fashion which is relatively explicit, open, systematic, and pluralistic (Stirling, 1997b; Wynne, 1997).

It is only when used in this way—as a heuristic rather than as a prescriptive tool—that a multicriteria approach might be referred to as 'multicriteria mapping' (Stirling, 1997b). Many of the more elaborate complications in other multicriteria techniques that are introduced in an attempt to justify the unitary prescriptive conclusions of the 'analytical fix' are superfluous under the heuristic objective of 'mapping'. Such an approach therefore also offers the additional quality of relative simplicity.

The GM case study

The introduction of genetically modified (GM) crops and foods in Europe is currently a highly topical and controversial risk issue (Levidow and Carr, 2000). The advent of GM strategies in agriculture opens up a new arena for discourse over technology and environment. Claims of unprecedented economic benefits are qualified by concerns over the potential for serious irreversible harm. However, there is considerable scientific uncertainty over the form and magnitudes of the possible effects and, as yet (in contrast with chemical or nuclear risks), little accumulated practical experience to draw upon. This has led to the evolution of a set of controls which are intended to be 'precautionary' in nature—accepting that action to avoid harm may be taken in the absence of scientific proof—with the conduct of risk assessment being required before experimental or commercial use of a particular genetically modified organism is allowed (von Schomberg, 1998).

Despite this proactive, 'precautionary', approach to risk regulation enshrined in the European Commission's Deliberate Release Directive (90/222/EC), the regulatory appraisal process has failed to gain confidence, either on the part of nongovernmental organisations (NGOs), private industry (Mayer et al, 1996), or the general public (EPCAG, 1997; Grove-White et al, 1997). This lack of confidence has arisen because, among other things: the scope of the regulatory appraisal is disputed; there is a general lack of trust in official 'science-based' reassurances over safety (particularly in the wake of BSE); and perceived benefits are not explicitly included in the evaluation process. Industry and regulators have expressed frustration in the belief that the precautionary approach is being used to demand an unrealistic absolute proof of safety. Despite a supposedly common approach to risk assessment (von Schomberg, 1998; Wynne and

Mayer, 1999), it has proven almost impossible to gain agreement between European member states over whether particular commercial releases of GM crops are environmentally 'safe'. Disputes routinely emerge over the appropriate scope of risk assessment (Levidow et al, 1997). Even where there is agreement over the possibility that effects will occur, notions of what constitute adverse effects remain strongly contested.

These sorts of problems with the regulatory appraisal of GM crops are typical of those which beset the use of conventional risk assessment and cost – benefit analysis in other areas, such as energy (Holdren, 1982), transport (Adams, 1996), technologies, and hazardous chemicals (Wynne, 1997). GM herbicide-tolerant oilseed rape was therefore chosen as the subject for this pilot MCM, both in order to provide a concrete focus and because this is a 'real' and topical development currently under intensive scrutiny but with wider implications. Although GM herbicide-tolerant oilseed rape is the specific subject of this inquiry, it was placed in the setting of alternative options for the production of oilseed rape. The immediate task was not to make a specific pronouncement on the safety, general desirability, or otherwise of GM herbicide-tolerant oilseed rape, but rather to evaluate its relative performance under different perspectives.

The framing of the present exercise

The twelve individuals who participated in this study were all senior representatives of leading protagonists in the current UK debate over the use of GM technologies in food production. As such, each participant held (albeit from different perspectives) a strong professional knowledge of the issues raised in contemplating GM strategies and their alternatives, as well as specialist expertise on certain aspects of these issues. Both as individuals and in their institutional context, then, the selected group of participants may be considered to be significant actors in the policy arena.

The group as a whole spanned a diverse range of institutional interests and perspectives. However, in order to secure involvement under the present conditions of the political debate it was necessary to give an undertaking of anonymity. Individual names and institutional affiliations are therefore not identified. Instead, each participant was assigned a letter that was used throughout the analysis and in the presentation of results. With the aid of these codes, in table 1 each participant is placed into one of four broad constituencies.

Table 1. The participants.

Area	Code
Agriculture and food industry	B, L, H, K
Academic scientists	C, J
Government safety advisers	E, F
Religious and public interest groups	A, D, G, I

To ensure some degree of comparability between the positions taken by different participants, six 'basic' policy options were identified and defined in advance by the researchers. All participants were asked to consider and appraise these six options and were able to add up to six further options which they were free to define (see table 2, over).

Some of the chosen options are somewhat hypothetical. For example, no organic oilseed rape is presently under production in the United Kingdom because the current processing system uses a chemical (hexane) which is not permitted in organic food production. Likewise, all the options under discussion are somewhat stylised. Categories such as 'organic', 'integrated pest management' (IPM), and 'conventional'

Table 2. The definition of the 'basic options' appraised by all participants.

Option	Definition
Organic agriculture	All farming and food production conducted under present-day organic standards.
Integrated pest management	All farming and food production conducted via systems designed to limit, but not exclude, chemical inputs and with greater emphasis on biological control systems than conventional systems.
Conventional agriculture	All farming and food production conducted under present-day intensive systems.
GM oilseed rape with segregation and present systems of labelling	Labelling based on the presence of foreign DNA or protein in the final product.
GM oilseed rape with postrelease monitoring	Monitoring for effects (mainly environmental) conducted on an ongoing basis after commercialisation.
GM oilseed rape with voluntary controls on areas of cultivation	Areas of growing of GM oilseed rape restricted on a voluntary basis to avoid unwanted effects such as gene flow and cross fertilisation of non-GM crops.
Up to six additional options to be specified by participant	Any option of participant's choice, including combinations of the above if desired.

apply across a variety of practices and contexts. However, such is necessarily the case in any practical comparative appraisal.

The basic GM options were chosen to reflect the three main approaches to regulatory control which are currently in place or being contemplated. Labelling on the basis of the presence of foreign DNA or protein is the approach taken in the European Commision's Novel Foods Regulation (258/97). A mechanism for post-release monitoring is one of the revisions to the Deliberate Release Directive being proposed by the European Commission (EC).[1] Voluntary controls on areas of cultivation are being contemplated in the development of industry guidelines on the growing of herbicide-tolerant crops (SCIMAC, 1998).

The three basic options unrelated to GM crops reflect the active debate over contending agricultural strategies and environmental protection (especially in relation to herbicide-tolerant crops), how they will affect the pattern of chemical usage, and what effect this may have. The assumption was made that each individual 'basic option' was pursued to the exclusion of all others in the United Kingdom.

The interview process

The twelve participants were interviewed on an individual basis between June and September 1998. Interviews lasted between two and three hours and were tape-recorded. One researcher (SM) attended all the interviews and the other researcher (AS) attended five. During the interview, a four-stage process was undertaken, comprising: (a) the identification of additional options; (b) the specification of appraisal criteria under which the options should be assessed; (c) the scoring of the performance of each option under each criterion; and (d) the weighting of each criterion in terms of its relative importance. The essential iterative and reflexive properties of the process

[1] Proposal for a European Parliament and Council Directive amending Directive 90/220/EEC on the deliberate release into the environment of genetically modified organisms [COM (98)0085 – C4-0129/98-98/0072 (COD)].

meant that participants were able to return and include further options or criteria during the interview if, as things developed, they thought of others they would like to add. Interviews were followed up with further bilateral communication and a group meeting to which all participants were invited.

