A review of the literature pertaining to 'perceived' risk and 'acceptable' risk and the methods used to estimate them

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Preface

The concept of an acceptable risk is an integral part of modern society. However, when we attempt to determine what an acceptable risk is in a particular situation, we have to consider questions such as 'to whom is the risk acceptable?' and 'where are the likely costs (risks) and benefits likely to fall?'. People's perceptions of risk are an important factor when determining a level of risk (or safety) for a particular activity such as the location of a chemical plant, the building of a bridge, effluent disposal in waterways, hydrofluorocarbon use and the many other hazardous activities that are integral parts of our current way of life.

Risks are not new to society. Many risk levels have been reduced considerably as a result of increased technical and scientific knowledge. However, people's perceptions of risk and their tolerance of risk have changed significantly in the past 20-30 years as greater publicity has been given to aspects of risk and failures of technical systems. The expert's credibility has been threatened by incidents and disasters such as Three Mile Island, Flixborough, Windscale and Bhopal. As a result, it has become imperative that experts and decision makers take account of people's perceptions of risk and their ability to tolerate or accept risk.

The literature on perceived risk and acceptable risk through a period of very rapid change is examined in this publication. Continuing development in this area means that we must continue to monitor techniques for estimating perceived risk and also explore the links with acceptable risk in order to provide decision makers at all levels with appropriate information.

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Summary

Chapter 2 What is risk?

Risk is a compound measure comprising a probability of occurrence of an (adverse) event and a magnitude of the consequences. Risk is always associated with a choice of actions with a series of possible outcomes that may or may not be known and quantifiable.

There are a number of different ways of defining risk, the most useful of which include real risk, statistical risk, predicted risk and perceived risk. Other descriptors used are actual risk, subjective risk and objective risk. Some authors also consider the concepts of technical risk and social risk.

Chapter 3 Approaches to the study of perceived risk and acceptable risk

The main methods used to study perceived risk and acceptable risk are described as revealed preferences, expressed preferences, implied preferences and natural standards.

The method of revealed preferences uses available statistics of behaviour to infer underlying preferences. It is a societal measure and is generally associated with the determination of acceptable risk. The method of expressed preferences involves questioning individuals directly. The information obtained is an individual estimate and requires aggregation in order to obtain societal estimates.

The method of implied preferences looks at societal institutions as a means of reflecting current values, while the method of natural standards uses geological time rather than historical time as a determinant of acceptable risk.

There are positive and negative aspects of all the above approaches and a combined approach is likely to be the most useful.

Chapter 4 Perceived risk/risk perceptions

Perceived risk is the individual or group evaluation of the risk likely to result from a certain activity. Risk preferences are used to infer perceived risk.

Reasons for studying perceived risk include the need to obtain greater understanding of where and how expert predictions and lay perceptions of risk differ. From this, we may be able to achieve greater success in resolving risk conflicts, not by explaining why public perceptions are 'wrong' but by improving the communication between experts and lay people and by increasing the mutual respect and understanding between the two parties.

There are many factors affecting the way in which people perceive risk, and one of the main themes of risk perception research involves identifying these factors and interpreting their influence.

People use a series of heuristics to estimate the probability of risk. These heuristics are well understood and may be used to influence the way people think about risk.

Risk decision making is a political process and perceived risk is one input to that process. Credibility of decision making is an important determinant of acceptable risk.

Chapter 5 Methods used to calculate perceived risk

The expressed preference approach to estimating perceived risk involves three main techniques: psychometric scaling, simple social surveys and attitude surveys.

Other less frequently used techniques include multidimensional scaling, contingent valuation and analysis of variance.

Chapter 6 Acceptable risk (or how safe is safe enough?)

One of the initial difficulties in estimating acceptable risk is in actually defining the term 'acceptable risk'. An early conclusion is that risks are not acceptable, but options (leading to outcomes) are. Other descriptors used in place of acceptable risk include accepted risk, necessary risk, tolerable risk and unknown (or apparently acceptable) risk.

Safety is also a form of 'acceptable' risk. Safety must, however, be thought of in relative terms, for example α is safer than β rather than as an absolute level of safety.

A common approach to acceptable risk has been the setting of threshold conditions below which there is considered to be no harm to humans. These levels change as greater information becomes available and there is often considerable statistical and measurement difficulty associated with them.

The relationship between acceptable risk and perceived risk hinges on a balance of risks and benefits (or perceived risk and perceived benefit). Perceived risk is a determinant of acceptable risk, or a major input into the acceptable risk decision-making process.

The relationship between acceptable risk and risk assessment and risk management is important also. Risk management (as a part of risk assessment) seeks to ensure that risks are kept within levels deemed 'acceptable' by the risk decision-making process, which includes risk assessment.

Chapter 7 Methods used for calculating acceptable risk

The methods used to calculate acceptable risk are very similar to the methods used to evaluate risk as part of risk assessment. This reinforces the notion of 'acceptable risk' as a process itself. They include risk aversion, risk balancing, cost effectiveness (or risk reduction) and cost(-risk)-benefit balancing.

Equity issues are an important part of the determination of acceptable risk levels, since an implicit risk-benefit balancing is implied. The question may become 'what is a fair or equitable risk' rather than 'what is an acceptable risk'.

Chapter 8 Implications for risk perceptions research

Attitudes towards perceived risk and the study of perceived risk have changed considerably over the past 10 years. It is now fairly widely accepted that perceived risk has an important part to play in the risk decision-making process, and that lay perceptions of risk should not be dismissed as irrational or irrelevant. Current efforts are being directed towards increasing understanding of why experts' predictions and lay perceptions differ, and improving communication between the two groups.

The future of risk perception research probably lies in the area of risk communication and using the information gained on risk perceptions to alert experts to the areas in which greater and better directed information is required.

The major conclusion is that perceived risk and acceptable risk estimates are very important components of the (environmental) risk decision-making process and that the credibility of the process requires greater recognition of the role of the public.

1.0 Introduction

This publication details a survey of the literature relating to the areas of perceived risk and acceptable risk. It comprises steps one to four of the research project being undertaken at the Centre for Resource Management for the Ministry for the Environment entitled "the analysis of common risk measures: 'perceived' risk versus 'actual' risk; 'acceptable' risk versus 'accepted' risk; and the relationship to conflict review and resolution". This publication is directed towards objectives one and four of the project, which are:

> to critically examine the literature on approaches to measuring and evaluating perceived risk and the relationship to actual risk; and
> to use the knowledge gained from the study of perceived risk to increase understanding of acceptable risk and risk comparisons.

