SAFETY SCIENCE Monitor
Special Edition 2006
Article 3
VOL 10

BRIDGING THE GAP BETWEEN EXPERTS & STAKEHOLDERS

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3.1 ISSUES, MODELS, APPROACHES, THE BICYCLE. - (FAHLBRUCH & WILPERT)

One motivator of the search for risk coherence across various industrial domains or different life contexts seems to be the general human tendency to reduce cognitive dissonance (Festinger, 1957). Why is it that with a slight raise of our shoulders we accept several thousands of deaths per year on our freeways while we react with considerable concern when we take in the report of a few hundred deaths due to air plane crashes? Apparently, risk coherence is the result of an exercise in sense making: Different risks are expressed in ways so that they can be compared and so that at the individual, organizational, societal levels, choices can be made which reflect the values of the stakeholders at these levels.

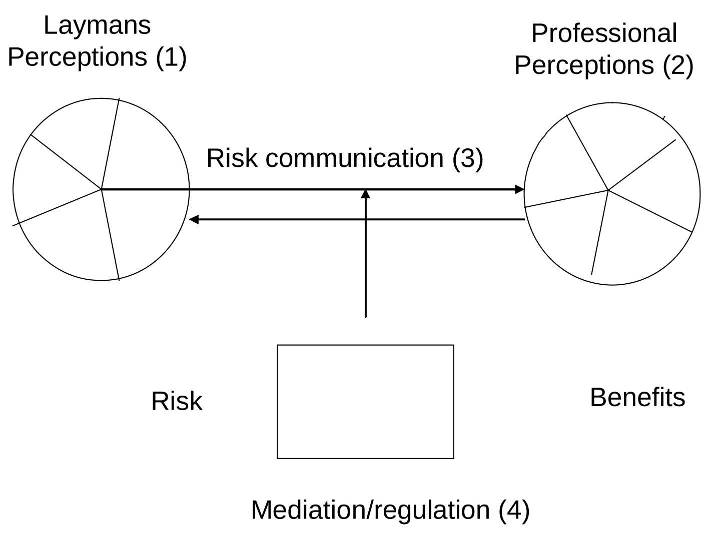

Figure 1 - The four tasks of risk coherencing risks

The exercise is fundamentally a process of risk assessment, risk perception and risk communication which take place in four theatres. First there is the theatre of the life of lay people who nourish a large variety of risk perceptions (Covello, Sandman & Slovic, 1988) which are linked to fearful notions of an event's threat to one's health, its potential negative impact on one's children, its long-term consequences for the natural environment. Second, there is the theatre of professional and industrial domains such as engineering sciences, medicine, traffic systems, whose experts use socially accepted algorithms to calculate "objective" risks in their respective domain and consequently arrive at their decisions They often use different assessment techniques and various frames of reference as time of exposure, amount of exposure, distances, hours spent in transportation systems, death per million, injuries per 1000 etc. Thirdly, there is the theatre of communicating risks between the layman's theatre and the professional one as well as between professionals. And fourth, there is a mediating function, or better: there should be one, which ought to be taken over by regulatory institutions setting minimax standards for societal risk acceptance, i.e. the balance between benefits and risks.

3.2 RISK COMMUNICATION AN ESSENTIAL FEATURE - (FAHLBRUCH)

Presentation of risk information can be found in media, in the discussion about new technologies as well as in health promotion. The discussion about technological risks shows that there is no shared sense about risks and that the question how to present or communicate risks is not answered yet. The discussion is mainly based on the limited degree of the perception of risks, which is related to the nature of risks; we do not have senses to perceive them, we can only indirectly perceive them through the means of communication, which is then the only relevant basis for judgment. In the following, results from studies on risk perception as well as trends in risk communication will be discussed and compared to experiences gained from a training program in the nuclear industry, in which more than 300 managers and supervisors participated.

3.2.1 Introduction

Because risk can not be perceived directly, risk communication becomes highly significant. Studies on risk perception show that experts and lay persons differ in their concepts of risk. Experts use a two dimensional concept: probability times severity of harm, lay persons have a multi-dimensional concept of risks taking characteristics of consequences and situations into account (Fischhoff et al., 1981; Jungermann, 1991; Wiedemann, 1992). The accelerating development of technologies and their inherent risks and hazards leads to an increasing importance of adequate communication. Over the last thirty years changes in the way of communicating risk can be observed.

3.2.2 Risk perception

Every day risk perception is not only based on probability times severity of harm, but on dimensions that reflect the characteristics of possible consequences like catastrophic potential, perceived dread of the risk, escapability from potential consequences, and harm to future generations as well as situational characteristics like voluntariness, controllability, familiarity, man-made vs natural sources and uncertainty (Bennett, 1998; Jungermann, 1991; Slovic, Fischhoff, & Lichtenstein, 1982; Slovic, 1986).

Catastrophic potential refers to the distribution of harm over time; the more expected harm at one point of time, the more risk is perceived. This dimension can explain why driving a car is often judged as less risky as taking an airplane. The perceived dread of the risk source also influences the risk assessment. The escapability dimension – "not in my backyard" phenomenon - was shown in a study of Marks and von Winterfeldt (1984) on the risk assessment of offshore oil drilling: risks, which could happen to oneself are perceived as higher.

The less voluntary, controllable, and familiar and the more uncertain the situation is perceived, the higher the risk is assessed. Man-made risk is perceived as bigger than risk from a natural source. But the risk perception is not only affected by the above dimensions. The framing of consequences, e.g. death or lives saved as well as heuristics and biases like availability, confirmation or overconfidence have an influence on the perception of risks.

Furthermore, there is a bias towards non-acting, the omission-bias (Spranca, Minsk, & Baron, 1991), action weighs more than non-action, e.g. parents avoid having their children vaccinated in the case of risky side-effect even when these are less risky than the possible illness. Especially the above heuristics and biases influence expert- judgments as well as lay-persons. How important the above dimensions of risk perception are, can be seen below.

3.2.3 Risk communication

Risk communication is a field with combines theoretical and practical approaches. Thus, one of the most important books is a manual for plant managers by Covello, Sandman, and Slovic (1988). Summarizing literature and trends, Fischhoff (1995) identifies eight different developmental stages of risk communication:

- "All we have to do is get the numbers right
- All we have to do is tell them the numbers
- All we have to do is explain what we mean by the numbers
- All we have to do is show them that they've accepted similar risk in the past
- All we have to do is show them that it's a good deal for them
- All we have to do is treat them nice
- All we have to do is make them partners
- All of the above" (Fischhoff, 1995, p. 138)

The right numbers – first stage

According to Fischhoff (1995), the main focus in this stage is on the control of design, execution and operation of technologies. Therefore, risk experts developed methods for quantitative risk analysis. The results showed that the numbers and risks are small and there seemed no need to talk about them, because in many industries they received no attention. But in case a risk of an industry becomes an issue, the silence could lead to distrust and be interpretated as information hiding. But even when the results of risk analyses are communicated this could lead to mistrust because of two reasons. On the one hand "…this is because of the unfamiliar, even esoteric qualities of risk analysis" (Fischhoff, 1995, p. 138). On the other hand this is because of the difficulties to perform adequate and comprehensive risk analyses. Unknown facts can not be reflected, but they can happen, which reflects shortcoming of these analyses as well as the problem that often the analyses rely on expert-judgment instead on empirical data. "Nonetheless, even the most sophisticated analyses are still exercises in disciplined guesswork …risk analysis may seek the rights of science without assuming its full responsibility (e.g., independent peer review, data archiving, credentialing processes)." (Fischhoff, 1995, p.138f). According to risk coherence this can be seen as a problem; it seems even more like guesswork to perform inter-organizational or overall risk analyses because of the increasing complexity and lack of empirical data.

Communicating the numbers – second stage

In this stage the main approach is to present the risk numbers, e.g., media statements, reports etc. But the question is: are the numbers making sense to the public? First of all that leads back to the results of risk perception, clearly the numbers reflect probability times severity of harm, but lay persons rely on more factors in their risk perception, like catastrophic potential or controllability. Thus, the numbers mirror only part of the understanding of risk that people have and the expert approach is somewhat different. Furthermore, different sources often communicate different numbers, one of the reasons is the uncertainty in the risk assessment, but this could lead to an impression of subjectivity in the numbers. Values might be inherent in the risk assessment, it might be a difference whether the criterion is fatalities or harm to future generations. Values are also reflected in the selection for which risk analyses are performed. Thus, the numbers will only make sense if the assumptions for assessing them are made explicit. Risk coherence problems arise because of risk being unequally related to the dimensions of risk perception.

Explaining the numbers – third stage

Because of the experience in communicating the numbers, which are not speaking for themselves, the next necessary step is to explain the numbers. Several studies on risk perception have tested the different possibilities of presenting risk: numerical, verbal and graphical presentations.

Numerical presentation is decimal (e.g. 0,00025), exponential ($2{,}5 \times 10^{-4}$), percentages (e.g. 0,025%) or proportions (e.g. 1:4000). Although these numbers reflect exactly the same risk, they need not be perceived the same and they might be misunderstood. For the common understanding, risk should be expressed either in proportions or percentages, exponentials are difficult to understand and very small decimals might lead to mistrust, because of assumed manipulation (Femers, 1992).

Verbal labels for risks like “headaches can occur” are easier to understand, but there can be large differences in mental representations of verbal risk information (Rohrmann, 1978) and dependencies on the context of the risk (baseline effects).

Graphical ways to present risk information are diagrams, histograms, risk ladders etc. Furthermore, risk can be presented in a more abstract (general case) and more concrete (single case) way.

Concrete presentations are usually understood more easily, but could be jeopardized by implicit values and exaggerations.

Each way to present risk is somewhat problematic, because of the underlying risk concept, information processing, emotional components and inherent values. Therefore, risks should be explained in multiple ways. Presenting risks should include at least the two dimensions probability and severity of harm, but risk numbers often reflect only aspects. Femers (1992) found five different categories of risk information: 1. Probability and severity of harm, 2. Severity of harm, 3. Probability, 4. Hazard sources, 5. Causes of harm. More problems can arise because of different references like populations, production units, geographical areas, time etc. because the dimensions of harm, which are usually multi-dimensional, are treated as one single dimension and because of the character of risk numbers, which reflect an average but not an individual risk.

According to Fischhoff (1995) it is important to know, what the public wants to know, i.e. communicating and explaining that what really matters. People might be interested more in the process and defences than in parameter estimates: “They may even feel that they can get a better feel for the degree of risk in a process from seing how it operates than from hearing about some esoteric numbers” (p. 140).

For risk coherence it seems important that processes are displayed as well as the risk are expressed with the same references on the same dimensions in multiple presentation formats.

Comparing risks – fourth stage

This stage refers to that point that people accepted and accept some risks and reject others: “All we have to do is show them that they’ve accepted similar risks in the past” (Fischhoff, 1995, p. 138). But risk comparisons are risky themselves as Covello, Sandman, and Slovic (1988) warned repeatedly “USE OF DATA IN THIS TABLE FOR RISK COMPARISON PURPOSES CAN SEVERELY DAMAGE YOUR CREDIBILITY” (p.335). Risk comparisons have the advantage that new and unknown risks can be presented in an understandable way, that they support imagination, that they deliver relations of risks and that it is not necessary to present very small probabilities.

But there are disadvantages as well: risk communication can be biased, there are implicit values inherent in comparisons, the quality of the data is often not very good and often the compared risks are not comparable on the dimensions of risk perception. Irritations of the public can be the result as well as distrust, if people have the feeling that someone compares apples and pears and risk or tries to diminish the risk.