The first step in the interview process was to discuss the specific definitions for the six basic options under appraisal for the production of oilseed rape. Depending on judgments concerning the completeness or resolution provided by this set of basic options, participants then defined up to six additional options of their own choosing.

Participants then defined a maximum of twelve criteria that they would use to evaluate the performance of the different options. There was no restriction placed on the scope or form of criterion which a participant could specify. However, although different criteria might be related in various ways, each was 'independent' in the sense that the associated assessments of performance were independent of judgments concerning performance under other criteria. Participants were asked to describe in as much detail as possible what each individual criterion meant to them, specifying precisely, for instance, what they meant by any broad general terms such as 'sustainability', 'precaution', or 'efficiency'. Because there might always be more than twelve criteria under which oilseed rape might be evaluated, participants were asked to concentrate on those they thought were most important in the evaluation. If new issues emerged as the appraisal procedure progressed, participants were free at any stage to develop new criteria and assess their options under these as well.

Having specified their appraisal criteria, the participants were asked to score each policy option under each criterion. This is the part of the MCM exercise which focuses on the ostensibly relatively 'technical' aspects of appraisal. Participants were asked to justify the scores which they assigned under their various criteria by reference to what might be called 'scientific' or 'technical' considerations. Participants were, in principle, able to frame their scores in terms of some established measuring unit appropriate to any individual criterion (such as tonnes of herbicide used, numbers of species affected, or monetary values). However, in all events, scores are expressed finally on a cardinal rating scale of arbitrary units (such as 1 to 10, or 1 to 100) in which, for example, a score of 4 expresses a performance rated as twice as good as a performance score of 2 and half as good as a score of 8. Explicit 'anchor points' proved useful for the assignment of scores: for example, reference to the current status quo as a mid-range score, or zero risk as a maximum score. In all cases a high numerical score corresponded with high performance and vice versa.

Participants were asked to assign both high (optimistic) and low (pessimistic) scores for each option under each criterion to express the importance of 'technical' uncertainties and context-dependent variability. Where neither uncertainty nor variability was felt to be a factor, the pessimistic and optimistic scores could be identical. Participants were also asked to describe the 'framing assumptions' which they were applying in each case—such as their confidence in good practice or regulatory regimes, or the assumptions they were making concerning dynamic changes over time.

A laptop computer running a simple procedure written by one of the authors (AS) on proprietary spreadsheet software was used in order to perform a straightforward 'linear additive weighting' multicriteria procedure. Essentially this involves simply taking the performance scores assigned by the participants and multiplying them by importance weightings which are assigned separately in the next stage of the exercise to express the relative priority attached to the different criteria. The result is a 'ranking' which reflects the overall performance of each option under all the criteria taken together, taking account of the relative importance of these criteria under the perspective in question.

The spreadsheet automatically 'normalises' the scoring scales to preserve the ratios while avoiding inadvertent bias due to the arbitrarily higher numerical values which might be employed under some rating scales compared with others. The results of the scoring process were displayed for the participants during the session by the computer in real time, as a bar chart. The bar charts showed the rankings of options under both 'pessimistic' and 'optimistic' performance scores.

The final step in the interview process was the assigning of numerical weightings to reflect the relative importance of each appraisal criterion. Although, as will be discussed, the process of scoring itself evidently embodies a variety of profoundly value-laden assumptions, this is the stage when explicitly subjective value judgments are made. The weightings reflect how much participants care about the differences in option performance under each criterion.

The assignment of weights is inextricably linked to the particular values taken by the scores under each criterion. This is because any attempt to express the relative importance of, say, employment compared with the risk of cancer, without knowing precisely how much employment and cancer risk are being traded off, is meaningless. Attention therefore focuses on the difference between best and worst options under one criterion compared with the difference between best and worst options under a second criterion. Where this difference under one criterion is judged to be twice as important as under another, for example, then the weighting assigned to the first criterion will be twice that assigned to the second. In this way, the final weighting scheme is a set of numbers whose ratios reflect the relative importance of scoring differences under the various criteria.

By contrast with many multicriteria exercises, participants were left relatively free to undertake the weighting process in whatever way they felt most comfortable, with the interviewer providing guidance where requested. Starting from a default position where equal weighting was assigned to each criterion, participants usually began by ordering the criteria simply in sequence of their relative importance. Starting with the least and the most important criteria, the intensity of the differences in importance between pairs of criteria were then addressed by altering the weightings criterion by criterion. This continued in an iterative fashion until a final set of weightings was arrived at with which the participant felt comfortable.

The arbitrary weighting numbers entered by participants were recalculated and represented on the laptop computer in simple percentage terms. This corresponded with an intuitive model of importance weighting in terms of the sharing of 100 'importance points' across the various criteria. The computer also displayed, as a bar chart, the consequences for overall option rankings of each change made to the weighting scheme. All participants had access to the computer at the end of the process and were able to manipulate the weightings themselves in order to explore sensitivities. The weighting procedure was only concluded when the individual participant expressed satisfaction that they had arrived at a meaningful expression of their position. Although only some made use of the computer in this way, all agreed that they were happy with the outcome.

Analytical methods

After the interviews, a preliminary analysis of the results was conducted. This included: (a) the grouping of criteria, (b) a systematic sensitivity analysis in order to examine the effect of increasing and decreasing each participant's criteria-weighting values, and (c) an exploration of the effect of introducing a degree of diversity into the mix of options, based on the rankings arrived at by each participant.

The total set of appraisal criteria reflects a wide range of considerations viewed from a disparate array of perspectives. However, there remained some scope for the grouping of criteria into a number of broad general categories for the purposes of exploring overall patterns. With this aim, the 117 individual criteria developed by participants were ordered by the researchers into six groupings: 'environment', 'agriculture', 'health', 'social', 'economic', and 'other' issues (see table 3). These categories were not established in advance of the interview process, but were developed relatively 'inductively' during the preliminary analysis on the basis of the criteria actually selected by participants.

Table 3. Classification of criteria into groups and subgroups.

Biodiversity	Agriculture	Health	Economic	Social	Other
Chemical use	Weed control	Allergenicity	Consumer price benefit	Individual consumer choice, benefit, need, and participation	Ethical
Genetic pollution	Food-supply stability	Toxicity	Farmers' or commercial users' yield/ profit benefit	Institutional impacts and demands	Knowledge base
Secondary wildlife effects	Agricultural practice	Nutrition	Society—economic benefit overall	Social need, benefit, and trajectory	
Unexpected effects	Other effects	Unexpected effects			
Ethical		Ability to manage			
Aesthetic					
Visual					

These six groupings of criteria are rather conservative in nature, tending to reflect the categories of issue which are most commonly recognised in the wider policy discourse. Another approach might, for instance, have been to categorise criteria according to their 'scientific', 'technical', 'ethical', or 'political' (to do with agency or control) content. However, this would have been much more difficult to do given the way in which the participants actually described their own criteria. Nevertheless, many such cross-cutting issues are intertwined in the six groupings.