The approach taken to achieving these objectives followed a series of tasks. These were:

(1) a bibliographic search of nine library on-line reference files belonging to the DIALOG Information Retrieval Service (see Appendix A for details of these files);

(2) a further search of the New Zealand Bibliographic Network;

(3) inspection of the title and abstract information obtained to determine which references required following up;

(4) acquisition of this material firstly by checking available library sources and then using interloan facilities;

(5) examination of the received material; and

(6) preparation of this publication summarising the information gained.

This publication is divided into chapters. Chapter 2 describes risk in general terms and provides definitions for the different risk measures delineated by risk researchers. Perceived risk and acceptable risk concepts are introduced and defined in the context of this publication.

The different attitudes that have been adapted to the study of perceived risk and acceptable risk are documented in Chapter 3.

Chapter 4 discusses perceived risk and risk perceptions and their character and implications for risk decision making, while Chapter 5 outlines the methods used to calculate perceived risk estimates and describes some of the reported studies.

Acceptable risk and risk acceptance are examined in Chapter 6. The links with perceived risk are drawn and the dilemma associated with the moral implications of the use of acceptable risk estimates is examined. In Chapter 7 the methods used to estimate acceptable risk are described.

Finally, in Chapter 8 the implications of risk perceptions and acceptable risk for risk decision making are considered, current positions with respect to perceived risk research are summarised, and suggestions for future research are made.

Appendix A contains information on the bibliographic search undertaken for this project, while in Appendix B some aspects of questionnaire design are considered. Appendix C contains outlines of a selection of specific studies where risk perceptions have been estimated. Appendix D provides a brief historical survey of the development of perceived risk and acceptable risk research.

This publication is part of a series of reports all concerned with risk and uncertainty and their place in the environmental decision-making process. Perceived risk and acceptable risk have important implications for risk assessment which is a component of this process.

2.0 What is risk?

> *Risk is "a compound measure of the probability and magnitude of adverse effect"*
> (Lowrance, 1979).

The research project which led to this project is part of an ongoing research programme with the primary objective of examining risk within the decision-making process. Therefore, it is appropriate to look at risk as having three elements:

(1) a choice of action;
(2) a probability of occurrence; and
(3) a magnitude or consequence associated with the outcomes.

It is important to stress that risk involves a choice, even though the action taken may involve remaining with the status quo. Risk has also been described as being a product of actions and not an attribute of things. This means that risk is associated with a decision and does not exist in isolation.

The characteristics of the outcome of the chosen action are size, timing and extent. The consequences may also be positive or negative - some risky decisions have gain as their objective, as in the case of financial risk.

Risk can be quantified for a particular outcome (where suitable data are available) by multiplying the probability of that outcome occurring by the magnitude of the adverse effect. Often, however, risk analysts prefer to keep the two aspects of risk separate so that risk is expressed in terms of a probability and a population at risk. There are reasons for and against this separation. One reason for it is that numerically equivalent risks (expressed in terms of a single number) may have totally different characteristics in terms of consequences, so that equating them becomes nonsensical. A low consequence high probability risk may be equivalent to a high consequence low probability risk but the character of the two risks and the way in which the risks are perceived will be totally different.

For example, the injury risk to a child of falling off a bicycle whilst learning to ride has a high probability and low magnitude (grazed knee). It may be numerically equivalent to a low probability, high consequence (death) risk such as the risk to a skydiver of a parachute not opening. This example illustrates some of the difficulties in measuring risk in that it is difficult to evaluate consequences where

units are very often non-commensurate. More importantly it demonstrates the need to keep track of the sensitivity and relative weights of the component parts when evaluating risk estimates.

There is an important although obvious difference between risk and hazard. The term hazard can be used as an explicit engineering term, however, in the general risk literature a hazard is the possible negative outcome about which there may be considerable uncertainty in terms of both likelihood and magnitude. The Royal Society (1981) description of a hazardous situation is a "situation that in particular circumstances could lead to harm, where harm is loss to human beings or human populations".

Lowrance (1979) classifies hazards into six categories: infectious and degenerative diseases; 'natural' hazards; failure of large technological systems; discrete, small-scale accidents; low-level, delayed-effect hazards; and sociopolitical disruptions. It is worth pointing out that these may not be exhaustive and are certainly not mutually exclusive. However, the classification is useful in that it goes beyond the more common man-made versus natural hazards. The research presented here is primarily directed towards environmental risk, which can incorporate most of these hazards.

Okrent (1980) uses the example of the hazard of drowning as an illustration of the differences between risk and hazard. Passengers crossing the Atlantic in an ocean liner face the same **individual** hazard of drowning (or the ship sinking) as the crew of a rowing boat crossing the Atlantic. To an individual, however, the risk associated with crossing in a rowing boat is greater than the risk associated with crossing in a larger ship (since the probability of drowning is greater).

This also illustrates the difference between individual risk and group risk. The **magnitude** of the risk to the **individual** is the same in both cases. The **magnitude** of the **group** risk is greater in the case of the ocean liner because a greater number of people is involved (the estimated group risk in the two cases may therefore be much more similar than the individual risk).

So far we have considered risk in terms of possible adverse effect on people. This may be viewed as health risk. We are also concerned with environmental risk or the risk to humans and the things that they value. This definition of risk is useful since it can include environmental systems that are largely unknown, but which have value because of their mere existence. For the remainder of this publication, the term risk will be taken to refer to environmental risk as defined here.

2.1 Different risk measures

This section is derived directly from Gough (1988a) with minor adaption.

Risk cannot be defined uniquely because we cannot measure risk until after the event. We can estimate or predict risk now but we cannot **measure** it now. When we consider the risk of a particular decision, uncertainty associated with both the probabilities and the outcomes means that we cannot accurately measure the (future) risk we are trying to assess. Starr *et al.* (1976) define four measures of (future) risk.