Covello, Sandman and Slovic (1988) identified 18 factors important in risk perception and evaluation: catastrophic potential, familiarity, understanding, uncertainty, controllability (personal), voluntariness of exposure, effects on children, effects manifestation, effects on future generations, victim identity, dread, trust in institutions, media attention, accident history, equity, benefits, reversibility, origin. The authors note “In selecting risk to be compared, it is helpful to keep these distinctions in mind. Risk comparisons that ignore these distinction are likely to backfire (e.g. comparing voluntary to involuntary risks)” (p.354). They suggested a rank order acceptance for risk comparisons, but in an empirical test by Roth et al. (1990) this rank order of acceptability could not be proofed.

For risk coherence this seems the most problematic feature: How to present and communicate all these different risk in one statement and maintain credibility?

Compensation of risks – fifth stage

The use of risk comparisons showed that even risks which are smaller as those accepted in the past need not automatically be accepted. One of the reason could be the benefits related to risks. People need for rational choices according certain activities information about benefits as well. Risk analysts and risk managers have to consider that the public has a right for the compensation of risk. But how to express benefits which can not be readily framed into money? Here issues arise comparable to those related to risk analysis, uncertainty or different ways of specification. Presenting risks and benefit means providing a base for individual trade-offs. But here framing effects can be expected, i.e. trade-offs can be influenced by the way the consequences are frame, e.g. lives saved vs lives lost. Changing frames could lead to an instability of preferences.

For risk coherence this may complicate the presentation as well, because different risk may have different benefits.

Trust – sixth stage

In this stage the communication process itself was focused, because it was recognized that despite of all efforts put into risk communication often the intended results could not be reached. Important for a successful risk communication is beside getting the numbers right, beside explaining the numbers and beside showing the benefits the respectful treatment of the public. Here action often speak louder than words. Openness is asked for as well the impression of voluntary communication, risk communication that is seen as required reaction to an event is seldom trusted. The more someone is perceived as having advantages the less he will be trusted. Even regulatory bodies and scientist lost credibility because of communicating different numbers or diminishing risks. In this stage also the importance of communication skills became an issue. But this could as well lead to problems as Fischhoff (1995) stated: “The ignorant smiles of PR types are a good tool for digging oneself into a hole” (p.142).

For risk coherence it seems important to find the right persons, credible and skilled in communication.

Participation of the public – seventh stage

This approach tries to get the public involved from the beginning of the planning. Psychological this can be seen as an overcoming resistance strategy. “Moreover, this kind of communication fulfills other conditions of a partnership. It shows an interest in the public without its having to cause trouble or even raise suspicions. It can also reduce expert’s fear of the public by offering direct contact, in regulated settings conductive to creating human relations. Those fear can color perceptions, if they create the impression that the experts have something to hide or just dislike the public. Recognizing that they are people, too, with foibles and emotions, is a part of expert’s developmental process” (Fischhoff, 1995, p.143).

For risk coherence this implies that the public should be involved already at the very early stage of selecting the risks for risk analyses.

3.2.4 Risk communication in the nuclear industry

Risk communication in the German nuclear industry was from the beginning under the slogan “We don’t want to be conspicuous”. This motto guided the communication efforts until the middle of the 90ies. It resulted in a lot of failures like non-reporting of events to the public until they were asked for (reacting instead of acting), not presenting benefits etc. Although the power plants do have nice information centers, the people working there are not trained communicators but former operators.

Since the middle of the 90ies communication changed, events were reported in the internet and the top-level management of a German utility judged risk communication as so important that it should be included into a training for managers and supervisors.

3.2.5 Training program on safety culture

One of the German utilities asked the Forschungsstelle Systemsicherheit (FSS, Research Center System Safety) to develop and to run a safety culture training titled “The role of the human being in the nuclear industry” for their managers and supervisors, i.e. persons with executive duties. Altogether more than 300 participants from different nuclear plants and the central administration joined the three day seminars which were run 24 times over a period of 30 months. The training course was developed by the members of the FSS in interaction with the top-level management of said utility. One of the training objectives was directly related to risk communication:

Professional identity relates to the self-confidence of someone’s own perceived responsibility for his performance (Seliger, 1997) and an open and exchange oriented attitude according to information demands and worries of the public (Covello, Sandman & Slovic, 1988).

Beside other topics principles of risk perception and risk communication (Fischhoff, 1995) were given and related to the present status of the nuclear industry in Germany. The participants discussed mixed and misleading messages (Jardine & Hrudey, 1997) and developed a risk communication strategy for different groups of the public (e.g. journalists, politicians, teachers).

Contrasting the literature on risk communication here also the individual (even private) communication was a topic as well, because it was agreed that all managers and employees can be seen as representatives of the utility.

Perceived problems

Reflecting on the trainings on problem was identified that was not found in the literature and could be expressed as self-defense bias. Through the missing acceptance of nuclear industry, now even expressed by the political decision to quit this option, people in that industry always feel attacked even when they are not. Automatically then they start with self-defending which is a killer for each communication process. This could lead to the feeling of missing respect on the other side, if questions are not answered but self defending speeches are held as well as to rising suspicion, someone who defends himself instead of answering questions probably wants to hide something. This self-defense bias was so strong that even in the training some resistance arose, but the majority of the participants weighted the recognition of this bias as very important.

Another problem can be seen in the missing discrimination of various groups in the public and their different communication needs. Also stereotypes of certain groups who serve as enemy or scapegoat like the media or the teachers can lead to problems in the sense of self-fulfilling prophecies.

More problems arise from an engineering attitude to be always very precise, correct and detailed which leads to a language which is not easy to understand for lay-persons on the one hand. On the other hand the aim of the communication can be lost by the attempt to be very precise. During the training the participants had the task to develop a communication strategy for an event scenario framed according to the categories problem, aim, action and expected difficulties. The majority missed to focus on the communication problem and centered instead the technical problem, which reflects this attitude.

3.2.6 Conclusion

Results from studies on risk perception and problems from the different stages of risk communication as well as the experience from the nuclear industry mirror questions and difficulties for risk coherence. First of all is risk coherence necessary or wanted? It seems very important to study the needs of the public? Do they want risk coherence? Are these numbers that are sense-making? How to overcome the problem of psychological factors / dimensions of risk perception of very different risks? How to treat individual risk communication? Won't this be always related to one organization? How to include benefits into coherent risk communication? It seems that at least the individual risk perception should be seriously taken into account otherwise people may have the feeling that apples and pears are compared. Furthermore, who could be the experts for risk and benefit assessment and the right persons for communication?

3.3 RISK CONSENT ANOTHER ESSENTIAL FEATURE - (DE MOL)

3.3.1 Introduction

Today, we live more comfortably than ever before supported by the understanding of the risks based on the concept of the Risk Society (Beck, 1992). The risk of personal discomfort and harm is well under control, but although small still present. This concept envelops only a limited part of the word population and focuses on an extended and better life for the lucky ones. This implies that political systems, societies in general, and cultures are major determinants for the efficacy of risk control concepts. Exposure to hazards and disease decreases quality of life. Therefore, risks encountered in areas of societal activities, such as dwelling, transportation, manufacturing, and - last but not least – politics, contain *the elements of fear and the need to avoid personal injury*. In other words, materialized risks become visible in the heath care system. An airplane crash results in societal loss for the relatives of the deaths, material damage, and injuries to the travelers, bystanders, and relatives. However, exposure to the health care system itself imposes a risk for the individual too. The health care system deals with the results of materialized risks in other areas, but it also i*mposes an incremental risk* to the hazard exposure accumulated during a lifetime. No need to see a doctor is the best result of a safe and healthy life. However, similar to other challenges in the risk society, dealing with health care becoming more complicated to patients. The simple causation rules and the dominant role of the doctor in decision making based on probabilistic risk analysis gave the impression of effective risk management. Emerging complex technologies and increasing criticism on the system as well as its side effects will result in situations in which patients will more often take more complex decisions. The major question is how to reinforce and improve risk handling by patients. The second question is whether this should be a matter of skills of doctors and patients alike, or a systems control matter. Circus or management?

3.3.2 The concept of risk in health care and medical technology

From the view point of risk control, the societal purpose of health care is to mitigate the personal sequel of an unwanted damaging impact. It is reality, however, that people seek medical treatment either for reasons of exposure to damaging influences or intrinsic disease and prevention. *A health care system implies a strong defensive barrier to protect or to reduce the consequences of risks of "accidents" and disease*. The availability of resources and political and cultural decisions determine who will benefit when under which conditions. When many resources are spent on avoiding physical harm in aviation and industry, it would be foolish to accept more deaths and disability in an as much wanted area of societal activity. Imagine that huge investments in aircraft development avoid numerous deaths during a landing crash, with a similar investment in rescue services enabling rapid transportation to hospitals, after which many victims die anyway due to incompetence and lack of resources. Therefore, in a system approach to control risks, medical care should be taken into consideration too. Sometimes, only mental and limited medical support can be provided such as in the case of mesothelioma due to asbestos exposure.

Within the spectrum of societal activities, health care and medical technology are separate entities with evident risk concepts of their own. It is worthwhile to investigate which factors make up for the difference, and whether the risks to which patients are exposed in these systems are acceptable compared to other exposure scenarios. Today, medical technology has a major impact on the health care system of the mainly western countries that can afford it. However, in these countries, questions arise about type and number of victims due to substandard practices (Institute of Medicine – To err is human) . In a previous contribution (Bad Homburg 1998), we focused on the medical device industry, the conflicts of interest in the case of serial failure, and the pivotal role of the treating physician as a risk manager. In a following contribution (Bad Homburg 2000), it was concluded that legislation should comprise a legal framework in order to give room to self-regulation for industry and medical profession, but also to avoid lack of engagement and commitment of the responsible parties. This implied a role of governments for proactive safety measurements and a strong consumer protection role for civil litigation in the case of failed medical technology. In this contribution, we try to analyze the meaning of risk and risk-related events, and we pay special attention to new developments, such as internet-guided patient self-management of care, new devices for treatment of heart failure, and stem cell therapy.

3.3.3 Risk in emerging medical technologies

When speaking about risk in medical technology, one should discriminate between intrinsic failure due to a flawed or poorly tested design, and interface or system failures when poor prescription, implantation, adjustment, or follow-up play a role. Established medical technology, such as devices, smart drugs, and equipment, tends to fail in a far lower rate than patients, doctors, and organizations. However, in medical technology, the design and testing should explicitly aim for "user robustness". The rate of instrumentational failure considered acceptable is within the 1 / 100 range for complex procedures such as a catheter technique for removing clots from a small brain artery. The procedural failure rate is often higher and 1 / 20 risk of death and disability due to the fact that the procedure did not work out is considered acceptable. There must be reciprocity between chances of survival and disability without the procedure and the risk of failure. Also the availability of alternative treatments and experience of the center should be part of the process of balancing the risk. In the individual case of a patient opting for an intervention, the patient faces only one chance or event that determines success or various degrees of failure. Sometimes there is a repair scenario present. This implies that decision making by the patient is experienced as either a game flipping the coin or moving some scenarios without having real free options. The mandatory need for informed consent and informed decision making serves the medico-legal format of the patient-doctor agreement and promotes risk acceptance rather than freedom to choose.