The group into which a criterion was assigned was determined by the definition articulated by the participant during the interview. In some cases, there was a degree of overlap across the six broad groupings. For example, one criterion was formulated as 'toxicity to wildlife and humans'. In such cases, which constituted only a minority of the criteria (7 out of 117), the aspect which was emphasised during the interview was taken as the basis for categorising the criterion. After the interview stage and preliminary analysis, participants were asked whether they agreed with the way in which their criteria had been grouped. Except for minor amendments, which were adopted, no disagreements were expressed.

In the preliminary analysis of results we also concentrated on the systematic examination of 'sensitivities'. This involved an exploration of what the final rankings would have looked like for each participant if their weightings on each of the six groupings of criteria (that is, environment, agriculture, health, social, economic, and other) had been different by a factor of 3 either up or down. In other words, the weighting sensitivities were examined for each of the six groupings rather than for the individual criteria themselves (this would have been prohibitively complex both to perform and for the participants to interpret). Bar charts were generated which displayed the overall rankings (averaged over 'pessimistic' and 'optimistic' scores) obtained

by the multicriteria process for the different options under the original weightings and a threefold reduction and a threefold increase on this base. The overall difference between the lowest weighting and the highest weighting for each criterion explored for each participant was therefore a factor of 9—representing a fairly considerable difference of possible views concerning the relative importance of the six broad groupings of criteria. No changes of weighting were suggested by any participant as a result of this further iteration in the process.

The preliminary analysis also included an exploratory investigation of the implications of pursuing a variety of different strategies in parallel. This permitted an assessment of the degree to which participants saw diversity as a means of hedging against serious uncertainties and of accommodating a plurality of social perspectives. For the sake of brevity, however, this aspect of the pilot study is not discussed in the present paper (see Stirling and Mayer, 1999; 2000).

Each individual participant was sent a copy of their own results together with an anonymised list of all the options, criteria, and weightings specified by others, together with the resulting option rankings. Based on the outcome of the provisional analysis described above, each participant was asked: (a) whether they were content with the way in which their criteria had been grouped, and (b) whether, in the light of the results of the sensitivity analysis, their weightings still reflected their opinions. Each participant was also asked to comment on the difficulty and utility of the MCM process as a whole and on its individual parts. Full responses to this review were received from seven of the participants. Although all expressed satisfaction with the exercise as a whole, the remaining five participants felt unable to reply in detail at that stage because of pressures of work.

Findings

Introduction

In a heuristic exercise such as this, the scope of what constitutes a 'finding' extends beyond the normal domain of discrete quantitative results or prescriptive narrative conclusions. The mode of engagement of participants, the ways in which they defined the various options and thought about the business of appraisal itself are just as important as the values of 'outputs' such as scores, weightings, and consequent rankings. Each will therefore be discussed in turn, and particular attention paid to the associated uncertainties and sensitivities.

Engagement

For various reasons, including lack of time, lack of information, and, perhaps, lack of empathy with the approach, two participants did not feel entirely comfortable fully engaging in one aspect or other of the multicriteria procedure. Participant G (public interest) felt uncomfortable assigning quantitative values either to the scores or to the weightings. Participant H (industry) felt a need for more technical information before assigning performance scores, but did feel confident enough to order criteria in sequence of their relative importance (that is, as ordinal weightings). In addition, participant L (industry), although comfortable assigning both scores and weightings, made a distinction between criteria under which performance trade-offs might take place and criteria which would serve as 'hurdles' under which options would either 'pass' or 'fail'—with failure leading to their complete exclusion. This left a total of ten participants who completed all aspects of the multicriteria procedure. However, useful information concerning qualitative considerations, such as option definition and criteria choice, was gathered for all twelve participants.

Options

Several participants commented in the feedback and during the interview that they found the concept of comparing several options difficult to grasp, having been much more familiar with the assessment of GM crops on a case-by-case basis.

Nine of the twelve participants added a total of seventeen options to the list of core options. Adding or combining controls and/or making them compulsory were the most common type of additional options (7 of 17). The use of GM crops within integrated pest-management or organic systems were the next most common type of additional option (5 of 17). Interestingly, such combinations were evaluated by participants from both sides of the GM debate. Other options involved 'quality' (in terms of 'added value'), public control, assessment of indirect effects, and need. Most of the additional options were described by participants as being candidates for their preferred or ideal option, although occasionally options were included simply because participants wanted to see how they would perform. For reasons of space, the options are discussed in full elsewhere (Stirling and Mayer, 1999).

In four cases (participants B, C, J, and K—industry and academia) one or all of the additional options performed as well as or significantly better than the basic options. These involved the use of a GM crop in an organic or IPM system, changing the decisionmaking process, and the quality of the final product. The other additions, which concerned modifications to the GM options (participants A, F, and I—government and public interest), tended to be of no, or only marginal, significance to the performance of the option and showed little impact on the overall ranking pattern. Participants G and H (industry and public interest) did not complete all stages of the MCM so their options could not be ranked.

Criteria

The definitions of many of the environmental, agricultural, and economic criteria included elements which could not be reduced to strictly 'technical' or 'scientific' parameters (see table 3 for the categories and subgroupings of the 117 criteria). For example, environment included aesthetic, ethical, and visual criteria. Agriculture included farmers' rights, food stability, and quality of life for agricultural workers. Economics included global economic considerations as well as sustainability. Even health, which seems to encompass the largest proportion of direct production-related criteria, also included nutritional impact and traceability. Nor were all the criteria tightly linked to the issue of genetic modification: many criteria were associated with the social and political ramifications of the adoption of the technology under specific conditions. These findings suggest that a broad range of nontechnical considerations are felt to be relevant to assessments of a technological development, even under headings which are conventionally considered to lie within the domain of technical expertise.

Agriculture contained the most mixed group of criteria, including very specific concerns over agricultural practice, such as 'impact of the herbicide on managing tolerant volunteers', and some criteria which would have been categorised as 'social' had they not been specific to farmers (such as 'quality of farmers' and agricultural workers' lives'). This probably reflects the particular positioning of agriculture in the assessment. Although agriculture has its own specific technical issues that demand consideration, other social issues are inextricably intertwined.

The social criteria were dominated by issues of choice, control and agency. Seventeen of the twenty-two criteria in this category could be thought of in this way. Interestingly these issues were raised only by those eight participants who were not part of either the production or formal evaluation process of the GM crop.

The selection of criteria was evidently influenced by the professional interests and perspectives of the participants. For example, eight of the thirteen criteria selected by participant A (public interest) were concerned with health, consumer cost, choice, influence, and information provision. In contrast, five of the six criteria selected by participant B (industry) were concerned with benefits for farmers or commercial users. The other two individuals from the food-supply chain (L and H) had criteria similar to each other, covering the breadth of the different groupings and including broader concepts such as sustainability and the requirement for traceability or controlability, emphasising consumer confidence as part of their rationale for such criteria—issues which were relevant to their businesses. The government safety advisers (E and F) excluded all social criteria.