(1) **Real risk:** determined eventually by future circumstances when they develop fully.
(2) **Statistical risk**: determined by currently available data, typically measured actuarily.
(3) **Predicted risk**: predicted analytically from systems models structured from historical data.
(4) **Perceived risk**: seen intuitively by individuals.

Real risk is thus a hypothetical concept. It is often never able to be evaluated, and can only be determined in the future if the risk being studied is defined over a specific time period. This temporal element is very important in any form of risk analysis since risk is inevitably oriented towards the future.

Statistical risk and predicted risk are often called objective estimates whereas perceived risk is known as a subjective estimate or sometimes, a personal probability. Frequencies or probabilities of death, injury or damage can be derived from numbers of recorded events and calculated populations. In epidemiological studies risk is calculated from recorded cases and the data are extrapolated to obtain estimates of risk for population sizes beyond the scope of the statistical sample. Simulation models can similarly be constructed to produce estimates of risk for situations that cannot be measured in nature. Examples of this type of calculation include models of nuclear power station explosions or similar events that have a very low probability of occurrence.

The difference between statistical risk and predicted risk can be quite subtle. They are both derived from historical information. The difference is that statistical risk is based on observed frequencies that can be evaluated by normal statistical means, whereas predicted risk is a theoretical probability valid only to the extent that the model from which it has been derived is able to be validated. They are both 'objective' probabilities and can be challenged as being irrelevant in one-off situations.

Perceived risk is a 'subjective' measure of risk. Perceived risk and predicted risk often represent maximum and minimum estimates of real risk with statistical risk lying somewhere in the middle.

The term **actual** risk is often used also. It means scientifically calculated or experienced mortality (we will return to the use of mortality as a risk measure later) and as such it is equivalent to **statistical** risk. The term actual risk is sometimes used as a synonym for real risk, however, as it is measured in the past it can only be an **estimator** for real risk. In common with Gough (1988a), we will try to avoid the use of the term 'actual' risk as it has misleading connotations. So-called 'objective' estimates often contain considerable subjective bias as a result of a lack of appropriate raw data and the need for assumptions in the estimation process.

Perceived risk is a judgement or valuation of consequences by individuals or groups of people. Whether estimates of risk are made by scientists or lay people, they cannot avoid containing elements of opinion. This derives from the way in which people design models or experiments, the weighting which they give to social importance, the way in which they select or derive data and even in the risks they choose to study (Douglas and Wildavsky, 1982b). Therefore, we must discard the notion of an absolute truth and recognise that people see the world differently (Otway and Thomas, 1982) and that they want different outcomes for themselves and others. The way people perceive risk also affects the way in which they view the outcomes.

2.2 Technical risk and social risk

So far, we have emphasised the definition of risk as a product of probability and magnitude. This is sometimes referred to as the 'technical concept' of risk. An alternative approach to defining risk leads to the 'social concept' of risk. In common with a number of other authors, Kasperson *et al.* (1988) believe that perception studies show that "most people have a much more comprehensive conception of risk". The primary argument is that a number of other factors influence risk, including voluntariness, ability to control risk, familiarity with the hazard, and the nature of the hazard in terms of catastrophe potential and 'dread' aspects. They conclude that "the technical concept of risk is too narrow and ambiguous to serve as the crucial yardstick for policy making".

Whyte (1982) postulates the expansion of the simple equation

$$\text{risk} = \text{p.m} \qquad (1)$$

where p = probability, and m = magnitude,

to

$$\text{risk} = \text{p.m}^n \qquad (2)$$

where n is variable and related to societal values.

This is an interesting way of exploring the relationship between technical risk, as defined in equation (1), and social risk, described in equation (2), but unless an attempt is made to quantify n it does little to increase our knowledge or add to our ability to predict and estimate risk.

Another hypothesis for explaining the difference is that people, either as individuals or groups, do not explicitly link the probability and magnitude of risk in this way, but simply consider risk in terms of two elements, each of which has relevance in different contexts.

The 'social concept' of risk, however, does not necessarily conflict with the technical concept of expected risk as a compound of probability and magnitude of consequence. In Section 4.3 we discuss factors affecting risk perceptions. These factors affect the way in which people develop their estimates of risk, which we refer to as risk perceptions or perceived risk. We note that experts and lay people differ as to their evaluation of magnitude of risk as well as probability of risk. The main difference here is that lay people consider risk in terms other than injury, death or loss of property. Both parties use partially quantitative and partially qualitative (affected by assumptions and hypotheses) processes to estimate risk. Our contention is that the only difference between the technical concept and the social concept is in the factors that influence the estimation.

3.0 Approaches to the study of perceived risk and acceptable risk

A number of approaches have been employed in the study of perceived risk and acceptable risk. These are generally classified as revealed preferences, implied preferences, expressed preferences and natural standards. The concept of preferences derives from economics, however, psychologists use the same tools under different labels. The counterpart of the revealed preference economist is the behavioural psychologist and the counterpart of the expressed preference economist is the cognitive psychologist working in the area of social psychology (Royal Society, 1983).

Renn and Swaton (1984) summarise three "key questions" of risk perception as:

(1) what are the social goals, values or motives that drive persons or social groups to attribute special concerns to specific risk sources;
(2) in what way do people process information about risk sources and what kind of logical structure do they follow in an overall judgement on the acceptability of a perceived risk; and
(3) what kind of motivational or cognitive biases are incorporated when people select information from the various sources that they have access to (and why do they apparently violate their own rules of reasoning)?

They divide risk perception studies into four categories: classical decision analysis, psychological decision theory, socio-psychological judgement and attitude theory, and sociological systems theory and policy analysis.

Classical decision analysis uses maximising utility axioms to look at the differences between intuitive perceptions and 'normative' risk assessment (question three). The method of revealed preferences fits in here.

Psychological decision theory emphasises an **individual's** common-sense approach and assumes that individuals have "specific value clusters which influence the weighting of attributes connected with the perception of a given object" (Renn and Swaton, 1985). The behavioural psychologist (Royal Society, 1983) tries to analyse how people process information and arrive at judgements using expressed preferences. This process addresses question two.

Social psychological research and the cognitive psychologist (Royal Society, 1983) on the other hand concentrate "on the interaction between social environment and personal judgement . . . . . ". Perception becomes "a process of deriving attributes . . . . . from specific social values and personal attitudes". It is directed towards questions one and two above and uses the method of revealed preferences.

