Risk and science - are we moving into the fourth age of risk concerns ?

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Introduction

Attention to risk issues is not new and safety concerns are of interest for a broad variety of activities in society (e.g. traffic, environment, food safety, biotechnology, industrial safety), and consequently several parties are affected by and interested in decisions concerning risk issues (industry, authorities, academia, public etc.).

Experience with public debates indicates that the more controversial an issue is, the greater the necessity to maintain a multi-perspective dialogue between the stakeholders. However, these debates are often highly normative, reflecting the degree of aversion to risk and uncertainty of the various stakeholders involved. Authorities and their scientific advisers often find these kinds of subjective discussions quite difficult and overlook that most problems are not bound to single scientific disciplines, but that solutions to many problems require multilateral dialogues across disciplines. However, differences in professional language and culture can make the dialogue difficult. With regards to this, Gibbons (1999) writes: "*Since expertise now has to bring together knowledge that is itself distributed, contextualized and heterogeneous, it cannot arise at one specific site, or out of the views of one scientific discipline or group of highly respected researchers. Rather it must emerge from bringing together the many different 'knowledge dimensions' involved. Its authority depends on the way in which such a collective group is linked, often in a self-organized way. Breakdowns in social authority arise when links are inadequately established, as has occurred in European debates over genetically modified organisms (GMOs)*". Bringing these knowledge dimensions together is not an easy task due to different epistemic cultures on the one hand, and the deliberate searching and maximisation of uncertainties on each side of areas of conflict. While the last is difficult to do anything about, the former can be approached by a shift of mind, where scientists and experts openly question their own value driven assumptions. The sophisticated tools and methods of science are designed to handle complexity with many variables. This is what Peter Senge (1990) label detailed complexity. However, in situations where cause and effect are subtle, and where long term effects are uncertain he talk about dynamic complexity for which, scientific methodology and thinking is not well equipped.

The aim of the paper is to discuss the role of science in relation to societal handling of risk and uncertainties. The core of the discourse is the methods and frameworks developed in the theoretical tetrahedron between the fields of risk assessment, systems analysis and technology foresight in a perspective of modern science sociology. The incentive is the debate on GM crops, which has highlighted new demands and requirements concerning risk issues among the public addressing topics such as normative values, transparency, uncertainty, precautionary principle and interdisciplinary collaboration. Using the commercialisation of genetically modified crops (GM crops) as case we suggest that approval procedures of controversial products or technologies with inherent elements of risk and uncertainty to comprise two parts: A generic part emphasising more principal questions, and a specific approval procedure focusing on technical and scientific elements. The observed tendencies lead to the reflection whether a new fourth age of safety concerns is commencing, where risk assessors, policy-makers and decision-takers have to rethink risk and apply interdisciplinary scientific advises as support for holistic risk decisions.

The theoretical tetrahedron

Technological risk assessment

Risk assessments are conducted to estimate how much damage or injury (to human beings, environment or property) can be expected from exposures to a given risk agent and to assist in judging whether these consequences are great enough to require increased management or regulation. Risk assessment range widely in scope and complexity, depending on the application: from simple screening analysis to major analytical efforts that requires years of effort and a substantial budget.

Technological risk is not a single monolithic quantity. Even under the most reductive analytical approaches, it is conceded that risk is a function of two variables - the probability of a hazard and it's consequences. Normally, the risks associated with any individual technology require the identification and aggregation of series of different hazards and consequences.

Fundamental controversies in the biosafety debate are more often about the hazard identification than about the risks. Hazard identification is the attempt to recognise possible unwanted effects of some endeavour. When a particular GM crop is applied in the field the question is what consequences may be expected. Biosafety controversies can be interpreted as disagreements of what is to be a sufficient set of relevant questions for the purpose of hazard identification of GM crops. (van Dommelen 1999). Thus, the concept of risk clearly has a normative component, namely the judgement of the acceptability of effects and consequences.

The risk debate has shown, that a wide range of disparate issues, such as lack of any perceived substantial benefits, socio-economic impacts and ethical questions, worries the public (see table below). The crucial point to many of these issues is that they are measured on different dimensions, and that many of them are irreducible qualitative in nature. The relative priority attached to the different dimensions of risk is intrinsically a matter of subjective value judgement. (Stirling 1999).