However, although participants did frame the problem by emphasising issues relevant to themselves, they also acknowledged other areas that had to be addressed. For example, eight participants included criteria subcategorised under environment as 'biodiversity', and eight also included criteria subcategorised under health as 'toxicity'. Participants recognised that many criteria were aggregates of issues that needed 'unpicking' and were very complex (such as 'the effect on the global economy' and 'biodiversity'), but felt they should legitimately be considered. Often criteria, although independent for the practical purposes of scoring, displayed close relationships: for example, 'transparency' and 'confidence in institutions'. These aggregated criteria, although they appear impossibly complex, give important indications about the range of issues that individuals feel should be considered and areas that might need further investigation. Several participants also commented that their criteria might change if the MCM was repeated even in the short term as new issues emerged and others faded.

Scoring

The scoring of options under the various criteria took up the longest period of the interviews. Some of the difficulties raised at this stage for the engagement of two of the participants have been commented on above. Several participants pointed out that although this particular example—herbicide-resistant oilseed rape—might score well or badly, their scoring for other GM crops might be very different. In their feedback, four participants (E, K, I, and J—from all sectors) expressed some initial confusion with the process at this stage, as did others during the interviews. This was generally associated with the inclusion of a wide range of options in the evaluation of a specific GM crop. Scoring under a criterion which was very specific to the herbicide-tolerant GM crop for options which excluded GM was found by some to be conceptually difficult.

As participants justified their scoring during the interview session, they frequently either asked for definitions of the options or spelt out their own. Clearly the context was important and the scoring of individual options was often influenced by how well the participant thought systems would work in practice:

> "If you speak to enough top quality organic people you can see that as a system that can be quite good, if you don't you won't and likewise IPM can be terribly misused ..." (E—government).

So, for example, while there was general agreement that organic farming was beneficial for biodiversity (compared with conventional systems), just how beneficial depended upon how 'good' the farmer was considered to be. A similar pattern was evident for the IPM option. Not only did opinions over likely practice influence the numerical values of the scores, they also influenced the uncertainties with which these scores were expressed. Expectations concerning the possibility for a range of good or

bad practices or different environmental conditions dominated much of the discussion during the deliberation over scoring:

"[weed control advantages] ... will vary from farm to farm because some people's land is more inherent to problems than others ..." (B—industry).

The importance of context was also seen when scoring the different GM options. There was some scepticism about the extent to which regulatory controls could manage risks:

"9 ... Perhaps, sorry number 6 might not be if it's voluntary controls. Can you regulate for voluntary controls? You can regulate that there should be voluntary controls in place but you can't enforce them ... so that's probably a 7" (L—industry).

"Equally with the voluntary control, voluntary most people would be good, but there's always the rogue" (D—public interest).

However, the exercise of controls was recognised to have potential effects beyond those intended; these could be negative or positive consequences. For example, voluntary controls on the area of cultivation, or the reduction in area grown, might restrict economic benefits:

"And if you control the area of cultivation I think you probably add to the cost" (F—government).

Labelling might have benefits in terms of recording and traceability, as well as providing consumer information, leading to improved performance of this option over several different criteria: for example, there might be a knock-on benefit of labelling for identifying weed problems.

"If you're turning labelling into record keeping, which is only another version of labelling, then in actual fact it would help because knowing what you did when and looking back next year you ought to be able to say ..." (B—industry).

There were also particular differences in scoring on some issues such as the safety of organic food and the environmental impact of herbicides, which highlighted areas in which more technical information would be relevant to the debate:

"For the organic, in theory they're supposed to be very safe but because they're not checked they could be very unsafe. And from the regulations ... other regulations don't apply to them, so they don't score highly on safety" (F—government).

The numerical values taken by the scores should therefore not be considered definitive, even in terms of the perspectives of individual participants. Many of the criteria are complex and would need further disaggregation to score with more confidence. Even then, there would remain important sources of variability in the divergent 'framings' imposed by different participants (see below). However, the present participants do have considerable expertise in many relevant areas and collectively represent a wide range of pertinent 'technical' perspectives. The general patterns in their scoring should provide, at the very least, a pointer to the broad character of the issues at stake.

Although we must bear in mind the importance of context and the limited nature of this exercise, it is possible to draw out some general themes from the overall patterns in the actual scores themselves for the six basic options (that is, those for which an array of comparable scores were provided). For reasons of space, the scoring schemes are given in full elsewhere (Stirling and Mayer, 1999).

Environment

All but one participant (L—industry) scored organic most highly under environmental criteria. All but one participant (F—government) scored IPM higher than GM options under environmental criteria. Under no viewpoint did the different

regulatory contexts for the GM options significantly affect their relative environmental performance. Of the GM options, the 'voluntary controls' regime tended to be scored equal best or marginally higher in environmental terms under all but one viewpoint (K—industry). Under only one viewpoint (F—government) were GM options assessed as performing significantly better in environmental terms than conventional intensive agriculture.

Agriculture

The pattern displayed by the scoring under agricultural criteria is quite volatile, with four of the six basic options scoring most highly under one viewpoint or another: organic (A and C—academia and public interest), IPM (J—academia), conventional (F and I—government and public interest), and GM with monitoring (E and K—government and industry). Likewise, all options score lowest or joint lowest under one viewpoint or another.

Health

The pattern of health scores is generally similar to those under environment, but more variable. Under two viewpoints, GM options were regarded as performing better in health terms than conventional crops (E and F—government), with a third viewpoint (K—industry) holding all options to be equally superior in health terms to organic cultivation. Under no viewpoint do the different regulatory contexts for the GM options significantly affect their relative health performance. By contrast with environment, however, there is a slight tendency for the 'labelling' regime to score most highly among the GM options in health terms. This arose because some participants thought that labelling would facilitate the early identification of any adverse effects and allow action to be taken. A striking feature is that the most favourable assessments of the non-GM options under health criteria are significantly less positive than the most favourable assessments of the GM options. This picture is driven by participant F (government), whose contrast between the health performance of GM and non-GM options was made on the grounds that the regulatory oversight of GM foods makes them safer, whereas people merely assume that organic food is safe.

Economics

Under economic criteria the organic option performed relatively poorly (scoring lowest under the viewpoints of participants A, B, F, J, and K—representing all sectors). Only one participant (C—academia) differed—and strongly—by rating the organic option highest under a broadly defined set of economic criteria. Participants were evenly divided as to whether GM options as a whole display economic advantages or disadvantages. Participants B, F, and K (government and industry) saw advantages: participants A, C, D, and J (public interest and academia) saw disadvantages compared with conventional crops. Interestingly, all but two participants (A and L—industry and public interest) rated the voluntary controls option as the worst or joint worst of the GM options under economic criteria. The discussions that took place on this point during scoring indicate that this was largely because voluntary controls were judged to restrict the areas of growth and thereby limit any economic benefits.