Sociological systems theory looks at the effects of social interrelations between groups, and group responses to risk (question one).

The development of the use of the different approaches to the study of risk perceptions and their influence on the concept of acceptable risk is summarised in Appendix D. The remainder of this Chapter looks at the different approaches and identifies the general conclusions associated with them.

3.1 Revealed preferences

The term **revealed preference** was introduced to economics in 1938 by Samuelson. The revealed preference axiom is that the consumer, by choosing a collection of goods in any one budget situation **reveals his preference** for that particular collection. The chosen 'basket' maximises the utility of the consumer and the revealed preference for a particular collection of goods implies the maximisation of the utility of the consumer (Koutsoyiannis, 1980).

The **revealed preference** method for estimating risk as initially proposed by Starr in 1969, is based on the assumption that society has adjusted to a balance of risk and benefit that it finds acceptable. It considers both risks and benefits in deducing a decision rule. A new technology's risks are considered acceptable if they do not exceed the level of risk associated with ongoing technologies which have a similar benefit to society (Fischhoff, Lichtenstein *et al.* 1981). The method of revealed preferences is thus associated with the calculation of acceptable risk.

Rowe (1980) represents this comparison of risks and benefits as a nearly optimal balance. A major assumption is that this balance is static and will continue into the future. Statistics of behaviour are then used to **infer** underlying preferences. Two further assumptions are involved in this approach: firstly, that costs and benefits can be measured in the economic market place; and secondly, that people have sufficient information available to them to make intelligent (rational) choices.

The revealed preference method is the tool of the behavioural psychologist. A major limitation results from the assumption that past accepted levels of safety are applicable to the future. These levels are based on current income distribution, social structures and value systems which may or may not be either currently applicable or desirable. Society does not have a fixed set of values: value systems are dynamic, as can be seen by the increasing concern about risk in our everyday environment.

The benefit of the revealed preference approach is that it deals with societal decisions, rather than models. The disadvantages are that it deals with the past, that multiple relationships make it difficult to extract the required information and also that it considers only with physical risks.

Starr (1969) used this approach to try to improve upon the simple comparison of risks that had been previously used. He considered the relationship between risk of death and economic benefit for a number of common technologies.

His four main conclusions were that:

(1) the indications are that the public is willing to accept 'voluntary' risks roughly 1000 times greater than 'involuntary' risks;

(2) the statistical risk of death from disease appears to be a psychological yardstick for establishing the level of acceptability of other risks;

(3) the acceptability of risk appears to be crudely proportional to the third power of the benefits (real or imagined); and

(4) the level of risk tolerated for voluntarily accepted risks is quite similar to the level of risk from disease.

Fischhoff, Slovic *et al.* (1978) refer to these findings as "laws of acceptable risk".

There have been a number of attempts made to duplicate the results derived by Starr. Otway and Pahner (1976) conclude that "while the Starr hypothesis regarding the identification of these determinants (or at least the first and third) was probably philosophically correct, the results could not be justified on the basis of his analysis. The Decision Research group of Slovic, Fischhoff, Lichtenstein and others also attempted unsuccessfully to repeat Starr's work. This illustrates one of the major drawbacks of the revealed preferences approach as a means of estimating acceptable

risk. It is very difficult to obtain consistent estimates of risks and benefits for technologies that are very different in character. Therefore the method has considerable measurement difficulties.

The second of Starr's conclusions has been refuted by many researchers. People's perceptions of risk vary according to possible types of injury and the type of hazard (dread/commonplace, catastrophic) involved. It has also been shown that people's perceptions are not solely related to death and physical injury, but also include mental and psychological damage associated with hazards.

An important point, however, is that although Starr's results were questioned, nobody actually questioned the use of the concept of acceptable risk as a basis for further investigation (Bicevskis, 1982). Risks exist in society, and decision makers are required to make decisions that involve risk. Therefore, it is important that decision makers are given information about the social acceptability of the risks.

Value of life studies use variants of the revealed preference method also. Examples include using life insurance statistics to estimate individual's perceptions of the value of life.

To summarise, the drawbacks of the revealed preference method are that:

(1) past behaviour is not a valid predictor of present preferences;

(2) the approach is politically conservative;

(3) it ignores distributional and equity questions;

(4) it makes strong assumptions about the rationality of decision making in the market place;

(5) it assumes that people have full information, and that they use it optimally; and

(6) there is considerable difficulty in developing the risk/benefit measures required. (Fischhoff *et al.*, 1985).

The method's major advantage is that it provides an aggregated social measure of perceived risk, albeit a retrospective one.

3.2 Expressed preferences

The method of **expressed preferences** involves questioning individuals and obtaining information directly from them. It derives from the original Fischhoff, Slovic *et al.* (1978) study and their attempts to firstly duplicate Starr's work and subsequently to develop an approach "analogous to the psychometric analysis of questionnaire data". Ways of getting information include referenda, opinion surveys, detailed questioning and taped interviews. There is thus no need to convert values into dollars (commensurate units) as is required in the revealed preference method. The assumptions are that people understand the questions they are being asked, that they are given enough information to make an informed answer and that their behaviour is rational and consistent.

The chief results from this research have been that researchers have concluded that perceived risk is indeed quantifiable and predictable (Slovic, 1987) and that the technique is suitable for looking at similarities and differences between groups with respect to perceptions and attitudes. A major finding has been that risk means different things to different people (see Douglas and Wildavsky, 1982b) and that judgements of risk are related to a number of different hazard characteristics. A further consistent result is that most people regard current levels of risk as being too high, confirming the belief that people judge risk according to a wider framework than technical experts (see Chapter 4).

The main difficulties with the expressed preference approach are associated with obtaining a large enough sample which is considered representative of the population at large. The main studies to date have used small samples with known characteristics and likely biases. As stated by Crouch and Wilson (1982), however, carefully designed questions and explicit recognition of likely biases can reduce these disadvantages. A further criticism made by experts is that safety issues are too complicated for the public to understand. Fischhoff *et al.* (1985) compared the expressed preferences approach with the revealed preferences approach. They consider that the results of this study refute the criticism that the public cannot understand the type of information they are asked for in the former approach.