In contrast to the patient, the doctor has many occasions to choose and to decide. From his point of view, the outcome of the decision making game may be manipulated by accruing as much foreknowledge relevant for the specific case and by being experienced. This explains why specialization for the relevant disease yields better outcome in case the disease is present. It also explains why overuse of diagnostic methods is general practice for reasons of gaining certainty, profit, and potential legal defense.

3.3.4 Risk handling and medical decision making

Medical decision making is primary doctor-oriented and therefore the probabilistic risk concepts work out well enough. Assumptions for larger or smaller groups are projected on the individual case. From that view point, a personal drama to the patient is the calculated risk in the equation - reasonably to be expected. In health care, it is common to take a negative outcome as calculated risk at face blank. A phenomenon or observation without need for further investigation, unless an unnatural death is expected. Clusters of events generate a drive to investigate and to improve. Another powerful source of benchmarking risks are publications in scientific magazines and professional guidelines. A probabilistic risk concept effectively supports the ethical requirements of the health care systems of the western society, which are basically utilitarian (Fielder/deMol). Decisions for the system, the patient groups, and the individual are based on predominantly risk/benefits considerations. In the minority of cases, decisions are based on benefits to society (the dying patient willing to participate in a medical experiment – compassionate use of technology) and the societal merits of the individual patient (the patient can afford the price or is privileged). In case doctor decision making remains dominant and well accepted questions about the risk concept are generally limited to the courts. This is especially the case for failed drugs and devices as companies use the same risk concept as the doctor. This is probably caused by two factors. Manufacturers deal with patients through the treating physician and do not have a conventional contractual relationship. Industry depends on risk concepts adhered to by the medical profession. Second, this risk concept is less critical as it avoids process and context analysis in the case of lack of effectiveness and in most cases of adverse events. When declared safe and effective by the health authorities, supported by the medical investigators, the technology remains untouchable for a while.

3.3.5 New uncertainty and new technology

This is a curious phenomenon for medical technology-driven care. This counts the more as professional risk considerations are experienced less certain due to the complexity of disease and treatment. Advancing knowledge raises more questions and several alternative solutions. Also from the perspective of medical research, medicine deviates from natural and engineering sciences. Trial by error is the standard. As proof can only be obtained by eating the pudding, randomized clinical trials are a prerequisite for evidence-based medicine. Two pillar methods of a new discipline in medicine clinical epidemiology, which is utterly probabilistic oriented. The two other pillars of medical evidence are the nested case control study and the meta- analysis. It demands another forum to explain the shortcomings of these methods to extract medical proof. Basically, it has to do with the fact that the professionals and industries in the system favor their own interests first. Second, the development of new insight is going fast and results in numerous product development opportunities.

The stem cell discussion in the US Congress is a good example of the confusion around promises, products, and treatment opportunities (Weissman, New England Journal of Medicine 2002). It is clear that only a very limited number of insiders understands the scientific issues, and even a smaller number the medical and political ones, although the number of discussants suggests the contrary. One thing will be clear: during clinical trials as well as in the case of accepted technology, the decision to undergo a specific treatment will be justified only with a decisive input from the patient. The best decision will be less clear, given the uncertainty in the longer term, but also the individual financial sacrifices. These treatments are becoming so expensive that is doubtful that even the citizens of most western countries can afford them.

On the other part of the spectrum, patient self-management of care boosts. It is cheaper and effective. It also improves quality of life, as the dependence on the bureaucracy lessens. Last but not least, the patient usually has become a disease expert, much committed to his own case. For this type of self-confident patient, probabilistic decision making by the doctor is judged paternalism. It also explains that self-management of care is still considered a privilege and an exception, only allowed when the regular professionals fall short due to lack of personnel.

In conclusion, modern medicine yields promises, options, and uncertainties. New technology complicates decision making for all parties involved. There will be a tendency to shield the patient from complex decision making by professionalizing the process. It is too complicated for the patient, experience will be gathered mostly in clinical trials too acquire “evidence”, and basically who is going to pay anyway? In this scenario, the patient should be provided with a better risk-handling concept for the mere reasons of patient protection. Also, in cases that decisions are transferred to the patient, the conventional risk/benefit-oriented and probabilistically supported concepts are too narrow.

3.3.6 New concepts of risk handling: gaming and answers to existential questions

Modern medicine should increase treatment options, thereby enabling patients to balance risks. All patients fear medical interventions. Although in terms of outcome medical technology deals effectively with fear in a retrospective way, the risk concept purely based on probability considerations is incomplete from the patient point of view and also from the point of view of patient’s right protection. As mentioned earlier, the patient has only one chance to play the game to be treated. Shifting the focus of decision making from doctor to patient creates the need to enhance the risk concept of the patient. Therefore, it is obvious to enhance that concept with *tools derived* *from game theory* (Kjel Hausken, Risk Analysis 2002) for reasons of patient's need as well asthe fact that care is to be seen as a dispersed system. Health care is costly, its organization fragmentized, and resources to improve the system's reliability are considered a public matter (risk – benefits), although the true risk in the individual case is affected by natural, behavioral, and technological factors.

The other approach should be focused on risk perception. The process of balancing the risks, which basically means that the doctor performs the juggling act and leaves the patient as the spectator fearing the failure. The patient fears a juggling mishap due to his lack of experience and the fact that he has only one opportunity to be part of the show. Usually, it is up to the doctor to judge whether the patient is competent and educated enough to play a role in the risk-balancing act. Especially, interventions with a life-saving or life-threatening effect require many discussion hours with patients and relatives. These hours are considered not available and expensive, but should be considered tightly coupled to the intervention. The way risks will be handled by the patient depends on existential factors present in any human being, such as fear for death, freedom and responsibility, isolation, and meaninglessness. All these aspects of a human's existence are touched by the process of informed decision making by the patient. However, as he is not experienced, we just let him talk, instead of providing him with a framework of risk acceptance based on a self-chosen position towards fulfilling existential needs. This *existential approach to risk perception* (Langford, Risk Analysis 2002) is probably most useful in groups of humans exposed to real risks with a high likelihood to occur. Patients are such a group, in contrast to remote environmental or industrial hazards.

3.3.7 Typical preoccupations with risks

The previous reasoning implies that the risk concept used in the usual patient /doctor relationship is flawed. Studying risks makes only sense in case the context and the effects of risks are taken into account. In health care and medical technology, the relevant risk is a risk of adverse outcome, which is *unintended* negative outcome. Other aspects of adverse outcome are (un) avoidable and (un) acceptable. The criteria to label an outcome as avoidable and unacceptable depend on professionally defined standards with respect to performance. Due to lack of knowledge and /or resources ,professional bodies consider certain performances safe enough. Today, also organizational and budgetary considerations determine the safety standard. In coronary artery bypass grafting (CABG), usually a vein retrieved from one of the legs is used. This is done by a 15 to 50 cm long incision in the leg. This results in an acceptable (Dutch standards) risk of infection of 12 percent. This number has been five percent but has increased over the past five years. In four percent of the patients undergoing CABG, an extension of the hospitalization with two to three weeks is necessary. It is true that patients suffering from overweight, diabetes mellitus, and/or serious heart disease contribute to this increment.

However, it is possible to remove the vein by means of a videoscopic closed method, requiring only two small incisions. Major drawbacks are the intensive training and an average of 30 minutes longer use of the operating room, besides an extra € 600, expense for the disposables. This safety measure bounces back on the fact that not enough operating time is available from the manager's point of view. The manager also restricts the use of this technology as he lacks hospital budget to invest in saving costs, which in case of infection are to be made by the hospitals providing the postoperative care. Surgeons do not object as it is wiser not to disclose a serious problem with leg wound infections (as it is felt a shame – Davidoff) and a preventive measure limits the number of operations and therefore the surgeons income. The presence of waiting lists is also named as a reason to push forward with the production, despite poor infection performance. In summary, under the pretext of strict economic control (Brazier) of health care expenses, safety tends to be ignored and results in costs to patients and society.

A very popular tool derived from industry is the Cumulative Sum technique (CUSUM). In medicine, it is used for detecting clusters of failures, such as surgical failures (Novick), deaths in a neonatal intensive care unit (Barrington, 2001, for the surveillance of health events (Rossi), and detection and monitoring of hospital -acquired infections (Morton).

In surgery as well as anesthesia and radiology, training on the basis of simulations is becoming more and more en vogue (Cook, Sica). These facilities are considered expensive and this type of training is non-obligatory. When an industry introduces new technology, training and training costs remain on the part of the sales department. Gynecologists in the UK recently constructed a training workbench to assess and improve knotting and tying. All surgeons, experienced and fresh, performed better,and the main issue is whether this simple training should be made compulsory and how to organize it (Treasure, 2002).

3.3.8 "Simple solutions" to reduce risk

Heart surgery draws quite some spotlight due to its high-tech nature and the risks involved (www.doh.gov.uk/bristolinquiryresponse). Public awareness and sometimes outrage also forces doctors in certain specialties to make their performance public. In the USA and the UK, report cards for hospitals that perform open-heart surgery are common. As of 2005, the personal performance of individual surgeons in the UK will be published (Vass). However, it is still not clear what the effect of the individual surgeon is on a complex process, which in certain hospitals is basically guided by bureaucratic principles as mentioned above. The surgeon is only one factor (Treasure). Also high premiums for malpractice insurance force the medical community to think about strategies to reduce errors and at least to promote safety. A well accepted and often recommended tool to improve outcome is patient selection (Kmietowicz) . It certainly means that high risk patients are denied beneficial treatment. At the other end of the spectrum recommendations such as a star-system may suggest to the public superior safety and performance (Harris). Apart from risk avoidance, the effects of these strategies remain unclear. Although these measures may initially satisfy the public needs, it may be better to look first at the care process, at how workers deal with clients, and initiatives can be better investigated or researched before applied to patients.

With respect to research innovation, risks are wrapped into the principles “earn as you learn” and “trial by error”. It is to be expected that with the concept of medical research as a life sciences discipline, principles of natural sciences and engineering science will be adopted. Another misconception is established by the principle that prior to testing technology in humans , experiments on living animals mimicking the human body is indispensable (Roberts, 2002). Last but not least, patients are not adequately informed about the risks of being a participant in a trial or its outcome. A recent dispute relates to the question whether the patient should be informed when a trial is flawed by fraud or poor performance by the clinical investigator (Goodare 2002, Mason 2002). In a complex system such as health care and technology, safety studies are considered to be extremely difficult to carry out. However, the above-mentioned situations make any course of action to improve patient safety very clear. Sector- specific measures are the gathering of information of the basis of confidential reporting (Runciman, 2001), increasing the autopsy rates for in-hospital deaths (Deiwick, 1999), dealing with shame and a culture that denies the existence of error (Davidoff, 2002), complying with instructions for use of devices (Spurgeon, 2001), and a legal framework that protects whistle blowers (Dyer, 2001).

3.3.9 Towards risk coherence

Medicine and medical technology present a wide array of risk concepts and perceptions. This variation occurs within the sectors and within the various practices. Compared to other industrial sectors, one may speak of splendid isolation, with own risk definition, risk analysis, and risk management rules. However, when medicine in the wider sense develops more and more into a consumer service and the patient’s role becomes more important, the common modes of dealing with risks in other parts of society will be adopted. A differentiation of risks will always be present. Exposure to risks of car traffic and hospitalisation is unavoidable. But these are minor side effects of a positive *risky existence.* It is generally accepted that the lethal risk by exposure to traffic is far higher than that of industrial hazards even when both exposures are sought voluntarily. From the consumer point of view, it is reasonable to accept that the risk of dying due to a hospital error is in the same range as dying from a car accident. *The public’s perception* of medical risks is biased due to the dominant role of the professionals and the common belief in the public benefit of health care which assumes to exceed the drive for personal profit. However, the public trust in health care and clinical research is very much under tension (Kelch, 2002).