Different aspects of technological risks - GM crops (Stirling 1999).

Broad issue	Class of effect
Environment	Biodiversity. Chemical use. Genetic pollution. Wildlife effects. Unexpected effects. Visual. Aesthetics.
Health	Allergenicity. Tox icity. Nutrition. Unexpected effects. Ability to manage.
Agriculture	Weed control. Food supply stability. Agricultural practice.
Economy	Consumer benefit. Benefit to processor. Socio-economic impact.
Society	Individual impact. Institutional impact. Social needs.
Ethics	Fundamental principles. Knowledge base.

An essential phase of the risk assessment process is 'risk characterisation' forming a critical interface for exchange of information from the risk assessors to the risk managers or stakeholders. Risk characterisation can be defined as follows (Stern et al. 1996): *"A synthesis and summary of information about a hazard that addresses the needs and interests of decision-takers and of interested and affected parties. Risk characterisation is a prelude to decision-taking and depends on an iterative, analytic-deliberative process"*. Recently Bier (2001) has pointed out, that risk communication to regulators and decision-takers not has received nearly as much attention as risk communication to the general public, and that only little research has been done in this area. In the future an increased focus is expected on inherent uncertainty and imperfect knowledge in relation to risk assessments. Several authors, e.g. van Asselt (1999), has stressed that a better understanding of uncertainty and how uncertainty is dealt with analytically is a prerequisite for improved decision-support. Information about uncertainty and imperfect knowledge is essential for risk communication between risk assessors, policy-makers and decision-takers, but the theory of decision-taking under uncertainty is a specialised subject, and often not transparent to policy-makers and decision-takers not trained in this methodology.

Technology foresight

New technologies create new possibilities and solutions but also new problems, controversies and uncertainties. It is generally acknowledged that the accelerating development of new technologies will have a profound impact on society in the years to come, and in the future policy-makers and decision-takers have to deal with intensifying social concerns about new technologies (mainly ethical and safety concerns). Successful and acceptable exploitation of technology has become critical to achieving economic competitiveness as well as for achieving sustainable consumption and production processes. The care for environment and sustainable development demands a forward looking approach and a vision on what future(s) we want (HLEG 2002).

Risk decisions are about future application of new technology and risk debates may sometimes resemble a battlefield, with a multitude of actors vying to further their interests. These controversies do indeed emphasise the essential question: what choice to make? Scientific risk assessments are normally only addressing hazards related to one single technology with well-defined area of application without leaving room for discussions of alternatives and values in a broader context. One way to rethink the risk assessment approach making them more flexible, transparent and broad in scope is to combine the risk assessment methodologies with the framework developed in the field of technology foresight. Technology foresight addresses information, viewpoints, controversies etc. covering different knowledge dimensions (economy, technology, environment, society, policy, and values). Foresight is about recognition of patterns of influences that leads to speculation about what may happen.

Foresight can be carried out by a broad set of analytical and participatory methods ranging from desktop research, expert groups, and stakeholder involvement to interactive brainstorming processes or broad participatory arrangements. Different approaches and methodological traditions have been established for long-range strategic outlook in such uncertain futures. One tradition has been established around corporate strategy, with focus on management of emerging technologies and on firms' future strategic environment. Godet (1987) and Day & Schoemaker (2001) are examples of this tradition. In this tradition Richard Slaughter (1998) defines technology foresight as: "*the ability to create and maintain a high-quality, coherent, and functional forward view and to use the insights arising in organisationally useful ways, for example, to detect adverse conditions, guide policy, and shape strategy and to explore new markets products and services*". Another tradition has been established within policy-making at governmental level seeing science and technology as important locomotives in national systems of innovation. Therefore, different types of technology foresight studies have attracted renewed interest during the 1990's, aiming at strengthening the national systems of innovation (Grupp and Linstone, 2000). Within this tradition, Martin (1995) has defined technology foresight as "*the process involved in systematically attempting to look into the longer-term future of science, technology, the economy and society with the aim of identifying the areas of strategic research and the emerging generic technologies likely to yield the greatest economic and social benefits*". Here, both adaptation of changes and creation of new changes are on the agenda.

The rationale behind our suggestion combining risk assessment and technological foresight to prepare a multiple dimension framework for risk decisions is located in the last of these two traditions. Our perspective is risk management and risk managers at regional or national level aiming at a new government policy.