Other criticisms of the expressed preference approach, however, which they list are that people do not have well articulated preferences, values may be incoherent, people may not know what they want and they may not be willing to adjust their attitudes in the face of this ignorance. All questionnaire approaches suffer from the limitation that by the very act of questioning people you affect their opinions. One way of ameliorating these effects is by posing the same question in several different ways, however, this does not eliminate the problem.

The expressed preference method is generally applied by the cognitive psychologist and has been used by Fischhoff *et al.* (1978, 1980, 1981; and see also Slovic *et al.* 1979, 1982, 1985, 1986) to estimate perceived risk.

Another perspective is offered by McCormick (1981) who suggests that a revealed preference study is "an adequate guide of people's perceptions" only if you believe that rational decision making should be left to experts who use past policies as a basis for prescribing future actions. Expressed preference studies will therefore be effective only if you believe that people's present opinions should be the primary basis for decision making, and also, if you believe that people act on their expressed preferences.

The Royal Society report (1983) recommends that comparisons between the revealed preference and expressed preference methods (for determining acceptable risk) should not be made, as the two approaches provide complementary information. We will consider further the relationship between acceptable risk and perceived risk and specific methods used for their estimation in succeeding chapters.

3.3 Implied preferences

Implied preferences are ascertained by looking at the (legal) institutions that society has set up with regard to risk in the past. These standards reflect current values and imply tradeoffs between costs, risks and benefits. Proponents do not view the balance as represented in law as an optimal balance but think of it as society's best attempt to date. Rowe (1980) sees this approach as a compromise between the revealed and expressed preference approaches.

The main deficiencies are that legal structures are neither complete nor entirely consistent. As a result interpreting the information can be tortuous and time consuming. In the United States further problems are introduced by inconsistency between local, State and Federal institutional arrangements.

3.4 Natural standards

The **natural standards** approach adopts the stance that safety standards should be independent of a particular society and that geological time rather than historical time should be used as a source of 'biological wisdom' (as opposed to social wisdom) (Fischhoff, Lichtenstein *et al.*, 1981). In this way, standards for residues of chemicals, heavy metals, radiation etc. would be linked to those found in 'representative' periods in archaeological digs. Another approach would be to allow levels that are minorly above those considered as naturally occurring (such as background radiation).

Douglas and Wildavsky (1982b) also explore this concept and describe it as "whatever levels of risk man and animals have lived with in the past are supposedly tolerable for the future".

There are considerable benefits to Douglas and Wildavsky's approach in that it removes the need to establish dose-response relationships and threshold levels, however, there is obviously limited applicability (in terms of substances for which there is no historical precedent). Other problems include dealing with multiple pollutants resulting from some technologies. Cumulative effects result from the fact the natural exposure does not decrease, and everything new is an incremental addition. Further, it is likely that in some cases the so called 'natural' level, which itself reflects historical cumulative effects, would be unacceptable to present society. This approach does not take account of changing values or of the great changes that people have already imposed on their environment that counter the spirit of the concept. Also, it is subject to individual or group bias that may be manipulated to reflect whichever version of reality the decision maker wants to see.

3.5 Choosing an approach

Fischhoff *et al.* (1985) make a number of points which need to be considered when choosing an approach to studying or estimating perceived or acceptable risk.

Firstly, account must be taken of political reality. That is, the chosen approach must reflect the political reality of the situation, otherwise it will be rejected. Decisions about levels of acceptable risk are political decisions. It is crucial to recognise this point. Risk decisions are made in the political arena and unless a technique is publicly accepted and politically credible the results obtained by its use will not be accepted by the decision makers. Technical experts are becoming more and more aware of this factor as they seek to regain lost credibility.

Secondly, no single approach to estimating perceived risk or acceptable risk is clearly superior to the others in all situations. Although this seems to be a reasonable conclusion there are many examples of techniques being used simply because the analyst is more familiar with the approach than because it is appropriate to the context.

Thirdly, there is a need for risk analysts to be open about the approaches used, to be clear about the quality of the data and to be prepared to revise estimates upon gaining additional information. Risk estimates are often derived from situations where a lack of appropriate data or other factors mean that uncertainty as to the actual outcomes and their likely effects reflects upon the quality of the results. Presentation format is a very important factor in convincing decision makers and analysts must take great care to provide all the relevant background information so that decision makers and the public do not feel that they are being misled.

Finally, Fischhoff *et al.* believe that as it is unlikely that better approaches will be developed analysts should work at applying combined approaches that will aim at improving understanding of the particular problems which the approaches are being applied to.

4.0 Perceived risk/risk perceptions

Perceived risk is the individual or group, judgement or valuation of the magnitude and likelihood of the possible 'bad' outcomes which may result from an action. Our willingness to take a risk is measured by the subjective probabilities which we place upon the alternative actions and our judgement as to the possible magnitude of these outcomes. This depends upon the environment in which the actions are taken.

In Chapter 2 we discussed subjective and objective risk estimates. We stated that perceived risk is a subjective measure. We also stressed that although statistical and predicted risk estimates are commonly considered to be objective risk measures, their calculation generally requires the use of assumptions and extrapolation of data which reduces the objectivity of the estimation. This is seen when different equally reputable experts or analysts are given similar information and data and yet produce different numerical estimates, all of which may be valid, according to the framework chosen for analysis. Therefore, when we talk about perceived risk as being a subjective estimate we are not implying that this subjectivity is to be measured against another purely objective estimate obtained by other means.

Risk preferences are closely connected with perceived risk. In Chapter 3 approaches to measuring perceived risk and acceptable risk were examined. The two most commonly used approaches rely on the analysis of individual and group preferences. The revealed preference axiom is a utility maximising approach while expressed preferences are extracted from direct questioning of individuals. The application of these methods is discussed further in Chapters 5 and 7.

Whyte (1982) describes risk perception as a "useful but compendium term" that in fact includes three components: awareness, knowledge and values. Being aware of a risk simply means that an individual recognises the name of the risk. It does not imply any knowledge of the risk other than that it exists (and that it is considered to be a risk). Knowledge is related to an individual's personal characteristics but awareness is not. People's value structures also contribute towards perceptions and these are correlated with individual characteristics and social context.

Slovic (1987) defines the aim of research into risk perceptions as being to aid risk analysis and policy making by:

(1) providing a basis for understanding and anticipating public responses to hazards; and
(2) improving the communication of risk information among lay people, technical experts, and decision makers.