The way sources of information are used and the way guidelines are generated by professional bodies are questionable. Like elsewhere, the financial interests of government, industry, and individuals are high, and the manipulation of the information and the media is essential to “survive”. This contribution merely focused on the aspects of an uneven *playing field, risk presentation, and risk compartmentalisation.*

In conclusion, the risk concept used in medical decision making at the level of the patient-doctor relationship needs enrichment by components of game theory and adjustment for the existential worries of the individual patient. There is a shift going on from a doctor-dominated risk juggling as a circus act to a frame work of risk analysis and risk management centered around the individual patient’s interest. It is the patient who has more options and complexity to decide about. This implies that the monopoly of the medical profession for defining and assessing risks is weaning. The patient / consumer, but also authorities can only cope with a limited number of risk concepts during their lifetime. Also for reasons of applying risk knowledge from other societal areas to improve patient safety, risk comparison is slowly taken place. Aviation is still the most wanted metaphor. However, it is also clear that risk coherence and comparison concepts are mandatory to promote the study of risks and the development of analysis and control tools in health care. It also moves risk analysis away from medical decision making and outcome analysis on the basis of the cost/benefit principle.

3.4 RISK DECISIONS AND THE BENEFITS/COSTS ISSUES (ANDREW EVANS)

Transport accidents usually arise from vehicles colliding with each other or with other objects, or from people being struck by vehicles. Sometimes fatalities and injuries arise from the hostile environment of certain transport modes: the sea, the air or tunnels. Sometimes fire is involved. The contributing causes of transport accidents are diverse.

The losses from transport accidents are also diverse. The principal losses are fatal and non-fatal injuries to humans, but accidents may also cause environmental pollution, damage and disruption. In some accidents, these other losses may be dominant, but we here focus on casualties, and specifically fatalities, because these are important and reasonably clearly defined.

After this introduction, the paper has two main sections. Section 2 considers comparative British data on transport risks, and is largely based on a short paper submitted to the Royal Statistical Society. Section 3 considers safety decision criteria, first in general and then as applied to road and rail safety measures. The section concludes with a short discussion of the strengths and problems of such criteria.

3.4.1 Estimates and Characteristics of Transport Risks

Data sources

There are separate accident reporting systems in Britain for each of the four main modes of transport: road, rail, air and water. By international standards, British transport accident reporting is reasonably good both in quality and availability, though data on non-fatal injuries are not available for all modes.

Road accidents involving personal injury are reportable to the police, who record accidents on a common national form. The Department of Transport, Local Government and the Regions (DTLR) assemble the data and publish the main statistics in *Road Accidents Great Britain* (DTLR, annual a). The principal weakness of the road accident data is under-reporting of non-fatal injury accidents, particularly single-vehicle and two-wheel vehicle accidents; this arises partly because there is no legal requirement for those involved in some types of accident to report the accident at all. Nevertheless, the British road accident database is recognised as being of good quality. It has been maintained in its current form for about 25 years, and goes back in more primitive forms for much longer.

Rail operators report accidents, dangerous incidents, and injuries to HM Railway Inspectorate (HMRI), which is now part of the Health and Safety Executive (HSE). HMRI dates back to 1840, and publishes an annual report on railway safety in Great Britain (HSE annual). Aviation accidents and incidents are reported to the Civil Aviation Authority, which periodically publishes a summary (for example, CAA 2000). Merchant shipping accidents and incidents are reported to the Marine Accident Investigation Branch (MAIB of DTLR), and are published in their annual report (MAIB annual). Because aviation and shipping are international modes, the accident data cover accidents to British aircraft and ships anywhere in the world, and also separately accidents to foreign aircraft and ships in British airspace and waters.

The DTLR's compendium *Transport Statistics Great Britain* (DTLR, annual b) brings together the key accident and casualty data from all four modes, along with many other transport statistics. It includes some modal comparisons of accidents and accident rates that are not available in the separate modal publications.

Transport fatality risk

Accidents are usually regarded as random events: if they were predictable, they could be prevented. A simple model is that fatal accidents in a specified system are presumed to occur randomly at a rate λ per unit time or per unit of activity, such as per vehicle-kilometre. Once an accident has occurred, the number of fatalities is also random, and has a probability distribution with mean μ. The mean number of fatalities per unit time or per unit of activity is then the product $\lambda\mu$. This quantity may be regarded as the primary measure of the risk of accidental death posed by the system. The values of both λ and μ may be reduced by safety measures, but generally not to zero.

The parameters λ and μ are not directly observable, but can be estimated. The obvious method is to use accident data from a period which is recent enough and short enough for λ and μ to be regarded as both stationary and still current. In that case, an unbiased estimate of the risk $\lambda\mu$ is total number of observed fatalities divided by the observed time period or amount of activity. This method works well for systems in which accidents are frequent and where the distribution of the number of fatalities in accidents is not too wide. The obvious transport system to which these conditions apply is the road system, in which it is often taken for granted that the most recent year's observed number of fatalities is a good estimate of the fatality risk per year. More generally, road accident analysis makes much use of statistical methods.

Estimating the current level of risk is more difficult for systems in which accidents are infrequent, but in which severe accidents are possible. The clearest example in transport is merchant shipping, in which there are now only a handful of fatal accidents each year involving British vessels, mostly with one fatality, but in which very severe accidents remain possible. Thus there were just 46 merchant shipping fatalities in the whole decade 1991-2000, but 1987 saw a single accident with 193 fatalities (the capsizing of the *Herald of Free Enterprise*); that is the worst British transport accident of the past three decades. In these circumstances, estimates of fatality risk based on past accident data are much less precise. The natural statistical approach is to seek more data, either by extending the time period analysed, in which case it may also be necessary to model the time trends in λ and μ if these are not stationary, or else by extending the coverage from the national to the international level, as is done in aviation.

An alternative approach is to develop a risk model of the type used in the nuclear and chemical industries. London Underground and Railway Safety (the industry organisation that coordinates safety on the national railway system) have both done that for their respective systems. The mean number of fatalities per year on the national system estimated by Railway Safety's risk model is more than twice as great as that estimated by the present author from past accident data; the reasons for the difference are currently not understood (Evans, 2002).

Fatalities per year

Table 1: Fatalities by transport mode: 1991-2000

Mode	Average number per year in	
	1991-2000	**2000**
All modes	3945.7	3679
Roads of which	3733.2	3409
Pedestrians	1084.9	857
Cyclists	186.0	127
Two wheel motor vehicles	493.2	605
Bus and coach occupants	20.4	15
Others, including car ocunts	1948.7	1820
Rail of which	176.3	226
Non-trespassers	43.3	39
Trespassers	133.0	187
Air	31.6	39
Water	4.6	5

Sources: See government publications in reference list. Rail data are for fiscal, not calendar, years. Road and rail data are for Great Britain; air and water data are for British-registered ships and aircraft

Table 1 gives the mean numbers of accidental fatalities per year on each mode for the decade 1991-2000, and for the year 2000. These are general estimates of the level of risk from the transport modes to the population as a whole.

The dominant transport fatality risk is from roads, despite Great Britain having a good road safety record by international standards. The observed number of 3,409 road fatalities in 2000 is a good estimate of the current risk. This represents some 0.5% of all deaths, and about one quarter of all accidental deaths. The average age of those who are killed on the roads is relatively young, so road accidents have a material effect on the expectation of life. In 2000, 25% of the fatalities were to pedestrians, 4% were to pedal cyclists, 18% were to two-wheel motor vehicle riders, 0.4% were to bus and coach occupants, and 53% were to other motor vehicle occupants, mostly cars. The general level of road fatality risk is falling over the long term, from a post-war peak of just under 8,000 per year in 1966. This can been seen in Table 1 in the fact that fatalities in 2000 were generally lower than the averages of 1991-2000; the exception to this trend is fatalities to two-wheel motor vehicle riders.

None of the non-road modes makes a substantial contribution to the national total of accidental deaths, though every accidental death is an individual tragedy. For these modes, the data for 1991-2000 are more reliable indicators of risk than the data for the single year 2000, because of the smaller numbers of accidents. For railways, the number of non-trespasser fatalities is about 40 per year, most of which occur not in high-profile train accidents, but in individual accidents such as passengers, track workers, or pedestrians at crossings being struck by trains. The surprising feature of the rail data is the large number of fatalities to trespassers, that is people illegally on the railway, which is about three times greater than all others combined. It is likely that some of these fatalities are actually suicides, though not identified as such. (Identified suicides are omitted from the data; it is likely that the high trespasser figure for 2000 will be revised downwards as some of them are reclassified as suicides.)

There were no very high fatality accidents in either aviation or shipping to British-registered vessels in the decade 1991-2000, though evidence from earlier periods in Britain or in the same period from other countries indicates that such accidents remain possible. Therefore the observed numbers of fatalities per year in Table 1 are probably underestimates of the underlying risk $\lambda\mu$ on these modes, though it is beyond the scope of this paper to derive better estimates. In aviation, the observed fatalities are dominated by accidents to small private aircraft (general aviation), whose risk is estimated reasonably well by the data. For merchant shipping, the observed fatalities are dominated by individual accidents on ships, mostly to crew.

Passenger fatalities per hour or distance travelled

Part of the reason why there are more fatalities on the road than on any other transport mode is that there is far more activity on the roads. Exposure is thus higher. In order to compare risks between modes, it is necessary to allow for exposure, and measure the parameter λ as fatal accidents per unit of activity rather than per unit time. This has been done by the DTLR for passenger travel, with passenger-hours, passenger-kilometres, and passenger-journeys as different units of exposure. The rates measure the risks only to travellers; they omit risks to anyone other than travellers, specifically to staff and third parties. It should be noted that the included fatalities differ somewhat between the modes: for example, passenger fatalities at railway stations are included, but those in seaport and airport terminals are not.

Table 2 presents the DTLR's estimates of fatality rates for passengers per passenger-hour and passenger-kilometre by mode. The periods over which these rates are estimated differ between modes for reasons discussed in section 4, though none of them exceed the decade 1991-2000. Therefore, again air and water are likely to be underestimates of the population parameters.

The impression given by these results is that travel by public transport remains safer than travel by car, even after exposure is taken into account, but the gap is smaller than in Table 1. Travel as a pedestrian, pedal cyclist or, most of all, two-wheel motor vehicle rider, is riskier than travel in an enclosed vehicle. If passengers use one of these modes to reach public transport stops or stations, their `whole-journey' risk may be greater than making the whole journey by car.

Passenger transport risk and other risks

In a previous paper (Evans, 1997) the author compared an earlier estimate of the passenger transport risks per hour with the accident risks per hour at home or at work. The author has not found the opportunity to update it, so the comparative results are now somewhat out of date, but they are reproduced as Table 3. The top panel of Table 3 is an earlier version of the data in Table 2; the more recent fatality rates are generally lower than the earlier rates, because most transport risks are falling.

It can be seen from Table 2 that passenger transport risks per hour are generally higher than non-transport risks, and for many people transport is likely to be their greatest everyday risk, especially road use as a pedestrian or cyclist.