Society

Only five participants formulated scores under social criteria, and the pattern in the scores assigned is similar in its volatility to the picture under agricultural criteria. In general, the GM options tended to score relatively poorly under the social criteria and the non-GM (especially organic and IPM) relatively well.

Other

Scoring data for the 'other issues' criteria is available for only two participants (C and D—academia and public interest). Participant L (industry) also assigned scores under ethical and knowledge criteria, but the criteria themselves were not weighted, thus rendering impossible the confident aggregation of this participant's scores under the six groupings. As a result of this restricted empirical base, generalisations over 'other criteria' are of very little value.

Uncertainties

There was a significant difference in the degree to which uncertainty was expressed in the scores assigned by different participants. Indeed, there is a factor of 10 difference between the extremes (when expressed as ratios to the mid-range values taken by scores under each individual criterion). Industry participants (B, K, and L) tended to be among those with relatively lower levels of uncertainty across all the different criteria groupings. This is examined in more detail elsewhere (Stirling and Mayer, 1999), but a general picture can be gained from figure 1 below. In general, the greatest uncertainties were expressed in the scoring of environmental performance, and (where they were assessed) the least with 'other issues'. Overall, agricultural, health, and social issues are evenly ordered between these in terms of decreasing uncertainty in scoring. However, environmental, agricultural, and health issues are all subject to the greatest uncertainty under one viewpoint or another. Perhaps unsurprisingly, significantly greater uncertainties are generally associated with the GM options than with the non-GM options. However, the appraisals of several individual participants display a significantly different pattern, with both organic and conventional farming subject to the greatest uncertainties under certain viewpoints.

Weightings

The averages of the weightings assigned under five of the six overall groupings—environment, health, economics, society, and other issues—are broadly comparable (that is, within factor 2—agriculture is the low outlier). This (together with the approval expressed by the participants for the assignment of criteria to groups), provides a crude confirmation of the validity of these overall groupings. Of the six broad groupings of criteria, five are dominant under at least one perspective or another (the exception being the 'other' criteria group). This provides a rough indication of the magnitude of the differences in the perspectives taken by different participants.

A special case in the assigning of weightings was participant L (industry) who identified three criteria under which performance was not subject to trade-offs with other criteria, but which served rather as 'hurdles' which each option would have to pass if it was to be judged admissible as an option. The three tests were 'regulatory approval', 'ethical acceptability' and 'commercial viability' (in terms of corporate strategy). With these hurdles passed, the scoring differences for the admissible options under the remaining nine of participant L's criteria (falling into all six general groupings of criteria) were all weighted equally.

Rankings

Figure 1 (see over) displays the overall rankings for each of the six basic options under the perspective of each of the ten participants whose numerical 'inputs' permitted the derivation of multicriteria performance rankings. For reasons discussed more fully elsewhere (Stirling and Mayer, 1999; and see below) the remaining two—G and H—expressed difficulties either in the scoring or in the weighting process. Each part of the figure represents the rankings elicited from a single participant. The sequence of basic options is the same in each case: organic farming, integrated pest management,

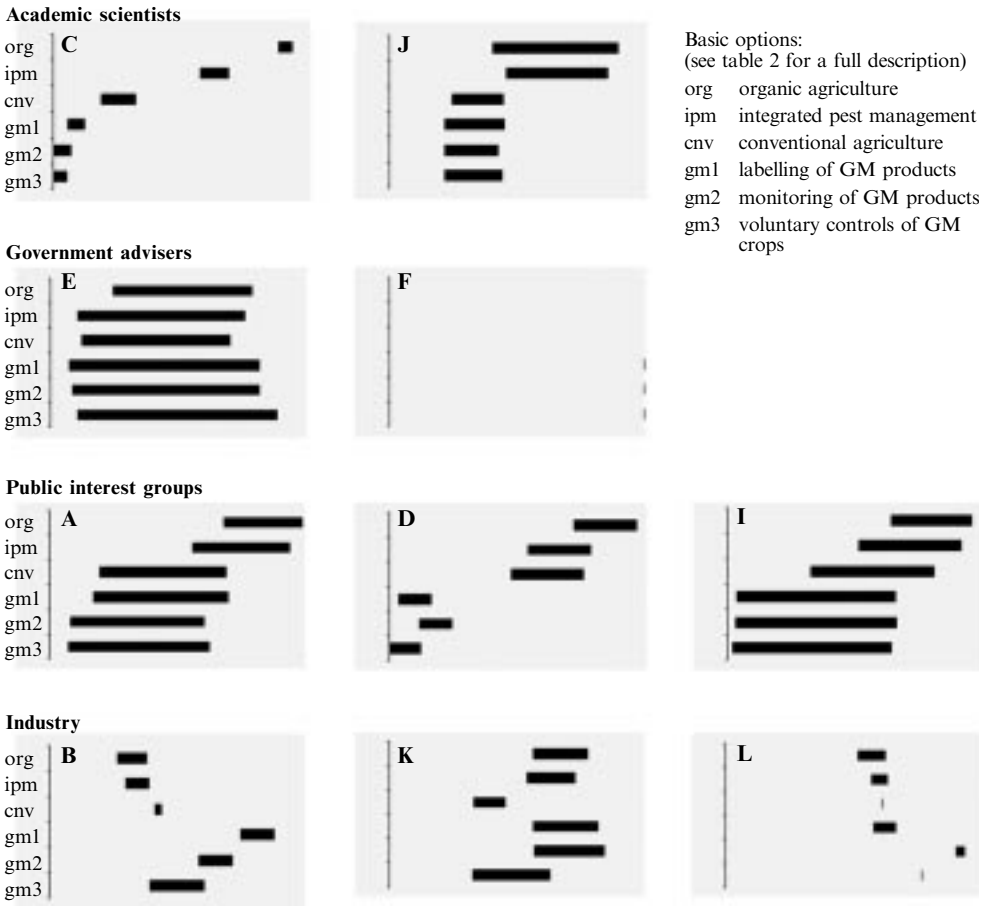

Figure 1. Final rankings assigned by participants (shown in groups).

conventional intensive agriculture, and GM crops with, respectively, (1) segregation and labelling, (2) monitoring, and (3) voluntary controls. The extension of the horizontal bars to the right reflects the overall performance of the option under that perspective: the further to the right, the better the performance. The scale is in arbitrary subjective linear units of performance. The length of the bars shows the difference between the performance under optimistic and pessimistic assumptions under each perspective, providing a useful indication of the relative importance of uncertainties. The differences of ordering in the left-hand and right-hand ends of the bars show the practical implications for option performance of adopting pessimistic or optimistic assumptions under each perspective.

Several general features emerge.

(1) The viewpoints taken by the different participants result in very different ranking orders across the six basic options.

(2) Whatever the overall rankings, a distinction can often be drawn between the pattern displayed by the three non-GM options and the three GM options. However, there are important exceptions to this generalisation: the GM/non-GM dichotomy breaks down in some cases, with variation within these groups sometimes exceeding the differences between them.