It should be noted that understanding that there is a potential risk is related to knowledge, but includes social and ethical aspects. This is an important factor in communication also, since value structures are often a barrier to effective communication.

So far we have discussed risk as a 'real' concept deriving from our society and our use of the environment. Douglas and Wildavsky (1982a and b) believe that part of the problem is more basic than this. From studies of different cultures and social principles they introduce the notion that different societies choose different 'sets' of risks to be concerned with. This is a form of risk perception in itself. We have earlier suggested that this selectivity introduces subjectivity into risk estimation. Douglas and Wildavsky suggest that the divergence between perceptions may be partially concerned with our society's failure to explicitly define the risks which it is concerned with. Thus, to alter risk perception social organisation must be altered.

Slovic (1987) believes that the message so far obtained from risk perception research is that "risk communication and risk management are doomed to fail unless they are structured as a two-way process" and that as well as lay people and experts having something to contribute to decision making and management, each side must **respect** the other.

This has major implications for the importance of risk perception research. Risk estimates, whether they be technical assessments or perceived risk estimates are input to the risk decision-making process. This process and its relationship to the risk-assessment process has been discussed fully in Gough (1989). The important point to bring out here is that both of these processes are incomplete unless the management function is also complete. We use the term risk management as meaning the implementation phase following the making of the decision. This includes actioning the recommendations associated with the decision, communicating the decision to all 'interested' parties, following up the actions by monitoring the results and, if necessary, providing for a re-assessment of the decision. Unless risk management is undertaken, it is not possible to evaluate the effectiveness of the risk decision-making process.

4.1 Why study risk perceptions?

Otway and Thomas (1982) adopt a cynical view of risk perception research, stating that they believe that in general the (implicit) objective of the research is a justification of the political decision-making process.

At the time, this stimulated a debate about the purpose of the research which was beneficial to both researchers and decision makers. It helped both parties to clarify the issues involved, to assess the implications of the work to date and to set directions for future work.

In Chapter 2 we described risk as a compound of probability and magnitude. The word 'compound' is used deliberately. Multiplying these together, as in classical decision theory, we can obtain an expected value of risk. This can be described as a technocratic viewpoint. It considers risk as a quantifiable estimate. In this context, perceived risk is simply another way of measuring or quantifying risk. On the other hand we can view the term compound more loosely and say that both factors are important, but it is not necessarily valid to multiply the two together.

The multiplicative version in part ignores the reasons why we seek to understand and estimate (in quantitative or qualitative terms) perceived risk. Macgill (1986) believes that the "complexities and determinants of perceptions of risk need to be explained using sound methodology and empirical evidence so that policy advisors and decision makers can address questions of risk assessment for a better informed position". This is consistent with the need for sound risk management as outlined in Section 4.0.

Politicians and decision makers have considerable difficulty in dealing with perceived risk because estimates of perceived risk are often widely divergent from statistical estimates. There is a tendency for technical experts and decision makers to view so-called objective characterisations of risk as somehow more real or more valid than individuals' perceptions of risk. But as Kasper (1979b) notes, for most people it is their perception that has the immediate effect on their thoughts **and actions.** Further, while citizens often make bad judgements, scientists do as well (Freudenburg, 1988).

A number of authors have used the apparent divergence between expert and lay perceptions of risk to conclude that lay people are not competent to judge technological risk and therefore perceived risk represents an emotive or irrational response that is not worthy of consideration. Lee (1981a) states that "it is tempting but false to think of objective risk as a moderately accurate way of arriving at real risks and of public perception as dealing only with 'imaginary' or 'irrational' risk . .

. . . . we have to be aware that gaining effective measures of intangible benefits is, if anything, even more difficult than assessing costs".

Why, therefore, does perceived risk differ from statistical risk? One of the primary reasons is the way in which we define risk. We have described the 'technical concept' of risk as a compound measure of a probability of occurrence and a magnitude or severity of impact. This mathematical approach to risk, which is common to engineers and scientists, ignores the social and cultural connotations of the term. Further, as pointed out by Lee (1981b), lay people measure severity in different ways to scientists. Some of the negative impacts that people use to measure severity when estimating perceived risk include loss of life, loss of dignity, damage to property and adverse effects in terms of values, quality of life etc. Statistical risk estimates are usually limited to severity in terms of loss of life, injury and sometimes damage to property.

Experts and lay persons use their experience differently. Lay people collect and process information from personal experience and from contact with others. Experts use the general experience of society or larger groups (Renn and Swaton, 1984). There are advantages and disadvantages to both approaches. The expert abstraction process does not take account of equity issues and is dependent on a reliable source of appropriate data. The personal experience approach may be deficient or inappropriate.

Smith and Irwin (1984) suggest that the original motivation behind research into risk perceptions was an attempt to explain public irrationality. This is a flawed basis for discussion which apart from implying that lay perceptions are inaccurate also ignores the disagreement between experts over levels of risk and the range of influences over public perceptions of which statistical frequency is only a part.

Continuing with this theme, Slovic, Fischhoff and Lichtenstein (1979) investigated the belief held by a number of 'experts', that the study of perceived risk is a way of finding out how to educate the public so as to reduce their 'irrational' fears. They concluded that fear of nuclear power is not irrational, nor is it based on misconceived judgements as to the 'actual' risks involved. It is due in great measure to a low ranking of the perceived benefits from nuclear power and in part to the recognition of technical uncertainties in the risk assessment process.

A further reason for the divergence is that extrapolation from the past is often a poor predictor of future experience. Lee (1981b) uses the price of oil as an example for this.

Fischhoff (in Covello *et al.*, 1981) lists six reasons why disagreements occur between the public and the experts:

(1) the distinction between 'actual' and 'perceived' risk is misconceived;
(2) lay people and experts are talking different languages;
(3) lay people and experts are solving different problems;
(4) debates over substance may disguise battles over form and vice versa;
(5) lay people and experts disagree about what is feasible;
(6) lay people and experts see the facts differently.

This list requires some explanation. We have already considered the semantic problem of 'actual' risk versus 'perceived' risk. This addresses reasons one and two of the above list. That 'lay people and experts are solving different problems' is an important idea. The most obvious example of this is the different ways in which experts and lay people perceive the hazard associated with an outcome. Lay people are concerned with lesser effects than death or serious injury, and when death is involved, the manner of death may also give rise to different values being placed on it.

