The Approach of a Regulatory Authority to the Concept of Risk

by H.J. Dunster

Risk is a poorly defined term and is commonly used in at least two quite different ways. I shall use risk in a qualitative way to mean the combination of the likelihood and consequences of possible events and I shall express likelihood as the probability or the probability per year of an event occurring and I shall define the consequences of the event as necessary. Risk assessment is then the process of assessing the numerical values of the probabilities and the consequences. It contains no element of social or economic judgment. However, the use of risk assessments must also take account of the way in which people react to real or imagined risks. It is unrealistic to expect that governments and regulatory bodies will take actions wholly on the quantitative assessment of risks — they will also have to take account of people's reactions to and perceptions of risk.

Methods of Risk Assessment

All risk assessment starts from a review of information about previous events and their consequences and it is thus a process of prediction built on this previous experience. A great deal of judgement is involved in estimating the extent to which the lessons of the past may have been effectively learnt so that the situation in the future may be somewhat better than is predictable from the past, and uncertainty in the opposite direction is introduced by the fact that many of our modern problems are the results of new or greatly expanded technology and the experience of the past is thus extremely limited.

It is not sufficient to take account merely of those accidents which have occurred in the past. It is also necessary to look at possible combinations of past minor accidents with more serious situations. For example, there have been no accidents having serious public health consequences in the nuclear industry. There have, however, been several accidents which could have had serious public health consequences if circumstances had been somewhat different. Similarly, releases of toxic chemicals and flammable substances have resulted in fairly small numbers of deaths in the past, compared with the scale of the disaster which could occur if all the circumstances were adverse. Risk assessment clearly has to take into account the possibility of these hypothetical combinations of adverse circumstances.

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It is not sufficient, however, merely to assess consequences. It is sometimes suggested that emphasis should be put on the worst possible accident and, of course, some attention does have to be given to very serious accidents. But for many industries the worst accident that could happen is exceedingly severe and its possibility is only tolerable because the probability of it occurring is very low indeed. We could not possibly permit aircraft to fly over cities if we were concerned only with the scale of the possible catastrophe. Risk assessment is, therefore, necessarily concerned with both probabilities and consequences.

The Acceptability of Risk

This is a complex subject in its own right and I propose to make only two points:

The first is that there is some level of risk which in any circumstances is generally accepted as being too high. In such circumstances, either the risk has to be reduced or the operation has to be abandoned. With modern techniques for controlling the risk this situation seems to be very rare indeed.

The second point concerns those risks which are not so high as to be totally unacceptable. In this region I suggest that the acceptability has to be a function both of the benefits brought by the source of the risk and of the ease or difficulty with which further reductions can be achieved. No risk which is easily reducible can be described as acceptable.

If this point is accepted there is no possibility of establishing any general acceptable level of risk. Each situation will have to be assessed on its merits and it will always be both possible and appropriate to make some risks smaller than others.

Some Applications of Risk Assessment by the Health and Safety Executive

The Health and Safety Executive (HSE) was set up by the Health and Safety at Work etc. Act, 1974, as a statutory body bringing together the major occupational health and safety inspectorates in Great Britain. It now comprises the Factory Inspectorate, the Mines & Quarries Inspectorate, the Agricultural Inspectorate, the Explosives Inspectorate, the Nuclear Installations Inspectorate, the Alkali & Clean Air Inspectorate and the Employment Medical Advisory Service.

In addition to its enforcement and advisory functions it contains the necessary groups for the development and preparation of new regulations, codes of practice and guidance material. It has a substantial research and laboratory services division, partly but by no means exclusively devoted to the problems of coalmining.

A fundamental feature of the Health and Safety at Work Act is that it has the effect of putting a general duty on employers to eliminate risks to their employees and to other people. An absolute requirement of this kind must clearly be softened in practice and the phrase used in the Act is "so far as is reasonably practicable".

The effect of this phrase is to require, at least in principle, that any residual risk shall be assessed and further reduced if the steps necessary for such reduction can be described as "reasonable". Risk estimates, sometimes quantitative, more usually intuitive, are thus

Table 1. Assessed Individual Fatal Risk at Canvey Island (10^{-6}/yr)

Plants	Initially	Improved
Existing	530	130
Existing and proposed	920	140

an integral part of both the policy and the enforcement activities of the Health and Safety Executive.

One example of an attempt at quantitative assessments was a major review conducted into the probabilities and consequences of major accidents in a petrochemical complex in the Thames Estuary at a location known as Canvey Island Ref. [1]. This study, which resulted from questions raised at a public inquiry, was the responsibility of the Executive, but the bulk of the work was conducted on their behalf by the Safety and Reliability Directorate of the UK Atomic Energy Authority, supported by the Factory Inspectorate and specialists from the Executive's staff. The report was published in May 1978.

The principal plants in the complex included a natural gas terminal, several oil refineries, a factory filling bottles with liquefied petroleum gases, a storage depot for miscellaneous chemicals and petrochemicals, and an ammonium nitrate fertiliser plant. There were proposals for new and extended refineries.

The study dealt only with major risks and identified the release of ammonia, hydrofluoric acid, liquid natural gas, liquid petroleum gas and flammable liquids in large quantities as the principal risks. Both the probabilities and the consequences of various events were estimated as realistically as possible, but it was recognized that some degree of pessimism was almost certain to creep into assessments of this kind. It was difficult to argue that the degree of pessimism was more than a factor of 10 in either probability or numbers of casualties.