Table 2: Passenger fatality rates by mode: periods to 2000

Mode	Fatalities per 100 million passenger-hours	Fatalities per 100 million passenger-kilometres
Bus or coach	0.7	0.03
Water	0.8	0.04
Air	0.9	0.002
Rail	2.5	0.04
Van	4.7	0.1
Car	12	0.3
Pedestrian	19	4.8
Pedal cycle	39	3.0
Two-wheel motor vehicle	517	13

Periods: Water, air, rail: 1991-2000; bus or coach: 1996-2000; others: 2000.
Source: DTLR (2002, unpublished)

Major accidents

It is useful to consider the frequency of major multiple-fatality accidents in transport, partly because, as noted above, this assists in the interpretation of observed data on fatalities, and partly because major accidents are important in their own right.

Table 3 presents data on accidents with 10 or more fatalities over the 32-year period 1969 to 2000. There were 44 UK such accidents in that period, which appears to be about twice the number of non-transport major accidents. The numbers of major transport accidents are fairly evenly distributed across all four modes. However, the proportion of fatalities occurring in major accidents differs greatly between the modes, from 0.1% on the roads to 44% in aviation; the proportion in aviation would be still higher if general aviation were omitted. Only 7% of rail fatalities occurred in major accidents, even when trespassers are omitted; most rail fatalities occur in individual accidents.

The sizes of the worst accidents in each mode in Table 4 are a reflection of the different shapes of their fatality distributions. Road accidents are by far the most frequent, but major accidents are rare, generally involving a public transport vehicle. Maritime accidents are infrequent but include the most serious, because ships are large and the sea is a hostile environment. (The loss of the *Estonia* in the Baltic in 1994 with 852 lives sadly illustrates that.)

Externalities

Transport by mechanised modes of transport poses risks not only to vehicle occupants but also to those outside the vehicle. There are no simple statistical measures of the relative threat of the different modes to third parties, but one useful indicator is the number of fatalities to vehicle occupants of a particular mode as a proportion of all fatalities in which that mode is involved.

Table 3: Accidental fatality rates for passenger travel and other activities: Great Britain: various dates

Mode	Fatalities per 100 million passenger-hours	Fatalities per 100 million passenger-km
Passenger travel:		
Bus or coach	0.1	0.04
Rail	4.8	0.1
Water	12	0.6
Air	15	0.03
Car	15	0.4
Pedestrian	20	5.3
Pedal cycle	60	4.3
Two-wheel motor vehicle	300	9.7
Employment: all	0.84	
Banking and finance	0.17	
Chemical industry	1.0	
Construction work	4.7	
Extraction of ores	12.3	
Being at home		
All ages	2.6	
People under 75	1.3	
People 75 and over	21	

Sources and periods:

Passenger travel: Collings (1994); Air, rail, water: 1975-1992; Bus or coach: 1988/9-1992/3; Other road: 1992

Employment: calculated by author for 1986-1993 from Health and Safety Executive data, assuming a 2,000-hour working year.

Home: calculated by author for 1982-1992 from OPCS and Scottish Office data, assuming an average of 3,500 non-sleeping hours at home per person per year.

This proportion varies greatly between modes: it is low for aviation and shipping, in which non-occupant fatalities are rare (though not zero), but it is much higher for bus and rail. Table 1 shows that there were 204 fatalities to bus and coach occupants in 1991-2000, and *Road Accidents Great Britain* shows that buses and coaches were involved in a total of 1,551 fatalities. It follows that 1,347, or 87%, of the fatalities involving buses were not bus occupants. This somewhat offsets the good safety record for bus occupants evident in Tables 1 and 2. Similarly, 84% of railway fatalities were not train occupants, even when trespassers are excluded.

Table 4: Major British transport accidents: 1969-2000

Mode	Number of accidents with ≥10 fatalities	Proportion of fatalities in accidents with ≥10 fatalities	Fatalities in worst accident	Place and date of worst accident
Road	12	0.1%	32	Dibbles Bridge, N Yorks, 1975
Rail	7	*7.0%	43	Moorgate, London, 1975
Air	16	44%	146	Tenerife, Canary Is, 1980
Water	9	29%	193	Zeebrugge, Belgium, 1987
All transport	44	0.9%	193	
Non-transport (estimated)	≈20		167	Piper Alpha oil rig, 1988

*Excluding trespasser fatalities; if trespassers are included, the proportion is 2.7%.
Source: Evans (1997), updated. For road and rail, the data are for Great Britain; for air and water, the data are for British-registered vessels world-wide.

A wider point is that the threat of accidents may impose costs on third-parties that are not reflected in accident data. For example, pedestrians may take, or be forced to take, circuitous routes to reduce traffic risk; parents may have to accompany children on journeys they would otherwise make on their own (Hillman *et al* 1990); some journeys may be deterred altogether. These measures all have costs, but, to the extent that they are successful, they will show up in the statistics as a benefit in the form of reduced accidents rather than as a cost. However, there exists no statistical indicator of imposed risk that is independent of accident data.

3.4.2 TRANSPORT RISK APPRAISAL

Risk criteria

The principal formal criteria for deciding whether risks are tolerable or not, and for appraising specific safety measures, are:

(a) Individual risk criteria

(b) Safety cost benefit criteria; and

(c) Accident frequency, or societal risk, criteria.

We say a little about each of these in turn.

Individual risk is usually defined as the probability of death per year to a specific or representative individual as a result of some specified activity. Individual risk criteria prescribe upper limits to the levels of individual risk that are regarded as tolerable. Such limits are not allowed to be exceeded: if an activity threatens to pose intolerable individual risks, then either the risk must be reduced without regard to cost, or the activity must cease. The most quoted values for the tolerable limits in Great Britain are a risk of death of 10^{-3} per year for employees and 10^{-4} per year for third parties and transport passengers (HSE, 2001). These risks are fairly high, rightly in the author's view, because they define the limits of what is tolerable. Some other countries have lower values. The general justification for individual risk criteria is equity or fairness in the distribution of risk: they prevent any particular individuals or groups being exposed to very high levels of risk, even in cases where the benefits from such exposure might be high. (Transport infrastructure maintenance sites are an example: lanes on motorways may be closed solely to provide protective barriers for site workers, even though the traffic delays from such closures may be high.)

Safety cost benefit criteria start with given safety measures, and compare their benefits and costs in monetary terms. The decision criterion is that a safety measure should be adopted if and only if the benefits exceed the costs. The benefits of safety measures include reductions in (a) the numbers of fatalities and injuries; (b) physical damage;

and (c) disruption and loss of business. In principle all these must be valued, though in practice there are always some costs and benefits that cannot usefully be expressed in monetary terms, and which are considered separately. In the analysis of safety measures the most important benefit is often (though not always) the reduction in the risks of death and injury. The widely accepted principle for valuing such reductions is the so-called "willingness-to-pay" principle, under which the value of preventing a fatality (VPF) is taken to be the aggregate amount that a large group of people would be willing to pay for a safety measure that will on average save one fatality among them.

The most common context in which such values have been estimated is road safety; most OECD countries have VPFs for road accidents, though not all use the willingness-to-pay approach (see Trawén *et al* 2002 for a recent international review). The current British VPF for a road fatality is £1.15 million at 2000 prices: this is in the middle-to-upper part of the international range. There are also valuations of injuries: £0.130 million for a serious injury and £0.010 million for a slight injury at 2000 prices.

Some work has also been done on VPFs in other types of accident relative to the VPF for roads. Jones-Lee *et al* (2000) used complex surveys to investigate VPFs for rail accidents and fires. In surveys carried out in 1998, they found, contrary to expectation, that the VPF in rail accidents was slightly less than that for roads: they estimated it to be 0.83 of the VPF for roads. They repeated the surveys in early 2000 after the serious Ladbroke Grove train accident; even when that accident was fresh in respondents' memory, the average rail VPF was only slightly higher, at 1.00 of the roads value. Even for regular rail commuters, the rail value was no more than 1.17 of the roads value. Bäckman (2002) has carried out similar surveys in Sweden, with similar results.

Individual risk criteria and cost benefit criteria are often combined. In that case safety measures are adopted if either of two conditions is satisfied:

(a) without them, certain individuals would be at an individual risk level that exceeds the tolerable limit; or

(b) their benefits exceed their costs, with benefits calculated using appropriate valuations of preventing fatalities and injuries.

The dual criterion may then be labelled a `constrained' cost benefit criterion (because the basic cost benefit criterion is constrained by the individual risk limits). Alternatively, the dual criterion can be regarded as an interpretation of the principle that risks should be `as low as reasonably practicable' (ALARP), in which `reasonable practicable' is defined to mean that the benefits of adopted safety measures should exceed the costs. The argument for combining the cost benefit criterion with an individual risk constraint is that each contributes a different and important consideration to the appraisal of risk. Cost benefit is concerned with applying the resources for risk reduction in such a way as to save the maximum number of lives, whereas the constraint is concerned with equity in the distribution of risk.

When the dual criterion is applied, in any particular application only one of the elements (a) or (b) above will generally be binding, and the other will not. If the individual risks are high, the tolerability constraint will bind, and safety measures will be required without regard to cost. On the other hand, if the individual risks are lower (as is usually the case), the tolerability constraint will not bind, and safety measures will be determined by the cost benefit criterion.

Accident frequency criteria prescribe limits to the tolerable frequency of accidents of specified kinds. They are also sometimes labelled "societal risk criteria". The most common versions of this type are criteria on FN-graphs, which limit the tolerable frequency of accidents with numbers of fatalities greater than a given size. This writer sees little intellectual justification for such criteria, at least if superimposed on the dual criterion above. They are not further discussed in this paper.

Application of appraisal criteria to road and rail transport

Road transport

The main appraisal criterion used to inform specific road safety measures is the cost benefit criterion. Direct data on past accidents are used to identify locations or areas or problems where action appears to be needed; experience of past remedial measures is used to estimate the expected accident reductions from the measures proposed; and the costs and benefits are valued, using the standard valuations of casualties discussed in section 3.1.

At present, road safety measures are reportedly extremely cost-beneficial; a recent study of British local authority road safety engineering schemes claims average first-year rates of return of 500% (Gorell and Tootill, 2001). That figure is probably too high, but first-year rates of return of 200% are commonplace, implying that the investment cost is recovered in accident savings in about six months. If the life of such schemes is modestly presumed to be five years, that implies an overall value of about 10 times the cost.

Although that sounds good, it implies that we are grossly underspending on road safety (even in countries with a good road safety performance relative to others). Local authorities have constrained road safety budgets, and if they can expect rates of return of 200% per year at the margin, this implies that they must reject schemes with rates below that level. That in turn implies that there are many potential road safety schemes whose benefits far exceed their costs, but which are not implemented for lack of resources, both of capital funds and of sufficient experienced staff.

To put it another way, the *de facto* marginal cost of preventing a road fatality is about £100,000, or one tenth of its value. This implies that at present road risks are evidently not as low as reasonably practicable: they could practicably be much lower.

Considerations of individual risk have not traditionally been used in the evaluation of road safety measures, even though the risks to some classes of road user appear to be close to what would regarded as intolerable in other contexts. As previously mentioned, one of the general justifications for having limits to the tolerability of individual risk is to ensure that risks are equitably distributed, and that no single person or group carries an unreasonable burden of risk. If this is accepted for industrial risks, the idea would seem to be equally applicable to road risks, which are generally much greater. That would justify priority for measures to reduce the risks of those at highest risk, particularly unprotected road users, irrespective of whether they were otherwise cost-beneficial.