(3) Uncertainties are important: under many perspectives, the worst options at their best rank higher than the best options at their worst.

(4) However, though there are cases where the differences between pessimistic and optimistic scoring are highly significant in the overall rankings, for the most part the differences between ranking orders under pessimistic and optimistic assumptions under individual perspectives are not as important as the differences between perspectives.

Each of the individual basic options is found to perform worst—and, for that matter, most are found to perform best—under the viewpoint of at least one or other participant.

In the light of the relative robustness of the rankings to the sensitivity analysis concerning both uncertainties and importance weightings, some key features of the rankings can be identified with some confidence. First, the GM options perform clearly best overall under the perspectives of only three participants, who are all associated with government or industry bodies (B, F, and L). Under five academic and public interest perspectives (A, C, D, I, and J), GM options perform generally worse than non-GM (especially the organic and IPM) options. Second, under the perspectives of two participants associated with government or industry bodies (E and K), the position is more equivocal, with non-GM options (notably organic) performing better under certain conditions. Third, the voluntary controls regime in general performs indifferently or worst among the regulatory strategies for GM crops under the perspectives both of industry and of public interest group participants. Only under the perspective of a government adviser (E) do voluntary controls appear unequivocally preferable to other GM regulatory strategies (under optimistic scoring), with the other government adviser (F) neutral on this point. Fourth, the charts display some interesting idiosyncrasies in the rankings derived by individual participants. In particular, the pattern arrived at by participant F (a government adviser) ascribes a maximum rank to all GM options alike, a minimum rank to all other options, and no uncertainty. This is a result of the scoring of these options under a human health criterion, coupled with a weighting of 100% on that criterion. Fifth, the conventional intensive cultivation option tends to perform generally rather poorly under all perspectives, both with respect to the GM options and with respect to the organic and IPM options (depending on the perspective). Under no perspective is conventional intensive cultivation identified as the single best option. This finding is particularly interesting, given that this option represents the status quo.

Sensitivity analysis

Uncertainties in scoring

The differences between the rank orderings obtained under optimistic and pessimistic approaches to scoring under each individual perspective are generally rather small compared with the differences that prevail between the perspectives themselves. Only relatively rarely did these overall uncertainties have any significant effect on the final ranking. According to the perspective of participant E (government), for instance, GM cultivation with voluntary controls moves from being the best-performing option under optimistic scores to being significantly worse than organic cultivation under pessimistic scores. The implications are that 'technical' dimensions of uncertainty are less crucial than the more intangible qualitative aspects concerning the divergent interests, values, and framing assumptions adopted by different participants.

Importance weightings

Remarkably, a ninefold variation in criteria weightings (a factor of 3 up and down from the base case) was found to have only a relatively small impact (typically less than 5%) on the overall pattern in the rankings: the only changes were the occasional exchange in positions of options ranked closely together. Nevertheless, there are a few examples where even threefold increases or decreases in weighting values yield apparently significant impacts on the final rankings. A factor of 3 reduction in the weighting

on environmental criteria under the perspective of participant E (government), for instance, changes the position of the organic option from being the most favourable to one of significantly lower performance than the GM options.

Conclusions

Nonengagement in quantification

The majority of participants (ten out of twelve) felt able to engage fully with the process, showing a strong intuitive grasp of what was involved and a readiness to deliberate in a disciplined and intensive fashion under an externally imposed framework and schedule. All participants responding to the interim analysis commented that they found the exercise worthwhile—some were very enthusiastic. No one withdrew from the process.

A single short session of some two to three hours may have been a disadvantage in that it may have been partly responsible for the incomplete engagement by two of the twelve participants. This is significantly less time than in most other fully fledged multicriteria appraisals, and compares with typical total commitments of several days in the context of a citizens' panel or consensus conference. However, the short duration of the process was also a positive feature of the present exercise, as it placed less of a burden on busy participants and probably made their participation easier to obtain.

Some of the incomplete engagement may be partly the result of conceptual or evaluative difficulties with MCM on the part of individual participants. However, the less restrictive assumptions and less circumscribed scope of MCM should make this a less pronounced problem than with other, more elaborate, quantitative approaches to appraisal such as cost–benefit and risk analysis.

Fundamental matters of principle are raised by the evident discomfort experienced by one participant in particular (G—public interest) in being asked to adopt a quantitative approach. The various antiutilitarian and wider philosophical concerns raised in the literature (Foster, 1997) apply most acutely where MCM is employed to derive a final aggregated prescriptive 'solution', rather than a decision heuristic as in the present case. In any case, such concerns apply even more strongly with approaches such as risk assessment and cost–benefit analysis. In the present exercise, as shown in the case of participant L (industry), nonutilitarian issues of principle can be well accommodated simply by excluding any options that display the offending characteristic.

This said, however, issues of principle did not seem to present any general pervasive difficulties in the present exercise. Some participants, for instance, not only felt comfortable in weighting broad criteria of 'ethics', but were also content to assign numerical scores to reflect the performance of the individual options under such criteria. Ultimately the ability of an MCM approach to address fundamental issues of ethical principle will vary from case to case, and remains to be fully explored. As a heuristic, it certainly seems to have broader intuitive appeal than is typically the case with risk or cost–benefit analysis.

The importance of framing

In the present exercise, the crucial determinants of the differences between perspectives lie as much in choice of criteria and the qualitative framing assumptions adopted in the scoring of the different options, as they do in the numerical values taken by the weightings or the explicit uncertainty ranges. The practical considerations which govern these framing assumptions are well documented in the critical literature on risk assessment—in which they exert no less of an influence on the results, but all too often remain unexplored (Stirling, 1997b). Issues such as the 'system boundaries' of the options in question; the timescales over which appraisal is applied and the treatment

of the passage of time; the feasibility, cost, and acceptability of remedial or regulatory measures; the trajectories which the development of options are expected to undergo; and the contingent influence of external events all provide important dimensions for legitimate and defensible differences in the scoring of options.

A positive feature of an MCM approach is the explicit attention paid to divergent perspectives which allows the better documentation of the practical importance of such framing assumptions. This information allows better understanding of the sometimes rather unexpected features in the performance of certain options. For example, in the context of the present case study, labelling may not only provide consumer choice but also the potential to track and record effects, and so this option performs relatively well under health criteria. In this way, the broad scope of an MCM may throw up unexpected benefits or, equally, disbenefits of a particular option.

When these issues are drawn together, there should be greater caution in assuming that differences of perspective can be fully captured in the quantitative weighting models of multicriteria approaches in general. In particular, serious questions are raised about the validity of aggregating criteria into an overarching 'value tree' spanning the perspectives of different participants. Such practices may conceal important differences in the ways in which ostensibly similar criteria are framed. As far as the present exercise is concerned, the basic structure evident in the option rankings seems to be governed at least as much by implicit factors in the choice of criteria and the scoring of options as by divergences in importance weightings.