Risk and systems thinking

In taking decisions, it is necessary to focus on some things and ignore others. In system terms, a boundary has to be placed between the system of interest and its context, or environment. The choice of system boundaries forms the basis for the subsequent risk assessment, and therefore it has important effects on results and consequently also on decision outcomes (e.g. by determining expertise and alternatives relevant to the decision).

One big contributor to the differences in risk assessment outcomes is the problem of mapping the complex reality in (simple or complex) systems, models and parameters (Poucet 1991). Defining and using systems are part of the discipline 'systems thinking' which has the following characteristics (Ossimitz 2001):

- Thinking in models: explicitly comprehended modelling.
- Interrelated thinking: a thinking in interrelated, systemic structures.
- Dynamic thinking: a thinking in dynamic processes (delays, feedback loops, oscillations).
- Steering systems: the ability for practical system management and system control.

Ossimitz is aware that system models can be developed and analysed in a completely qualitative manner, which Peter Senge (1990) is an excellent example of.

The paradigm 'systems thinking' has been opposed by Jackson (2001) proposing the perspective 'critical systems thinking and practice' and by Emblemsvåg & Bras (2001) arguing that 'process thinking' is a better paradigm than 'systems thinking'. 'Critical systems thinking' is derived from two sources: social theory and systems thinking. It recognises that social theory and systems thinking possess complementary strengths and weaknesses. The social sciences are strong in theory but they are weak on practice. Applied systems thinkers, on the other hand, are dedicated to practice but often neglect theory. Critical systems thinking can provide its greatest benefits only in the context of paradigm diversity, and the point of critical systems practice is that it brings appropriate methodologies and tools to bear on problem situations whatever their nature. Emblemsvåg & Bras (2001) point out that change is the very essence and even foundation of life, and therefore it is of significant importance to understand and manage processes of change. They argue that systems thinking does not recognise processes as being the essence of life, but rather relationships. A systems approach would focus on how to better relate the components to benefit the whole (i.e. focuses on the result of the processes); in contrast, a process approach focuses on what the system actually does, and thus science and engineering must be process-oriented. The process orientation also means strategies, the usage of methods, implementation of results and the feedback loops must be processes.

Modern science sociology

This is the fourth point of our theoretical tetrahedron and the perspective we discuss the role of science in relation to societal handling of risk and uncertainties. Summing up, society is becoming more risk-aware and divergences in values and interests are of increasingly significant importance to the public debate. Knowledge and science are expected to be amongst the main drivers of change, and much attention is being given to how to assess the quality of knowledge, the conditions for the production of knowledge and the manor in which knowledge is applied in policy development. In this paper we will consider three theories from this field: a) the triple helix model of innovation, b) Mode-1 & Mode-2 knowledge production, c) post-normal science.

The triple helix thesis model of innovation states that the boundaries and relationships between public (universities, research institutes etc.) and private driven research are in flux. Public and private organisations are assuming tasks that were formerly the province of the other sectors, and shaping these relations is increasingly a subject of research and technology management at different levels (Leydesdorff 2000). University-industry-government relations can be considered as a triple helix of evolving networks of communication and co-operation. The triple helix model argues that a knowledge infrastructure is generated in terms of overlapping institutional spheres each taking the role of the other and with hybrid organisations emerging at the interfaces. The common objective for many countries and regions is to realise an innovative environment consisting of university spin-off firms, tri-lateral initiatives and strategic alliances among firms, governmental laboratories and academic research groups (Etzkowitz & Leydesdorff 2000).

According to Gibbons (1999), a new social contract between science and society is under development. Under the prevailing contract, science has been expected to produce reliable knowledge (i.e. in areas as defence and nuclear), provided merely that it communicates its discoveries to society. The contract under development must ensure that scientific knowledge is socially robust, and that its production is seen by society to be both transparent and participative. This change in knowledge production is by Gibbons et al. (1994) characterised as a transition from Mode-1 knowledge production to Mode-2 knowledge production. Mode-1 knowledge is generated within a disciplinary, primarily cognitive context and Mode-2 knowledge is created in broader, transdisciplinary social and economic contexts. Mode-2 knowledge production has not only lead to an increase in 'knowledge' workers and a proliferation of sites of 'knowledge' production, but has also tended to erode the demarcation between traditional 'knowledge' institutions as universities and research institutes and other kinds of organisations. Novel 'knowledge' institutions are arising as e.g. small and medium-sized high technology companies. 'Knowledge' institutes have to become learning organisations in order to develop their intellectual capital. (Nowotny et al. 2001).