Two types of risk were estimated:

The first was the probability of an individual in the vicinity of the complex being killed as a result of a major accident.

The second was the probability of events large enough to cause multiple fatalities.

During the study it became clear that improvements could be made, both in the existing plants and in the proposed new and extended plants, that would reduce the initial estimates of risk. Some typical figures from the report are shown in Table 1 and 2.

Even allowing for the fact that the probabilities in Table 1 and 2 may be somewhat over-estimated, the Executive concluded that the initial estimates of risk represented a situation which had to be improved. Once these improvements had been defined, however, they also concluded that the proposed plants and extensions did not pose a high enough risk to justify advising that they should not be permitted.

Table 2. Assessed Risk of an Accident at Canvey Island causing more than 1500 Deaths (10^{-6}/yr)

Plants	Initially	Improved
Existing	1700	300
Existing and proposed	2910	400

At present no quantitative criteria for acceptance of risks have been proposed by the Health and Safety Executive, who deal with situations predominantly on a case-by-case basis. However, some move towards establishing criteria has taken place in relation to nuclear risks, where a recent report from the Nuclear Installations Inspectorate Ref. [2] has defined a concept called the Assessment Reference Level.

This is a point where, in the judgement of the Inspectorate, the level of risk is sufficiently low that it is unlikely that detailed assessments of the feasibility of further reductions will be justified. Where such reductions are easily and obviously obtainable they should be made. But if their availability can be assessed only by detailed and complicated investigations then these investigations are not regarded as justified and the level of risk corresponding to the Assessment Reference Level is then accepted without further review.

It is extremely important to emphasize that the Assessment Reference Level is not a limit. Limits, when they exist, correspond to higher levels of risk and the term should be used only to mean limit subject to enforcement. By contrast, an Assessment Reference Level has the primary objective of concentrating limited professional resources into areas where the risks are significant and away from areas where the risks are already very low.

In general terms, the Assessment Reference Level for occupational exposure to ionizing radiation corresponds to a risk of fatal cancer of about 50×10^{-6}/yr, while the corresponding figure for the so-called critical groups, the groups in the population most heavily exposed as a result of waste disposal operations, is 2×10^{-6}/yr.

Similar figures are used in relation to the likelihood of various scales of accidental release of radioactivity from nuclear installations, and the combination of the probability of the event and the probability of consequences give a range of probabilities of fatal cancer corresponding to the Assessment Reference Levels in the range from 5×10^{-6}/yr to 5×10^{-7}/yr.

It is clear from these figures that effort is being applied to the prevention of serious nuclear accidents at much lower objective levels of risk than is the case for routine situations in the nuclear industry or accidental situations in most of conventional industry. The apparent imbalance of this policy is a matter for neither criticism nor congratulation. It merely reflects a wide sense of what is proper — a fact which makes the policy expedient but not necessarily right.

Table 3. Deaths per annum for 1000 MW station (load factor 75%)

Coal	Oil	Nuclear
0.47 to 2.13	0.1 to 1.28	0.05 to 0.43

One effect of the policy is to apply effort to an area where risks are low but anxiety is apparently high. It is not easy to weigh the benefits of reducing anxienty against those of saving life, but our society certainly does not require the saving of life to be given complete priority over the reduction of anxiety.

Some Comparative Risks in the Provision of Electrical Energy

Many studies have now been carried out on the comparative risks of producing electrical energy from different sources. The methods used in these studies are not always strictly comparable and the quality of the data varies considerably through the different industries. As a result the comparability of the results is at least in part suspect. One notable example of this is in the handling of the long-term problem of toxic materials. In the nuclear industry it is commonplace to pay some attention to the consequences of the presence of radioactive material in the environment for decades and even centuries after the process first giving rise to the materials.

By contrast the release of toxic materials from the combustion of coal and oil is normally related only to the short-term situation. One effect of these comparative studies will be to increase the degree of uniformity in the methods adopted. It does not necessarily follow that the nuclear industry should be taken as a pattern. A good case can be made for arguing that the nuclear industry has been excessively preoccupied with the very small health effects of very small radiation doses. An extension of this approach to other industries might reasonably be described as a form of infective paranoia.

Tables 3 and 4 show the range of some recent estimates of the numbers of deaths per year resulting from the provision and operation of a 1000 MW power station operating at a load factor of 75 per cent.

The range of estimates is large and is even further extended if account is taken of non-fatal accidents and less easily definable health effects than cancer. Nevertheless, it is possible

Table 4. Deaths per annum for 1000 MW station (load factor 75%)

	Cancer	
Coal	Oil	Nuclear
0.1?	0.1?	0.05 to 0.5

to reach a broad consensus view that the probable order of merit from this point of view is nuclear, oil, coal. This order of merit takes account of the probability of catastrophes but is clearly based on risk assessment which does not take account of society's reactions to risk.

Conclusions

Our use of risk assessments and our attempts to make quantitative comparisons between risks of alternative decisions such as energy sources together make it clear that we lack a great deal of necessary information. We know little about the real magnitude of many existing risks and still less about society's attitude towards these ill-defined risks. I suggest that we need to attempt more risk assessment and that we need to publish more of the results. These results will only be one factor in the process of making decisions and indeed the existence of such studies may often make the decisions more difficult to reach but eventually we should gain confidence that our decisions are being taken in a consistent and possibly even in a logical way.

References

[1] Canvey — An Investigation, HSE (1978)
[2] Nuclear Installations Inspectorate, Safety Assessment Principles for Nuclear Power Reactors, HSE (1979)