Rail transport

Traditionally rail safety measures were implemented in response to accidents and incidents; these responses remain important for small-scale day-to-day safety measures, but in the last decade formal appraisal processes have been developed for major safety measures. The railways in Britain in principle now use the dual criterion outlined in section 3.2 - the constrained cost benefit criterion or the ALARP principle. Because railways are relatively safe, the tolerability constraints do not bind, so the dual criterion effectively reduces to the cost benefit criterion.

The railways adopt the same VPF as in road accidents for most railway fatalities, but they use a value about 2.8 times greater for fatalities in train accidents, such as collisions and derailments. The higher value was first adopted in the early 1990s, when it was believed that people were willing to pay more to prevent such fatalities, particularly because they had no control over them. The higher value has been retained, notwithstanding Jones-Lee *et al*'s findings (2000, 2001) mentioned above.

In practice, the applications of formal criteria have been rather few, largely because it is often difficult to estimate the number of fatalities that particular safety measures are expected to save. Nevertheless there have been some of applications, the most important of which have concerned "automatic train protection" (ATP), that is devices to prevent errors by drivers resulting in signals being passed at danger (SPADs), with the possibility of serious accidents. The difficulty with about train protection is that it is expensive when installed as an overlay on existing signalling, and the number of fatal accidents it prevents are rather few (about one every two years in Great Britain, each with an average number of fatalities of about 4). Therefore, the cost per fatality prevented is high - much higher than even the higher VPF.

British Rail considered ATP in the early 1990s. After much debate, and with advice from the Health and Safety Commission, the transport minister rejected system-wide fitting in 1995, largely because its estimated cost of about £14 million per fatality prevented (subsequently revised to £11 million, at 1994 prices) greatly exceeded the 1994 VPF in train accidents of £2 million. Nevertheless, the railways did pursue a simpler system, which was expected to cost less, and save 80% of ATP-preventable fatalities; this is now being installed. However, the costs of even the simpler system are turning out to be much greater than expected, and are of the order of £10 million per fatality prevented at today's prices.

In the period since ATP was rejected, three ATP-preventable fatal train accidents have occurred (which is about the expected frequency), one of which was the exceptionally severe 31-fatality accident at Ladbroke Grove in 1999. Major public inquires have been held, one of which recommended installing the European version of ATP (ERTMS) in a relatively short timescale to supersede to simpler system mentioned above. Given that the simpler system will already be preventing 80% of ATP-preventable casualties, the additional safety benefit of ERTMS is very small: its cost per fatality prevented has recently been estimated been at £75 million, which is about 70 times the current road VPF, and 700 times the marginal cost of saving a road fatality. The debate continues.

Discussion

The case for safety decision criteria

From a dispassionate point of view the case for having safety decision criteria is very strong, on grounds both of equity and efficiency. The grounds in equity are that it is reasonable to treat all risk reductions equally, irrespective of to whom they accrue, unless there are clear reasons to do otherwise, as there are in the case of individuals at particularly high risk. The grounds in efficiency are that, given the sanctity of human life, it is desirable to deploy society's safety resources in such a way as to minimise the number of accidental deaths: this requires equal marginal cost per life saved. If this is not achieved, more lives could be saved for the same resources.

These arguments have long been accepted in the case of road safety measures, even if not nearly enough resources are devoted to road safety, and even if there are variations in the implementation of road safety criteria. The arguments are partially accepted in rail. British Rail and its successors formally accept them, but they do not fully implement them in practice. Few other railways accept them.

The difficulties with criteria

The problem about safety decision criteria is that they may sometimes lead to a recommendation that particular safety measures should *not* be adopted, as in the case of BR's ATP above. That in turn means that certain risks are accepted that could technically be avoided. That gives no problem so long as no preventable accidents occur, but it may give rise to severe problems when preventable accidents do occur, as with ATP. In the aftermath of a preventable accident, it seems at best incompetent and at worst criminal that the known-about measure to prevent the accident had not been implemented.

The difficulty is compounded by the fact that, although the risks to people affected may be both very small and widely dispersed at the time that safety decisions are taken, after a preventable accident, the identities of people whose lives are lost are known; their photographs appear in the media; and their deaths can be laid at the door of those who took the decision. Moreover, decision-makers know that this is so.

These reactions were very clear after the 1999 Ladbroke Grove accident. The facts that Ladbroke Grove was ATP-preventable, and that ATP had been considered and rejected were quickly established by the media. The much-quoted "£14 million per life saved" was widely (though not uniformly) interpreted as improperly "putting profits before safety". On the other hand, the facts that the case against ATP had been strong, not marginal, and that the decision had been taken by the transport minister with the concurrence of the Health and Safety Commission were lost. The HSC did not feel able to remind the public that it had concurred in the decision.

The same problem does not arise after road accidents, even though many are preventable, and road risks are evidently not as low as reasonably practicable. This may be because it is more difficult to link particular road accidents with specific decisions concerning road safety measures.

3.5 BALANCING TECHNICAL AND SOCIO-POLITICAL ISSUES IN MANAGING RISK, A NUCLEAR INDUSTRY PERSPECTIVE - (TAYLOR)

3.5.1 Introduction

The risks of radiation are relatively well known and doses to the public arising from radioactive discharges from nuclear installations are now very low indeed. Even to those few people who receive the highest doses (the so-called “critical group”) around Sellafield, the individual risk of developing a cancer from exposure to present discharges is only a little over 1 in a million per annum. Very significant resources have been expended over the last two decades to reduce peak doses by nearly two orders of magnitude, but there is strong continued pressure for discharges and associated doses/risks to be further reduced.

This example from the nuclear industry raises wider questions. How should the concerns and perceptions of various stakeholders be factored into the decision making process? If these views are to alter the course of action indicated by technical/ economic analysis, how can this be done clearly and transparently with clarity about the implications for priorities in the use of resources to reduce risk?

After briefly reviewing our knowledge of radiation risks and presenting a brief history of efforts to reduce discharges at Sellafield, the above questions will be addressed using radioactive discharge reductions as an example of the wider issue. In particular the proposed use of a regulatory “balance sheet” will be presented as one way of addressing transparently broader “political” issues as part of the decision making process.

3.5.2 The Risks Arising From Exposure to Radiation

In the absence of a full understanding of the mechanisms by which radiation induces cancer, risk factors have to be based upon epidemiological studies which are inevitably imprecise. Such studies have been carried out on populations exposed to high doses of radiation, often over a short period of time; that is, in conditions rather different from those in which a radiation worker or member of the public is normally exposed. Nonetheless, the risk factors associated with exposure to low doses of ionising radiation are probably better known than for any other environmental carcinogen.

The cancers induced by radiation cannot be distinguished clinically from those which occur naturally. Even if radiation risk factors were to be increased by a factor of 10, the extra cancer deaths consequent upon exposure at the level specified above, would still be few in relation to the numbers occurring naturally. More importantly, they would be few in comparison with the variations in those numbers. The latter are believed to arise from a range of environmental factors, e.g. diet, drinking and smoking habits, lifestyle and occupation as well as hereditary factors. To observe an excess of radiation induced cancers and to quantify the risk, a large population exposed to known radiation doses must be followed up for a long period. A control population is also required; that is a group of people who are, in principle, identical to the study population in every respect except that they have not been exposed to the additional radiation.

This ideal situation is never achieved in practice but, in comparison with most carcinogens, there is a relatively good basis for assessing the risks associated with exposure to radiation. It is drawn from observations on an assortment of populations exposed during the course of medical diagnosis or treatment, occupationally exposed, accidentally exposed, or as is the case with the atomic bomb survivors, as the result of acts of war. As a result of painstaking analysis and intercomparison, the magnitude of overall radiation risk is now known quite well. It is unlikely that changes in the average value by more than a small factor (upwards or downwards) will occur as a result of new data or reanalysis.

For the purposes of radiological protection, it is assumed that any radiation dose, no matter how small, carries with it some risk of detrimental health. Authoritative advice on the relationship between radiation dose and risk is given by a number of national and international bodies, most notably the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the United States National Academy of Sciences Committee on the Biological Effects of Ionising Radiation (BEIR) and the International Commission on Radiological Protection (ICRP). In the UK, the central point of authoritative reference is the National Radiological Protection Board (NRPB) which is charged with advising government departments and statutory bodies on the acceptability and application of recommendations made by the International Agencies.

The International Commission for Radiological Protection has estimated the risk of death from exposure to radiation to be 5 x 10^2 per Sievert for a general population and 4 x 10^2 per Sievert for a working population; the difference reflecting the different age structures of the populations (ICRP, 1990). Similar risk figures for the UK population have been provided by the NRPB (NRPB, 1995).

These risks are expressed per Sievert of dose received. However, it is important to realise that the Sievert is a very large dose of radiation. The NRPB periodically publish similar data showing the range of doses experienced by the UK population. For the average person in the UK, exposed to a little over 2mSv per annum from naturally occurring background radiation, the annual risk of death is about 1 in 10^4 based on the above risk estimates. The additional risk to the average radiation worker in the UK is a little lower. However, the risk to even the most exposed people is very much lower. For the Sellafield critical group the exposure gives rise to a risk more than one order of magnitude lower than the background (equivalent to an annual risk of a few parts per million), the majority of which arises from historical discharges rather than today's operations. The various exposures to radiation risks are illustrated for typical groups in Figure 1.

Table 1 Typical Doses to those Exposed to Radiation

20 mSv pa	Dose limit for workers
~8 mSv pa	Average dose from exposure to natural background radiation received through living in Cornwall
~2.5 mSv pa	Average dose to us all from exposure to natural background radiation
~2 mSv	Average additional dose to airline crews through exposure to cosmic rays
~1.3 mSv	Average dose to a Sellafield worker from occupational exposure
1 mSv	Dose limit for members of the public from "practices"
~0.12 mSv	Highest (critical group) dose to public from Sellafield (about half historic)
~0.02 mSv	Target doses from Sellafield by 2020
~0.02 mSv	Dose received from return flight from UK to Spain
~0.001 mSv	Highest dose to member of Irish population from operation of Sellafield
~0.0001 mSv	Dose received by consuming one Brazil nut

Figure 1

Another way of putting radiation exposure into perspective is to estimate the consequence of exposing 20,000 people to a dose of 1mSv (the dose limit for the public and about 10 times higher than the exposure of the Sellafield critical group). On the basis of current risk estimates, about one extra cancer death would be anticipated eventually to occur in that population. This would be indistinguishable from the 4000-5000 other cancer deaths which would occur "naturally" over the remaining lifetime of the exposed persons.

It is also important to note that radiation risk estimates are deliberately estimated to err on the side of caution. It is assumed that exposure to any level of radiation can cause adverse health effects and, with the inclusion of the Dose and Dose Rate Effectiveness Factor (DREF), a linear extrapolation is made from high doses to zero dose without threshold. It should be noted that this assumption is different and substantially more conservative than that often made for exposure to chemical carcinogens. Figure 2 illustrates the approach used. To add to the conservatism, critical group doses are deliberately calculated on a conservative basis (e.g. Hylton Smith, 1997).