The problems that involve post-normal science are ones, where typically facts are uncertain, values in dispute, stakes high, and decisions urgent, e.g. risk assessment of GM crops. In these problem situations applied science and professional consultancy are often inadequate, and something extra must be added onto their practice, which bridges the gap between scientific expertise and a concerned public. This is post-normal science, comprising a dialogue among all stakeholders in a problem, regardless of their formal qualifications or affiliations (Funtowicz & Ravetz 1992). The concept of post-normal science can be characterised as a way to create insight on the changing contexts in science and society. Normal science is largely associated with certainty, based upon optimism about eventual human control over nature, but the post-normal science concept argues, that the normal way of practising science is no longer adequate since society faces new transnational and transgenerational problems. A new scientific practice has to be developed, acknowledging the irreducibility of certain risks and uncertainties and aiming at managing these irreducible risks and uncertainties instead of eliminating them (Ravets & Funtowicz, 1999). The post-normal science approach indicate that inevitably various sorts of uncertainty and value-commitments enter into decisions on risks, and because of that the scientific side of the work must be complemented by other considerations, deriving also from its policy aspects (Marchi & Ravets 1999).

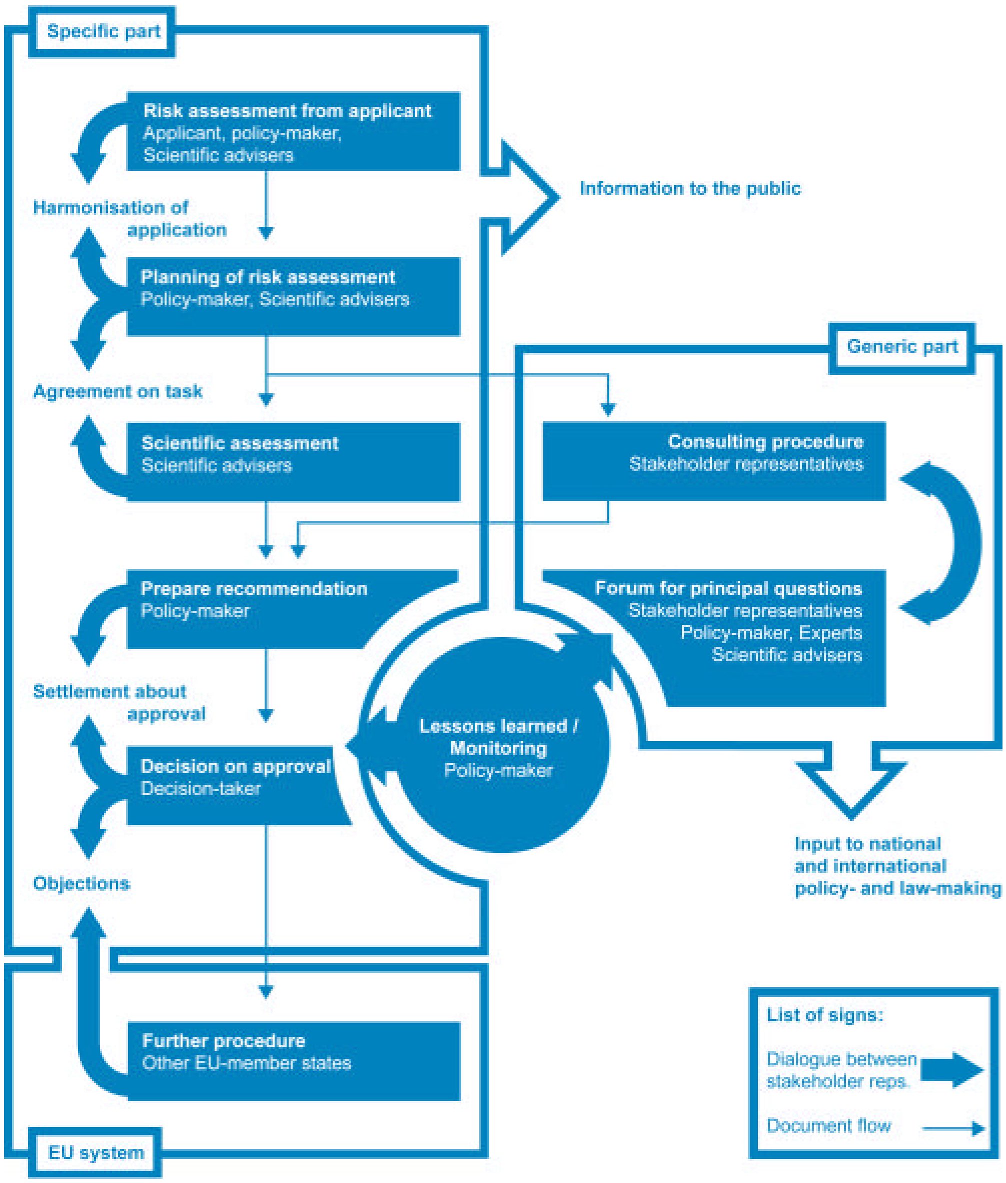
Empirical work

Our empirical work comprises two cases both addressing risk issues related to GM crops. One (Case I) was aiming at developing an overall frame for the preparation and application of risk assessment in relation to the deliberate release of GM crops according to EU Directive 2001/18/EC, and the other (Case II) directs technology foresight for a specific GM crop (in this case GM ryegrass). In both cases it was important to discuss and delimit the systems in question in order to clearly define and explain the content and concepts of the problem to be analysed.

Specific environmental and health risk assessment of GM crops

A characteristics concerning the risk debate is that questions raised are often more numerous than the suggested solutions. Public and scientific risk debates are often focused on discovering and highlighting controversies, but recommendations on how to take decisions are often lacking. From our point of view especially the regulatory and operationally aspects are significant. Supporting policy-makers and decision-takers is difficult because information and uncertainties on different knowledge dimensions have to be assessed and given priorities.

A project with the Danish administrative authorities for approval of GM crops for production and deliberate release into the environment (case I) resulted in a suggestion for an overall framework for risk assessment of GM crops (see figure below).