The divergence between 'actual' risk and 'perceived risk' does lead to public conflict. Risk conflicts tend to be conflicts of value rather than conflicts of interest (Gough, 1989). As a result, the source of the conflict may be disguised either deliberately or unintentionally in order for one or other of the two sides to increase their credibility. An example from New Zealand recent experience arises from the application by Telecom to build a new, much larger microwave dish tower in Victoria Park on the hills above Christchurch. Objections on aesthetic grounds were received from adjacent local authorities. Residents also objected to the presence of the tower as a health hazard. There is a belief that part of the residents' objection was due to a belief that the tower would reduce property values in the immediate area. The residents' concerns were amplified by the fact that previous to this proposal Telecom had simply increased the height of an existing tower on this site without any recourse to the planning system. This also illustrates the effects that mistrust of the motives of the developing agency may have on peoples' perceptions and actions.

Reason five above suggests that lay people and experts disagree about what is feasible. As an example, they may disagree about the ability (or willingness) of operators to conform to necessary strict codes for proper (safe?) handling of goods and use of toxic substances. Experts also disagree amongst themselves. The Victoria Park microwave tower application contains elements of this. Telecom insisted (initially) that the tower proposed was of the minimum height required to

perform the function. Other experts disagreed and the final option implemented was lower than that originally proposed.

Lay people and experts do not so much 'see' the facts differently, but disagree as to what 'the facts' are. Risk assessment is primarily a technical process producing results that are seen by the experts as 'facts', however, lay people view these same results as containing subjective assessment and assumptions that are not consistent with the term 'fact'.

Elms (1989) adds reason number (7) to this list: that lay people and experts have to make different decisions. Although this may seem logical, it must be remembered that decisions (in the context of this discussion) are made by decision makers. Lay people and experts have input to the decision-making process, but they are not decision makers.

A further area of conflict is that experts and lay people tend to define the boundaries of risk differently. For example, consider the Seaview LPG storage facility location hearings. Experts had performed quantitative risk assessments for the facility itself, but did not consider the complete transport system associated with the storage of LPG for use in the Wellington and Hutt area. Local residents including the Petone area were very concerned that this aspect had been omitted and felt that the whole question of storage and transportation should have been addressed together.

Risk assessment (Gough, 1988a and 1988b) is a two-step process of determination (comprising identification and estimation) and evaluation. Risk evaluation is an evaluation of the significance of the estimated risk (Griffiths, 1981). Expert and lay perceptions about the risk being studied are part of the input to this social evaluation process.

Perceived risk is important because it is associated with the evaluation stage of risk assessment. Risk analysis usually involves a great deal of uncertainty about both the possible outcomes of activities and the probability and magnitude of occurrence. Therefore, in order to make 'good' decisions (the objective of risk assessment), decision makers require information about:

(1) the technical, social and environmental aspects of the risk;

(2) the assumptions associated with technical calculations of probability and magnitude of the consequences of the risk; and

(3) the public's perceptions regarding the probability and the (potential) consequences.

Methods for determining risk perceptions provide decision makers with important tools to evaluate the significance of the physical, social and political environment in which the risk decision is being made. Risk perception thus contributes to societal decisions about risk acceptability.

If one of the criteria used for (political) decision making is social equity then decision makers should take account of the public perspective. Jasanoff (1987) believes that perceived risk is important because perception is reflected in political action. The Royal Society (1983) also notes that the public's viewpoint is an "essential datum" for risk decisions. However, as Renn and Swaton (1984) reiterate, perceptions are only one input into the decision-making process and in the event, both 'objective' and 'perceived' risk estimates must be considered and (eventually) reconciled (Lee, 1981a and b).

4.2 Individual and group perceptions

If measures of perceived risk are required for the public decision-making process, then it is necessary to estimate a measure of group perception. This may dictate the approach used. Methods for measuring revealed preferences, implied preferences and natural standards all produce group estimates of perceived risk. The method for measuring expressed preferences produces estimates of individual perceptions, which must then be aggregated in some way to a societal measure. As we will see later, one of the main difficulties associated with practical applications of the method of expressed preferences is the need to extrapolate from individual perceptions of risk to group perceptions. Associated with this another practical problem is that of obtaining representative samples, and further, of presenting this information in aggregated form.

On the other hand, the definition of perceived risk that we have used refers to "risk as seen intuitively by individuals". Therefore, the individual aspect of perceived risk is also important. How we use this information is less clear. Slovic and Fischhoff defend their use of small, unrepresentative samples by suggesting that the difference between these samples produces the most useful information. This is important in that by characterising different community groups we may be able to predict their attitudes towards certain risks.

The 'not in my back yard' (NIMBY) and 'not in anybody's back yard' (NIABY) attitudes towards particular risks are pertinent in this context also. Equity issues associated with the distribution of perceived risks and perceived benefits affect

people's attitude towards risks. In particular, in the United States it has been shown that people are happy to accept hazardous waste dumps in the abstract (or somebody else's back yard) but not in their own local area (except in cases where such dumps already exist). This is reflected in political action by the efforts made by the United States Government to establish dump sites on Pacific Islands and in ocean trenches.

4.3 Factors affecting risk perceptions

Slovic *et al.* (1979), Griffiths (1981) and Covello *et al.* (1981) list some of the factors that affect our perceptions of risk probabilities and outcomes.

They are:

(1) whether the risk is voluntary or involuntary;
(2) whether the consequence is likely to be immediate or delayed;
(3) whether the subject is familiar or unfamiliar with the risk;
(4) whether the risk is known to science or not;
(5) what measure of control over the risk the subject has;
(6) whether it is a 'new' risk, or whether it has been previously experienced (not necessarily directly);
(7) whether the effects are chronic, cumulative or catastrophic in nature;
(8) whether the consequences are common or dread;
(9) the severity of the consequences;
(10) the size of the group exposed to the risk;
(11) the distribution of the risk - is exposure equitable;
(12) the effect on future generations;
(13) the degree of personal exposure;
(14) the global catastrophic nature of the risk;
(15) the changing character of the risk;
(16) whether there is seen to be any easy way of reducing the risk;
(17) the availability of alternatives;
(18) the necessity of exposure;
(19) whether the hazard is encountered occupationally;
(20) whether it affects 'average' people;
(21) whether there is likely to be misuse; and
(22) whether the consequences are reversible.