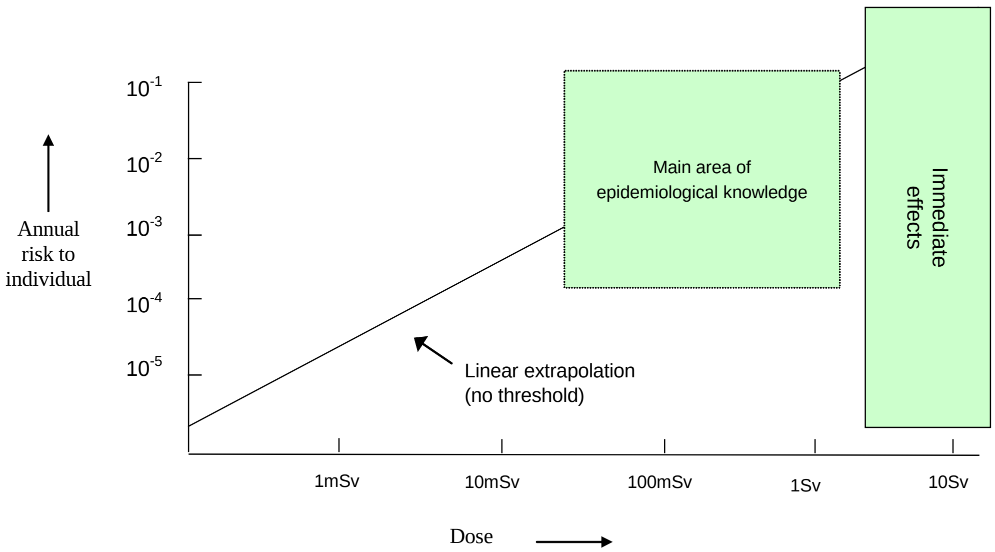

Figure 2 - Radiation Risks

There are those who argue that it would be more appropriate to introduce a threshold since mankind has always been exposed to natural low level radiation from his surroundings and we may thus have evolved repair processes to deal with the damage done to cells at such low levels of exposure. There are also those who argue that exposure to very low levels of radiation can have a beneficial effect in stimulating the body's natural repair mechanisms when radiation causes damage. Whilst this debate continues, properly cautious assumptions are made for radiological protection purposes.

However, the linear, no threshold assumption has one consequence which needs to be carefully borne in mind. The concept has led to the widespread use of what is referred to as collective dose. This aggregates the exposures to radiation of individuals and uses the resulting figure in man-Sieverts to estimate potential consequences. For example, it is assumed that the exposure of 1 million people to 1 mSv (1000 man Sv) has the same carcinogenic potential as the exposure of 10,000 people to 100 mSv each (also 1000 man Sv). Given that some radio-isotopes are very long-lived and can be circulated globally, the concept must be treated with great caution. For example, consider a dose of $^1/_{10}$ of a micro Sievert given to an individual, (roughly the dose received by consuming one Brazil nut). The estimates above would suggest that the resulting risk to the individual of developing a cancer from this single exposure would be rather less than 1 in 10^8 per annum. This is negligible by any standards. If, however, the collective dose approach is used and the same dose applied to (say) the population of Europe for 1000 years – the same release would give a collective dose of about 25000 man Sv and the assumption would be made that this would lead eventually to more than 1000 excess cancer deaths. The same argument would lead to the conclusion that the exposure of the world population to medical radiation (~1.8M Man Sv) leads to about 90,000 deaths every year (~1000 in the UK) and that exposure of the world's population to the natural background (~13M Man Sv) leads to about 650,000 deaths (~ 6000 in the UK).

The conclusions are therefore that:

We have a relatively good knowledge of the risks of exposure to radiation. It is a relatively weak carcinogen, and detecting its effects even at high levels of exposure is a difficult task.

Doses for members of the public from nuclear power operations are small compared with naturally occurring radiation doses received by us all.

Risks of exposure to these very low doses are estimated conservatively. Concepts (peculiar to radiation exposure) such as collective dose are employed to estimate potential effects, again on a conservative basis.

Annual risks to the handful of people comprising the Sellafield critical group are a few parts per million and to others, progressively with distance, orders of magnitude lower.

In scientific terms, it can be concluded that we are dealing with very small risks from a relatively well-understood, easily measured and very strictly controlled carcinogen.

3.5.3 The Sellafield Story

Figure 3 and Figure 4 he discharges of alpha-radioactivity and beta-radioactivity from Sellafield discharges over the last forty years or so. Figure 5 shows the dose to the critical group (combined high fish, crustacea and mollusc consumers). All three graphs show relatively high values in the 1970s (doses comparable with the natural background for these most exposed people), followed by a dramatic decrease in all three parameters – discharges typically having been reduced by two to three orders of magnitude.

By today's standards, the doses in the 1970s and early 1980s were unacceptably high. Very significant efforts were made to reduce those peak values, the two most significant of which were the construction of SIXEP, the Site Ion Exchange Plant which reduced discharges of radioactive caesium and strontium arising from corrosion in fuel ponds of Magnox fuel, and EARP, the Enhanced Actinide Removal Plant. The total cost of these two projects was ~$2B, each reducing critical group dose by about 0.7 mSv. This reduction in individual risk to the few most exposed people was a very important factor in determining these investments. However, using recommended monetary values for the saving of detriment associated with the collective dose reduction (derived from Government recommended values for preventing a fatality), the cost to benefit ratio of the total investments was about 20 to 1.

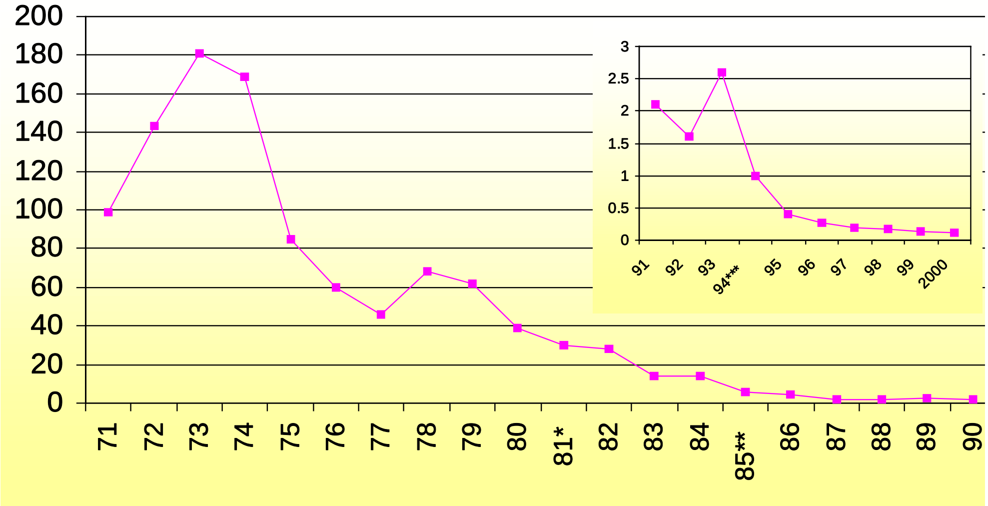

Figure 3 - Sellafield Alpha Liquid Discharges (TBq)
*1981 - MAC cessation. **SIXEP started 1985. ***EARP started 1994

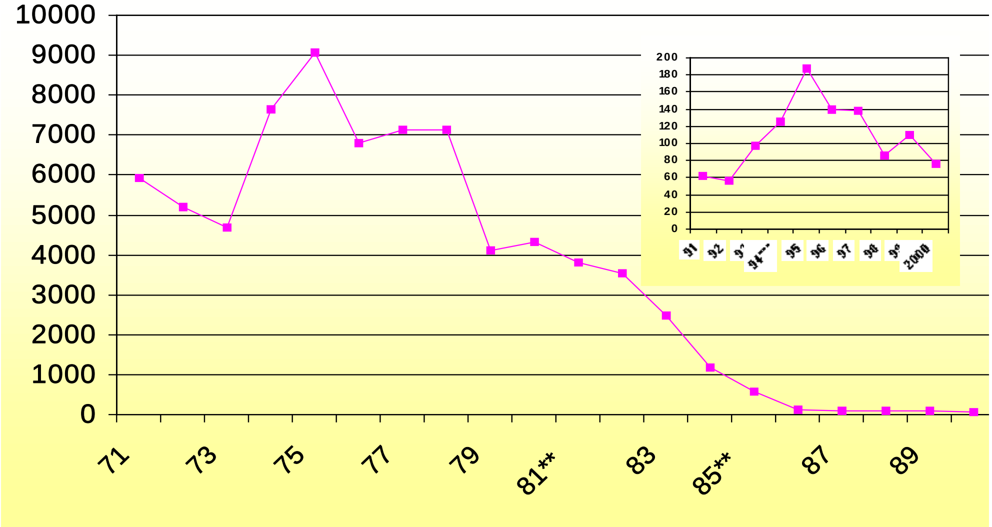

Figure 4 - Sellafield Beta Liquid Discharges (TBq)
*1981 - MAC cessation. **SIXEP started 1985. ***EARP started 1994

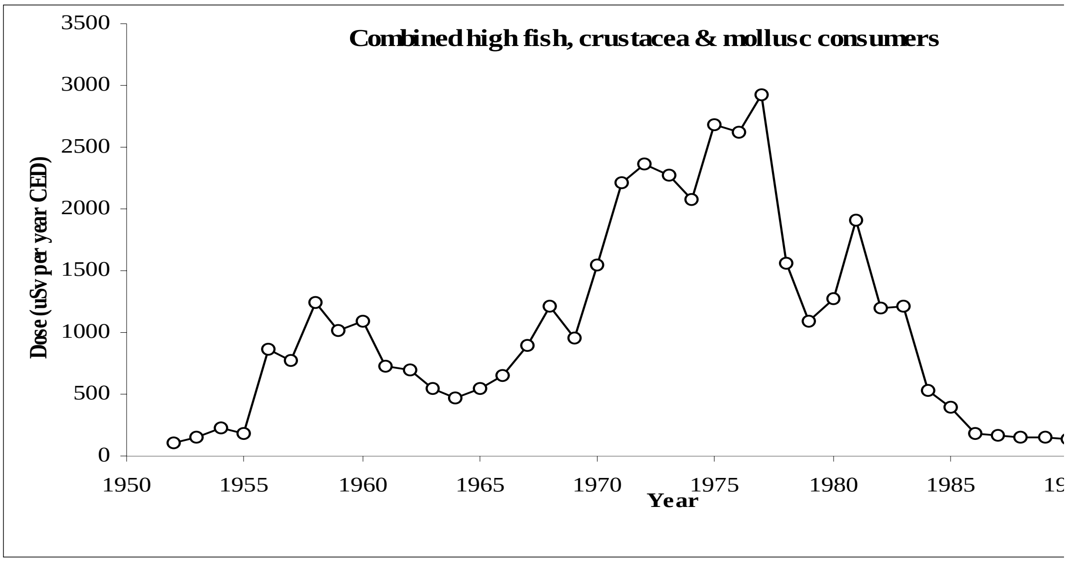

Figure 5 - Combined high fish, crustaceae and mollusc consumers

We are now in a position where the dose to the critical group from current Sellafield discharges is about 0.06 mSv. However, there are still strong pressures for discharges and doses to be reduced further. There is a particular concern from neighbouring states that Sellafield discharges may lead to a loss of confidence in their fishing industries and suggestions that even the minute doses received by their populations may lead to ill-health. A substantial pressure for further reductions arises from the OSPAR Convention to which the UK is a contracting party. This deals generally with reducing pollution to the North Atlantic and, inter alia, requires that "by the year 2020, the OSPAR Commission will ensure that discharges, emissions and losses of radioactive substances are reduced to levels where the additional concentrations in the marine environment above historic levels, resulting from such discharges, emissions and losses, are close to zero". Various caveats relating to technical and economic feasibility, safety of nuclear workers, etc., qualify the requirement.