Overall framework for risk assessment of GM crops.

Decision-taker: a person with the authority to take a policy decision.
Policy-maker: a person or organisation charged with assessing a decision-taker in reaching a decision by providing policy analysis, generating policy options, or by conducting risk assessment.
Scientific adviser: a person or organisation responsible for providing scientific input to policy-making or decision-making.
Stakeholder representatives: a person or organisation representing the interests and opinions of a group with an interest in the outcome of a particular policy decision.

We suggest that risk assessment and technological foresight can be combined to prepare a multiple dimension framework for risk decisions. We have prepared the first version an overall framework (figure above) for risk assessment of GM crops comprising a specific part focusing approval procedure of specific crops, and a generic part (see below) emphasising more principal questions by a broader group of actors and stakeholders. The two parts are closely linked by an authority driven task concerning lessons learned from specific risk assessments of GM crops and regular evaluation of the risk assessment procedure in a broader context.

In addition to the technology foresight methodologies we have been inspired by: a) Stirling & Mayer (1999) have developed a multi-criteria mapping approach which can be used to demonstrate how a risk debate can be mapped - establishing the main contours and identifying the key areas of difference and convergence. b) Model process for securing and using scientific advice with the primary aim to offer recommendations for improving the quality of scientific advice received by government and the way it is used in policy development (OXERA 2000).

<u>CASE I – an example of specific approach to risk assessment</u>

The study was carried out in co-operation with the Danish Forest and Nature Agency (Rasmussen & Borch 2002). The aim was to develop an overall frame for the preparation and application of risk assessment in relation to the deliberate release of GM crops according to EU Directive 2001/18/EC. In this context a risk assessment comprises ecological and agricultural effects and human health issues. Emphasis was laid on how scientific advises are used in the decision process and approaches for generation and rating of decision criteria. The project had the following tasks:

- Discussion of principles, practices and experiences concerning environmental risk assessment of GM crops.
- Discussion of lessons learned and development trends from other fields using risk assessment.
- Detailed discussion of similarities and differences between risk assessment of GM crops and risk assessment of pesticides.
- Uncertainties related to environmental risk assessment and the precautionary principle.
- Discussion of advantages and disadvantages of different approaches for generation and rating of decision criteria and formulation of alternative solutions, e.g. by use of multi-criteria mapping.