Validity

There are clearly limitations to this pilot exercise. Only twelve participants were involved, of whom only ten completed the MCM procedure in its entirety. The participants were selected informally and cannot be seen to represent a statistically valid or otherwise representative sample. More minor reservations may be expressed concerning the information available to participants in the scoring exercise, the amount of time taken in the weighting of criteria, the relationship between the focus on oilseed rape and the general references to GM strategies in general, and the extent to which the final results of this study have been tested by in-depth deliberations involving all participants.

However, even as a pilot exercise, the principal findings may (if interpreted carefully) be regarded as useful. The twelve participants embodied an impressive array of expertise and institutional experiences and spanned a very wide range of the perspectives currently reflected in the debate over GM crops. All participants are professionally engaged in the issues associated with GM crops and food production at a level where they might serve on an official advisory committee. The scoring process in particular was the subject of an impressive degree of careful deliberation on the part of all participants, with the researchers serving continually to probe and document the consistency of assumptions. Furthermore, the present exercise is far less circumscribed in scope than are other typical appraisals in this field, lending a greater degree of completeness to the picture generated. Finally, the results obtained have been subject to a fairly intensive process of validation, both during the interviews themselves and through subsequent consultations.

The degree to which uncertainties and discrepancies between the positions taken by different participants have been made explicit by the MCM methodology should not be mistaken for a lack of robustness on the part of the exercise as a whole. The tendency in conventional appraisal to exclude, evade, and even deny, differences of perspective should rather serve to render this more complete, transparent, and systematic exercise all the more robust. As long as care is taken not to extrapolate

beyond the present results to generalisations concerning the balance of views among different constituencies or society as a whole, then, as a heuristic exercise, the present pilot study may cautiously be regarded as a source of a number of quite interesting and relatively robust insights concerning the general structure and dynamics of the current debate over oilseed rape in particular and (with more care) over GM crops in general.

Mapping the debate

Our main objective in the present pilot MCM exercise was to fulfil a heuristic, rather than a prescriptive, function. The utility of the results lies as much in the insights derived concerning the structure and dynamics of the current debate over GM crops as in the normative implications for agricultural strategies or regulatory policy. In this regard, a number of conclusions may be drawn, some of which confirm findings made elsewhere, others of which suggest surprising and potentially significant challenges to certain received wisdoms.

First, there are a series of other agricultural strategies that are thought to be viable and broadly comparable with the pursuit of the basic organic, IPM, conventional, and GM strategies considered here—at least with regard to oilseed rape. Hypothetical applications of GM technology to organic farming regimes were one such example, and, under the perspectives in which they have been formulated, these tended to perform relatively well in this exercise.

Second, a very wide range of criteria are thought to be relevant to the evaluation of GM crops and alternative food-production strategies, many of which are quite remote from the narrow scientific and health issues addressed in orthodox risk assessment. An important group of criteria address issues not only of consumer choice but also of citizenship and wider questions of participation and agency. This picture echoes that currently emerging elsewhere in the literature. Analyses of the failings of present regulations point to exactly these two issues. A recent workshop concluded that, unless broader issues were included in the evaluation of GM foods, then the regulatory system would struggle to gain public support (Barling et al, 1999). The issue of agency and ability of the consumer to make choices or influence decisions has been highlighted in public attitudes research, both in the United Kingdom and in the Netherlands (Grove-White et al, 1997; Hamstra, 1995). The results obtained here tend to confirm this broader picture.

Third, with regard to the performance of GM and non-GM options under health and environmental criteria, questions are raised concerning certain assumptions which might otherwise have been taken for granted. Although the differences in the pattern of option scores under these groups of criteria are quite strongly influenced by the viewpoint of a particular participant, they underscore that performance under health and environmental criteria may not necessarily be well correlated. In particular, there is less agreement over the health implications of GM crops than over their environmental performance.

Fourth, with regard to the perception and treatment of uncertainties, the consistent adoption of 'optimistic' or 'pessimistic' approaches to the scoring of options does not generally affect the picture of overall performance as much as do differences in framing assumptions (such as criteria choice, scoring, and weightings). The differences between ranking patterns obtained under optimistic and pessimistic scores are generally rather small compared with the differences between perspectives. Therefore, it is not the technical dimensions of uncertainty which are the key issue: rather, it is the more intangible qualitative aspects concerning the divergent interests, values, and framing assumptions adopted by different participants.

Fifth, environmental criteria and the GM options tend to be the areas of greatest uncertainty, with generally more certainty expressed by participants drawn from an industry background. However, this broad impression overlies a richer texture of small-scale variability, with significant uncertainties also identified under different perspectives for all the broad groupings of agricultural, health, and economic criteria and for conventional as well as organic production methods. The perception of uncertainty and variability is thus a highly complex and context-dependent factor—a finding which casts doubt on automatic assumptions that the key uncertainties necessarily concern the environmental and health effects of GM crops. Under some perspectives, for instance, uncertainties over the large-scale economic effects of a switch to organic farming present similarly profound issues of ignorance and precaution.

Sixth, the different priorities attached to the different groups of criteria by different participants is perhaps unsurprising. Perspectives drawn from the biotechnology industry and food-supply chain are conspicuous in their relatively low emphasis on the social and/or environmental and safety considerations which are prominent under all other perspectives. The perspectives adopted by government advisers have the distinctive characteristic of being at the same time relatively narrow in scope whilst emphasising environmental and safety considerations. The perspectives expressed by the nonindustry participants (that is, academic scientists, government advisers, and religious and public interest groups) share a markedly lower emphasis on economic or agricultural considerations.

Seventh, with regard to notions of overall performance, GM options perform best overall only under the perspectives of government or industry participants, whereas they perform generally worse under the perspectives of academic and public interest participants. However, even under certain government and industry perspectives, non-GM options—including, notably, organic cultivation—perform better under certain conditions. Perhaps most surprisingly, the voluntary controls regime performs worst or joint-worst among the regulatory strategies for GM crops under the perspectives both of industry and of public interest group participants alike.

Policy implications for agriculture

For a policymaker charged with making decisions over the regulation of a GM crop or a class of GM crops, what implications might be drawn from this pilot study? There is a generally favourable picture of the performance of organic systems of production. The superior environmental performance of organic techniques is a matter of consensus among participants. The benefits were evident also from the choice of additional options for appraisal. Even those most positive about the technology consider that if GM crops could be included in an organic system then this might offer the 'best' option. Although profoundly in tension with established definitions of organic practice, this raises serious questions over the extent to which R&D strategies presently support such a progression towards organic and IPM systems or allow the more detailed evaluation of their large-scale feasibility.

Conventional intensive agriculture was consistently seen to perform poorly. Therefore, when evaluating GM or other developments in agriculture there may be some merit in going beyond the use of the conventional agriculture status quo as the yardstick by which harm is evaluated. At present, for example, when deciding whether a GM crop will have an adverse effect on the environment, the UK's Advisory Committee on Releases to the Environment considers that an effect which is no greater than that caused by conventional systems cannot be considered adverse (von Schomberg, 1998). Regulatory appraisal of individual options may be more robust if carried out on the basis of comparison with a wider range of alternatives than just the present status quo.