In accordance with the programme of work agreed by OSPAR, the UK Government is shortly to publish a National Discharge Strategy, to show how the UK intends to meet its commitments. It is estimated that since the UK made its commitment to OSPAR, BNFL has announced intended programmes of early closures of plant which are likely to reduce critical group doses from current operations (excluding decommissioning) to about 0.03 mSv by 2020. The UK Strategy (in its consultative form) states an intention to achieve group doses of 0.02 mSv or below. Although programmes for closure have been influenced by a variety of factors, meeting OSPAR commitments has been a major consideration. The total cost of these early closures has been estimated to be in excess of $1B in direct costs, with even greater indirect costs arising from unemployment and impacts on the local economies in remote regions. Furthermore, replacement fossil generation will lead to higher carbon emissions.

Based purely on a scientific and economic evaluation of the facts, it is very difficult to see how any of these further reductions can be justified. One of the three internationally adopted guiding principles in radiological protection for workers and the public is the ALARA (As Low As Reasonably Achievable) principle (the others are Justification of a practice and the adoption of dose limits). ALARA requires that radiological doses and risks should be reduced to a level that represents a balance between radiological and other factors, including social and economic factors. This is reflected in UK law which requires that risks be kept as low as reasonably practicable (ALARP) by the employment of Best Practical Means (BPM). The key to these requirements is one of "balance" or "proportionality" with costs (money and resources) not being grossly disproportionate to the risk averted or detriment saved.

There are other quantifiable factors which also need to be considered in achieving a proportionate approach. For example, reducing public dose at the expense of increasing dose to workers, reducing nuclear safety levels or incurring other detriments to the environment either by discharging environmentally damaging material as part of the process to reduce dose or through the impact (eg CO_2 emissions)of alternative electricity generation would seem to be sensible components of a balanced, holistic approach. One way of ensuring this balance is for regulatory requirements to operate to broadly standard criteria. If environmental regulations, for example, operate to different standards from those governing safety, it is likely that resources will be applied preferentially to one area rather than the other. This is clearly a matter of preference, but it is vital that it is made as a result of careful consideration rather than as a result of failure of "joined up" thinking.

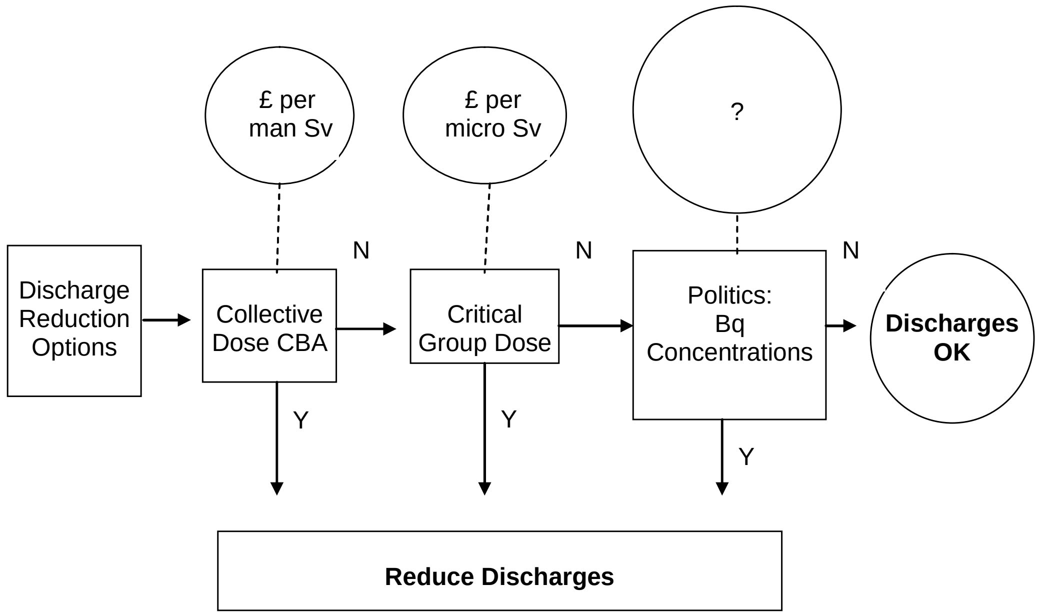

Figure 6 - Discharges - Decision Framework

Figure 6 provides one view on how decisions are made about the reduction of discharges of radioactivity in practice in the UK. The use of conventional CBA, based on estimates of detriment saving from collective dose calculations provide one step in the decision making process.

Other factors may justify a substantial disproportion .

For example:

- Political Commitments (eg OSPAR)
- Public perception that radioactivity is "Special"
- Environmental "Values"

but need a transparent approach

Figure 7 - Inclusion of Socio-Political Factors

Increasingly over the last two decades or so, critical group dose has become an increasingly important "test" in the decision making hierarchy. The construction of SIXEP and EARP at Sellafield (discussed above) were illustrations of this. Here, the critical group saving benefit outweighed the arguments relating to established cost-benefit considerations based on collective dose. In the last decade however, both of these factors have become secondary compared to the last "test", Figure 7, which has been broadly labelled "politics". The ramifications of this and the mechanisms which might be needed to ensure continued transparency and proportionality in risk management are the subject of the next section.

3.5.4 Maintaining Proportionality – Dealing Transparently with the "Politics"

Figure 8 illustrates some of the concerns about discharges of radioactivity into the environment even at the very low levels which occur now. They include perceptions that radioactivity is in some way uniquely dangerous and insidious, views that no level of pollutant in the sea is acceptable, and concerns that, whatever the scientific evidence, discharges may impact on other legitimate uses of the sea. These are, in many cases, genuinely and strongly held views which deserve to be taken seriously into account in any debate. However, it is important that they are considered alongside the technical and economic arguments in a transparent way so that their full implications in decision making can be assessed.

One important implication is that the consideration of “political” factors and response to perceptions will lead to much greater resources being spent to prevent a statistical fatality (or other consequence of a reducing risk) in one area rather than another. Figure 8 illustrates this point from UK experience.

The baseline Government figure for the value of a fatality prevented is about £1M ($1.4M). This is used, for example, to determine investments in road improvement schemes as a contribution to reducing the 2500 or so fatalities on UK roads each year. Significantly lower sums would save real lives in the health sector in the UK through the increased provision of hospital beds or better treatment of life threatening medical conditions. Interestingly, use of the same radiological protection criteria as those discussed above would imply that a significant number of statistical lives would be saved by expending resources on improved radiation controls and new radiological equipment in the health sector.

Studies of Implied Values to Prevent a Fatality (UK)

Health Service <<£1M
Roads ~£1M
Railways ~a few million pounds?
Radiological £10s-100sM

How does this reflect National priorities?

Figure 8 - National Implications

Recently, there has been great concern in the UK about railway safety. New requirements to introduce advanced automatic braking systems will require investments with an implied value for a fatality prevented of many times that being used for road safety. Interestingly, this issue has now been recognised more widely and has been the subject of public interest and some concern. At the extreme end of the spectrum, investments to reduce radioactive discharges from the nuclear power sector imply values to prevent a fatality of tens and, in some extreme cases, hundreds of millions of pounds, as is illustrated by the examples given above. The position is not peculiar to the UK. More detailed studies in the USA (Belzer, 1992, Tengs et al., 1994) and in Sweden ( ) for example have exposed the issue even more clearly. One important outcome of these analyses is to question the extent to which decision makers should treat the data as a proper reflection of public preferences or a source of concern and a lack of awareness that resources are not being applied on a coherent basis. There does not always seem to be an appreciation that employing resources for risk reduction in one area often means that higher risks elsewhere are not being addressed.

So long as these variations in expenditure genuinely reflect public priorities, it is quite reasonable and proper that the variations exist. The key question, however, is whether taking account of the non technical/economic arguments has been carried out in a transparent way. Are decision makers and other stakeholders aware of the full balance of arguments and who is addressing these wider issues of choice and priorities in the use of resources to reduce risk?

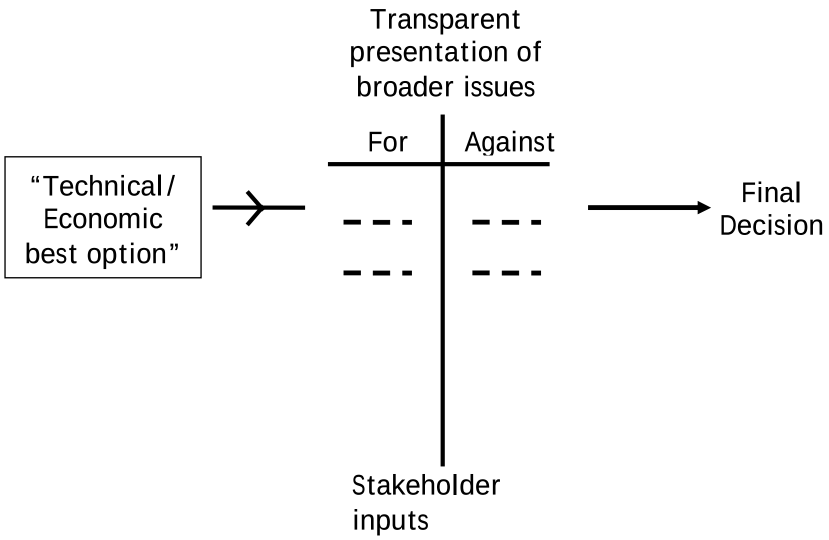

Figure 9 - Balance sheet

One approach which may help to address the issue of transparency is the concept of a simple "Balance Sheet" to aid the decision making process. An illustration of this approach is shown in Figure 9.

Such a balance sheet would first provide the results of the best technical and economic appraisal of an investment option to reduce the risk of concern. As far as possible, this should emphasise the uncertainties and thus the range of outcomes which might reasonably be considered. Against this background, the second part of the balance sheet tries to present as objectively as possible the factors which might strengthen or challenge the technical/economic appraisal. The important aspect of this approach is the separation of "objective" analysis and presentation of legitimate concerns in a clear and transparent way. Those making the final decision will therefore have available the main issues affecting their decision and will have a clear duty to make clear the weight that they have attached to the factors in determining the preferred outcome.

3.5.5 Conclusions

The risks arising from exposure to radiation are relatively well understood. Very cautious approaches have been developed to achieve protection of the public including concepts such as collective dose which are special to radiation. Risks arising from the discharges of radioactivity have been reduced by several orders of magnitude over the last two decades and risks, even to the few most exposed people, are now at very low levels. However, there remain concerns and political pressures to spend very significant resources to reduce discharges further. On the basis of technical/economic arguments, to do so would be grossly disproportionate to the benefits achieved.

These disproportionate sums to reduce discharges of radioactivity are not unique (although an extreme case). There is a very significant range of expenditure to prevent fatalities across various sectors from health to transport to power production. There does not appear to be coherence between regulators and it is far from clear whether such variations truly reflect public priorities.

It is vital that public concerns are fully addressed and this may well alter the outcome of technical/economic analysis of options. However, this should be achieved in an open and transparent way so that trade-offs between the factors influencing a decision are clearly visible, the consequences in terms of the use of resources to reduce risk are understood and stakeholders are aware of the reasons why decision makers have arrived at their final view. As an illustration, an approach based on a simple "balance sheet" is provided. This attempts to identify the factors influencing a decision in a transparent way and by separating the conventional technical/economic analysis from broader socio-political factors allows the reasons how and why such factors have affected the decision to be clearly brought out.