<u>Technology foresight facilitating generic risk assessment</u>

Inclusion of a generic part has been inspired by the ideas proposed by Funtowicz & Ravetz (1992) that scientific discussions need to be extended to a wider peer community, incorporating more participants who have an involvement with the issue and by the two proposed paradigms 'critical systems thinking and practice' and 'process thinking' emphasising the importance of interdisciplinary and process-oriented decisions.

The empirical work related to the generic part of the framework is a feasibility study systematically analysing the challenges of the development and marketing of GM crops in Europe (case 2). The overall experience from the study is that the technology foresight process assists a dialectical debate by reducing the comprehensibility gap between different scientific disciplines and between different stakeholders, in a learning process. Moreover, it was identified who has the responsibility of taking the appropriate decisions, considering both scientific and ethical matters. This has is a good fundament in preventing the erosion of public trust in established institutions, science and the biotechnology industry.

The rationale behind the generic part of the framework is to establish a forum for dialogue and discussion between authorities, scientists and interested and affected parties. Risk assessment of GM crops is a rather new area with an ongoing discussion of criteria and principles reflecting a need for more principal debates among stakeholders. Topics for the forum could be: values in risk decisions, acceptance criteria, system boundaries for risk assessment, prospective analysis of GM technology, feedback to policy-makers, special Danish interests according to EU legislation. We know it is difficult to establish a forum of this kind. One question is to select forum members such that all parties are treated in a democratically acceptable way. Another thing, there is no reason to think that such a forum will reach consensus and what does that mean for application of their work. Further, it has to be decided how much power and influence to be delegated to the forum. (Jensen et al. 2001)

Our suggestion is supported by the findings recently published by the EU High Level Expert Group on 'Developing Foresight to strengthen the strategic basis of European Research Area'. According to HLEG (2002) participative, forward-looking methods are needed when policy-makers and decision-takers are trying to find solutions for the above described challenges. Foresight can offer a valuable tool for this endeavour:

- *It helps in making choices in ever more complex situations by discussing alternative options, bringing together different communities and stakeholders with their complementary knowledge and experience.*
- *It thus leads to a more transparent decision-taking process, and hence provides a way to obtain public support.*
- *Foresight can promote a common understanding of issues and sometimes shared visions about the future. It might even go so far as to establishing joint agendas for action.*

CASE II - an example of generic approach to risk assessment

To address the increasing public skepticism towards GM crops, it is necessary to examine the risks and benefits of GM crops across scientific disciplines, and discuss these with the authorities, the agricultural industry and the consumers. We used a methodological approach to systematically analyse the uncertainties faced by the biotech industry and public authorities when GM crops are commercialised. We studied the development of a GM ryegrass (by a Danishbreeding company) which are incapable of producing stems and flowers during grassland farming (biological encapsulation). The method used was a technology foresight framework, using a life cycle inventory to define the system complex, a stakeholder panel to identify drivers (of change) that influence the direction of future developments, and weighted stakeholder questionnaires to prioritise these drivers. Once quantified, the weighted stakeholder opinion generated a clear criterion for prioritising drivers that were judged to be important in the future development of a GM-ryegrass but whose precise impact was uncertain. The four drivers prioritised were (Borch & Rasmussen 2002):

a) Being the first to market the GM ryegrass was not surprisingly considered important by most of the respondents. However, they disagreed over whether the grass breeding company will in fact be first to market. Early activity of this kind will allow for a monopolistic period during which a return on any initial investment can be secured. It should be noted that there was a certain amount of skepticism about whether GM ryegrass will in fact produce significant profits. This skepticism was probably due to the well-known public resistance to GM crops.
b) An efficient network of biomolecular and grass breeding know-how was also rated as very important, but doubt about that the network could be established. The perceived necessity of a network was probably connected with the belief that complex knowledge is required for this type of research and development.
c) Public dialogue and participation in regulation procedures will influence on public acceptance of GM ryegrass, but it is uncertain whether a dialogue is capable of narrowing the gap between expert and lay opinion. The respondents (all having some degree of expertise on GM technology) were aware of the apparent disparity between their and the public's assessment of the risks of GM technology, and they appear to agree that this is unlikely to change in the near future. But in addition, they did not believe that the general public was capable of being educated so as to acquire knowledge-based opinions on gene technology.
d) Utility value also emerged as an important driver so far as public acceptance of GM crops is concerned, but the predominant stakeholder opinion discloses uncertainty about whether such utility can be secured in the near future. Interestingly, this uncertainty was not cancelled out by the predominant opinion that GM crops offer novel alternatives in specific areas, which cannot be obtained by traditional breeding methods.