Although there was evidence of support for controls on GM crops for a variety of reasons, ranging from consumer choice, through consumer confidence, to the ability to track effects, there was some scepticism from a variety of perspectives over whether voluntary controls would be effective. Doubts were evident both with regard to the feasibility of such controls in principle once GM crops have been released, and with regard to the confidence that may be placed in the actual observation of voluntary controls in practice. Most noticeably, the addition of options with a wide variety of postcommercialisation controls did not have a marked effect on the general performance of the GM options. That this result was sustained over such a disparate array of perspectives underscores questions concerning the confidence that may be placed in the effectiveness of such voluntary controls.

Policy implications for regulatory appraisal

The wide spectrum of criteria that were thought relevant to the appraisal of GM oilseed rape under virtually all perspectives in this exercise raises serious questions over the scope of existing approaches to the regulatory appraisal of GM crops in the United Kingdom. Such concerns have already been widely voiced, for instance in recent statements by the Royal Society (1998) and the Royal Commission on Environmental Pollution (RCEP, 1998b). Even in appraisal of performance in the relatively narrow terms of environmental and health impacts, issues were raised by a wide range of participants which are not exclusively concerned with the 'technical' details of the method of production and so are presently entirely excluded from current approaches to regulatory appraisal: for example, aesthetics and impacts on biodiversity (under environment) and nutritional consequences (in relation to health). This picture is compounded in considering many of the social, economic, and even agricultural criteria raised by participants from all sides of the debate, which are also routinely excluded from the procedures of regulatory appraisal for GM crops. In this light, the broadening of the scope of the regulatory appraisal process may be seen to offer an important way of improving the match with the wider debate, and this has corresponding implications for the fostering of trust and the reduction of polarised conflicts.

A similar point can be made with regard to the essentially comparative character of the present exercise—involving consideration of a wide range of different options rather than the examination of individual options on a case-by-case basis under some absolute yardstick of performance (such as 'safety', 'risk', or 'cost'). The deliberation by participants over the conduct of scoring across a variety of options significantly enriched, extended, and refined the exercise, by continually suggesting new factors or novel implications of established understandings. Likewise, the need to compare and contrast helped to elicit a better understanding of the nature of the relative strengths and weaknesses of the different options. Many of these features might easily have been marginalised in the case-by-case appraisal of individual options. In addition, of course, there is always the possibility that a satisficing approach to regulatory appraisal—seeking simply to establish the acceptability of a single option in isolation—may all too easily lead to the neglect of alternative options which might otherwise have performed even better.

Although the numbers involved are too small to bear statistical examination, the basic structure in the option rankings is governed at least as much by the choice of criteria and by the divergent framing assumptions adopted in scoring as it is by divergences in weightings. Divergent knowledges, values, interests, and other commitments are only partly reflected in the weighting schemes. They are also expressed through all the other qualitative stages and elements in the appraisal process. This

finding reinforces the rationale for emphasising the importance to policymakers of the 'risk characterisation' process as voiced (for instance) in a recent influential report by the US National Research Council (NRC, 1996). Drawing a contrast between risk characterisation and the more programmatic, quantitative, aspects of risk assessment, the NRC observe that:

> "In addition to the biological and physical outcomes that are typically covered, decision makers and interested and affected parties often need to know about the significant economic costs and benefits of alternatives, secondary effects of hazard events, or the efficacy of alternative regulatory mechanisms ... . A risk characterisation will fail to be useful if the underlying analysis addresses questions and issues that are different from those of concern to the decision makers and affected parties" (page 29).

An appraisal process which excludes factors which are held by some constituencies to be important may fail to secure the crucial property of public confidence. It will also fall short of basic principles of analytical rigour in appraisal (Stirling, 1999). By instilling a misleading impression of completeness, robustness, or rigour, risk assessments based on such incomplete risk characterisation may leave regulators and business highly exposed to a subsequent backlash on the part of the excluded constituencies.

The addition of 'ethics' as a separable (and often final) 'bolt-on' stage in the process of regulatory appraisal may also often prove inadequate and misleading. Clearly, values, interests, and other commitments are all inextricably intertwined with the application of 'knowledge' in appraisal. Appraisal procedures which are predicated on the separation of these elements seem likely to fail.

Overall, this exercise has demonstrated that MCM does offer a way of combining ostensibly 'technical' and explicitly subjective factors in appraisal. Indeed, crucially, MCM provides a means of systematically documenting the inextricable relationships between these two often-reified aspects of appraisal. It does this in such a way as to display—at least to some extent—the following properties:

(a) relative flexibility and breadth of scope;
(b) openness to divergent choices, values, and framing assumptions;
(c) candour about uncertainties;
(d) a heuristic for 'mapping' (rather than prescribing) assumptions;
(e) systematic discipline and rigour;
(f) transparency and verifiability under external review;
(g) accessibility to participation; and
(h) feasibility and efficiency as part of a regulatory process.

The limitations which have been acknowledged and discussed underscore that MCM cannot be regarded as a panacea for the complex and intractable challenges of risk assessment and technology appraisal. The complexity of the exercise and of the results means that MCM can certainly not be regarded as an everyday tool. Its use can only make sense, for instance, as part of a wider deliberative process of appraisal—a process within which MCM may help contribute the key properties of systematic discipline, transparency, and verifiability.

The plurality and relative open-endedness of these results show that an MCM such as this cannot provide an 'analytical fix' for arriving at definitive 'right' or 'wrong' answers over what constitutes the 'best' (that is, most 'reasonable' or most 'consensual') choice of option from the point of view of society as a whole. However, far from being a difficulty, this is a positive feature of the use of an MCM heuristic. In fact, it was this feature which secured the trust and involvement of such a broad array of interests in the present exercise. Although a technique such as MCM may be used to identify and

explore the relative importance and interactions of issues such as option choices, framing assumptions, value judgments, uncertainties, and 'technical' evaluations, the final decision and its associated justifications must remain—at least to some extent—intrinsically contingent and subjective. In short, an MCM approach makes explicit that the justification of final decisions must be as much in terms of political legitimacy and democratic accountability as in terms of 'sound science' or 'rational economics' in appraisal.

For a politician, it may sometimes appear that an apparently simple, ostensibly precise, 'safe', 'unsafe', or 'safe enough' verdict is more appealing than having to look at the more messy subjective factors in comparative appraisal. In reality, however, the opposite may be the case. Apparently simple conclusions are often rather poorly sustained by the real complexities of appraisal. They are widely contested and no longer serve the purpose either of reassurance or of justification. A more effective way to achieve such ends and achieve more robust decisionmaking may be to show precisely how different considerations and perspectives have been involved in an evaluative process and what were the implications. This would not necessarily require the repeating of an entire MCM exercise in each individual instance (for instance, with regard to each GM crop). Once the framework and general parameters have been set, the specifics pertinent to an individual decision might be added relatively easily. Used in this way, and under the right conditions, MCM does seem to offer an effective means to facilitate more robust policymaking and decisionmaking at many levels.

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