Discussion

Are we moving into the fourth age of risk concerns ?

There have been three overlapping ages of safety concerns (Hale & Hovden 1998). The first was the technical age in which the main focus was upon structural and engineering methods. In the second age attention shifted towards human errors, since human factors were often found to be the cause of an unwanted event. Recently the focus has moved to the socio-technical age. Experiences have led to the conclusion that the safety problems cannot be attributed exclusively to either technical or human factors, but they emerge from the interactions between the social, organisational, operational and technical aspects.

At present risks of GM crops are assessed predominantly on basis of natural scientific evidence, with relatively little focus on uncertainties, while ethical issues are treated as a separate issue (Carr & Levidow 2000). In other areas as, e.g. industrial safety, risk assessments furthermore comprise analysis of human factors and organisational aspects, but ethical issues are also here treated separately if they are considered at all. Several authors argue that a more integrated and interdisciplinary approach is needed structuring knowledge elements from various scientific disciplines in such a manner that all relevant aspects of a social problem are considered in their mutual coherence for the benefit of decision-taking including uncertainties and ethics (van Asselt 1999, Carr & Levidow 2000). According to Stirling & Mayer (1999) new risk appraisal tools are required which are: flexible and broad in scope; open to divergent interest and values; able to acknowledge uncertainty; whilst being systematic, transparent, verifiable and accessible as well as practically feasible and efficient.

According to Slovic (1998) a new approach must highlight the subjective and value-laden nature of risk and conceptualise the act of defining and assessing risk as a game in which the rules must be socially negotiated within the context of a specific problem. Further Slovic argues, "*that whoever controls the definition of risk (i.e. determines the rules of the risk game) controls the rational solution to the problem in hand. If you define risk in one way, then one option will rise to the top as the most cost-effective or the safest or the best. If you define it in another way, perhaps incorporating qualitative characteristics and other contextual factors, you will likely get a different ordering of your action solutions. Defining risk is thus an exercise in power*".

On the one hand research and experience indicate a need for new assessment tools. On the other hand legislation and regulations concerning risk and safety issues rarely demand interdisciplinary analyses and statements. Risk assessments carried out for approval purposes are nearly always financed by the applicant (e.g. a company).

From a financial perspective, it is in the best interest of the applicant to fulfil the legal requirements, and not to invest extra resources into providing more documentation than required by the authorities.

The challenge is to develop a framework for future risk decisions, which is operational (from a administrative and legal point of view), transparent and interdisciplinary. In this context it is important to understand risk and science new role in society with an increased focus on knowledge, values and uncertainties. We are raising the question, if the development trends can be seen as the beginning of a new age of risk and safety concerns, and what the characteristics are of this new age. Risk assessments shall still answer questions related to technological, human and organisational aspects, but it seems that a fourth dimension is needed in the risk assessment process related to an early integration of values, costs and benefits.

Knowledge and competencies

In public regulation of GM crops the mechanism for selection of scientific advisers can be extremely critical. Two drivers dominate the selection of advisers: a) the need to obtain a high level of expertise, b) the need to identify and manage bias and conflicts of interest (OXERA 2000). Today private companies carries out a significant part of the research concerning GM crops, and it is expected, that in future the private research will increase further compared to public funded research. Plant breeding based on GM technology is very specialised demanding considerable resources making it nearly impossible for a public funded research base to reach the same level of knowledge and insight related to a specific GM crop. This means that regulation concerning risk and safety issues to a large extent will rely on results from private research placing public policy and approval work in a difficult and problematic situation; on the one hand ensuring the availability of high competent scientific advisers to evaluate and review the risk assessments carried out by the private companies, and on the other hand fulfilling the requirement of being able to identify and manage bias and conflicts of interest (Rasmussen & Borch 2002).

Providing knowledge and competencies for regulation of GM crops is one aspect related to and influencing the relationship between government, industry and academia. Referring to the triple helix model and the Mode-2 knowledge production theory, cross-institutional and cross-disciplinary networks and co-operation characterise modern knowledge production making it rather difficult to clarify and identify interests and conflicts between government, industry and academia. According to Morris (2000) the academics most qualified to advise (e.g. government) will increasingly be bound by collaborations, consultancies and directorships to commercial interests that may disqualify them from the role of independent advisers. In regulation related to GM crops different groups of stakeholders, e.g. NGOs, often demand more transparent decisions also comprising an explanation of the values on which the decisions are based. To some extent the triple helix model can be used to explain why the public often views government, industry and academia as being one piece in contrary to independent and separate working institutions leading to the stakeholder requirement concerning transparency and openness in risk decisions. This is in accordance with the post-normal science approach saying that the changing context in science and in society has focused a new need and demand for critical insight. Post-normal science shows why it is necessary, not merely for political justice, but also for the quality of the decisions themselves to have a dialogue between all stakeholders in policy-making and decision-taking on science-related issues. Morris (2000) (looking at control of biological medicines) presents the point that it may soon be possible to identify some relevant analysis and practicable models for importing the public interests more effectively into the regulatory process. She argues, that the triple helix model should acknowledge more explicitly a fourth strand, and as innovation triggers public disquiet and social disruption, the interactions and networks shall involve four partners: government, industry, academia and the public.

Detecting and framing risk decision processes

Decision issues always involve two major dimensions: 1) beliefs about the cause/effect relations and 2) preferences regarding possible outcomes (Thompson, 1967). Simplifying the decision process each of these dimensions can be either certain or uncertain leading to the four extreme decision situations presented in the table below:

		Preferences regarding possible outcomes	
		Certainty	*Uncertainty*
Beliefs about	*Certain*	computational strategy	compromise strategy
cause/effect relations	*Uncertain*	judgmental strategy	inspirational strategy

Real life decisions will be a mix of these four extreme decision situations. Regarding the debate on GM crops they can be characterised as having disagreements and controversies on both dimensions, and if we have to choose one of the four extreme decision situations, it seems that ‘inspirational strategy’ is the best fit. Discussing strategy related to this situation one choice can be to postpone the decision and another to divide the decision into very small sub-decision continuously collecting experience in order to reduce possible damages resulting from mistakes due to uncertainty or imperfect knowledge. Our suggestion to establish a task concerning lessons learned and stakeholder forum for principal questions can be seen as one element to launch a decision strategy that reflects the characteristics of the decision situation.

According to Pellizzoni (1999) the basic questions in the risk debate are: first, what does the understanding of risks depend on and, second, what is the key resource of risk-related social processes. Reflections and responses concerning these two questions can be manifold, but one important factor is the ability to formulate political consensus around problem situations. Formulation of problem situations involves at least two aspects: 1) detection and selection of issues, and 2) framing of the system of concern.

Policy issues may emerge from many sources and they may be triggered by different kind of events, e.g. accidents. The early detection of a policy issue is desirable, because it maximises the number of policy options available and the time available to analyse them. Looking at modern science sociology it is difficult to find solutions to the numerous problems that are raised, e.g. how to improve early detection and definition of issues. In our framework we suggest a forum for handling principal questions in the decision process. A possible role for the forum might be to carry out foresight exercises that seek to detect issues before their effects can be felt. This might include systematic modelling of scenarios and monitoring of scientific developments and their possible effects.

The aim of system definition is to explain and describe the content and concepts of the problem to be analysed. Risk related issues can emerge and be motivated by substantial different reasons and purposes, and it can be hard to reach consensus about problem framing. According to Carr & Levidow (2000), challenging system boundaries can be a powerful way of challenging decisions, by revealing the decision-takers’ unspoken assumptions and values. Questions testing system boundaries could be an approach to set the scientific evidence with its changing social context, in a way that examines value judgements and considers science, risk, uncertainty and ethics as inter-related rather than separate.

Briefly speaking, a decision process can be characterised as a preparation and evaluation of alternatives where objectives of different types and values are weighed out. But as scientific risk assessments normally address one specific technology with well-defined areas of application, alternatives are only discussed in a few words if at all. The lack of alternatives in risk decisions has been criticised several times, and from our point of the view possible alternatives could be part of the system framing with focus on the functionality of technology and alternatives to that functionality.

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