This list of factors is not ordered in any way. Various studies of risk perception (see Chapter 5) have attempted to isolate the major factors associated with perceptions of risk with some success for particular studies of specified risks. A complicating factor is that these factors are not independent.

It is likely that different factors take precedence for different types of risk, or risks of similar character encountered under different circumstances. A simple example is that of a motor cycle racer who will happily race his bike at high speed on a track, despite high apparent danger to the observer, but who will refuse to ride the same bike on the public highway. Mountain climbers will similarly view two climbs of similar technical difficulty as vastly different in terms of risk if one is under a hanging ice-cliff (so called objective danger). In both these cases the factor which takes precedence is the degree of control which the subject feels he has (often misjudged) over the situation.

In addition to these factors, or hazard characteristics as they are sometimes called, a number of demographic and socio-economic determinants such as age, sex, education, social class and income strata will affect individual and group perceptions. Whyte (1982) divides all these factors into three groups: the characteristics of the person, the context (social and economic) and the characteristics of the hazard. This grouping is useful. The characteristics of the person are influenced by personality as well as demographic factors. The social and economic context is important because it affects the way in which people apparently accept certain risks.

For example, risk encountered occupationally is often treated differently to similar risk encountered outside the workplace. Workers at the Sellafield nuclear plant in Britain had different perceptions of the danger associated with the plant than retired people in the community, not because they had any greater knowledge of the risks associated, but because they were dependent on work from the plant (MacGill, 1986). In other circumstances, where more choice is seen to exist, workers will not accept levels of risk in the workplace which they will happily face at home.

Starr (1969) postulated that the voluntary nature of an activity influences its acceptability. Fischhoff, Slovic *et al.* (1978) demonstrated that averages over 30 voluntary and involuntary hazards showed that perceived risk did not correlate with voluntariness. This does not contradict Starr's conclusion because of the multiple relationships involved. The difference between perceived risk and acceptable risk levels may result in cases where participants do not feel satisfied that the regulatory mechanism effectively balances risks and benefits.

Krewski *et al.* (1987) conclude that three main factors seem to affect risk perception, and these are dread, understanding and the number of people involved. However, a high level of correlation between the factors means that the dread aspect is affected by control, catastrophe, fatal consequences and inequity whilst understanding is influenced by observability, newness and immediacy. This is consistent with the results of Slovic and Fischhoff in their earlier studies.

One of the fundamental questions of risk perception is why do people emphasise some risks whilst ignoring others (Douglas and Wildavsky, 1982a). Experts in the past have used this as a rationale for the argument that lay perceptions of risk are 'irrational'. One answer to this is that risk choices reflect values and beliefs about social institutions and moral behaviour. Articulating risk preferences is seen as a way of influencing these social institutions.

Risk perceptions are not static. This is one of the major limitations of the method of revealed preferences and also a problem in the technical estimation of risk. How perceptions change is not known and Johnson and Covello (1987) note that there is little in the current literature representing a "systematic and rigorous analysis of how perceptions and judgements arise from a host of complex factors including historical trends, underlying values, ideological currents and social, cultural, economic, scientific and political institutions".

4.4 Heuristics

Some attempts have been made to examine the thought processes which people use to make estimates of the probability of risk.

Most of this work derives from Tversky and Kahnemann (1982) who suggest a series of heuristics or shortcuts which people use when they attempt to estimate risk. Heuristics are particular judgemental rules which people use to evaluate situations such as risky situations.

The three most important of these are availability, representativeness and anchoring.

People using the **availability** heuristic judge an event as likely or frequent if instances of it are easier to imagine or recall than rare events. Therefore, the frequency (that is either frequent or infrequent) and most recent examples affect availability. People tend to give higher probabilities than is really warranted to comparatively rare events if they have seen or heard of an occurrence and lower probabilities to commonplace accidents.

The **representativeness** heuristic means that people 'place' an event by its characteristics. They estimate the probability of an event by its similarity to another type of event. The major fallacy or bias is associated with the so-called 'gambler's fallacy' which misjudges the law of probabilities and assumes that because something has not happened over a particular time period it is more likely to occur now. This fallacy is particularly evident when people are asked to judge comparatively rare events such as floods.

Anchoring involves linking the risky situation to an initially presented value. If a risk is not particularly well known, and an initial estimate is given, then people tend to revise their estimate by making minor positive or negative adjustments to that initial value. Typically they make insufficient adjustment.

Heuristics are valid in some circumstances and can lead to 'good' estimates of statistical risk in situations where risks are well known. In other cases (little known risks) they can lead to large and persistent biases. Although such limitations and biases can be easily demonstrated, it is not valid to label them as irrational since in most everyday situations, availability is a very good approach to estimating risk levels. Further, given appropriate information, people can be shown to apply judgement in cases of small sample situations.

It must be remembered that experts also rely on heuristics when they have to apply judgement or rely on intuition. Fault trees, for example, are subject to the availability heuristic in terms of the options selected for study.

It is an interesting point that the use of heuristics often leads to overconfidence in the results. Both lay people and experts place considerable (sometimes unjustified) faith in judgements reach using heuristics. It is important to remember in this area that 'awareness' of a hazard does not imply any other knowledge than that the hazard exists. People happily make judgements on such knowledge.

Slovic (1986) looks at the difficulties people face in making unbiased estimates of risk in regard to risk communication. He discusses in particular, the influence of the media, the way in which recent events and experiences colour perceptions, the fact that people's beliefs are difficult to modify, however inaccurately formed, and the ease with which it is possible to manipulate people's views (unformed) by varying presentation format.

4.5 Response to hazard

"*People respond to the hazard they perceive*"
(Slovic *et al.*, 1982a)

If people's perceptions are faulty in some sense then efforts at 'protection' by social agencies are also going to be misperceived and conflict is likely to ensue. People's response is important as an **outcome.**

As we have previously discussed, risk assessors commonly assume that the reason perceived risk and statistical risk estimates are at variance is because the public does not understand the 'true' risk. We have mentioned the 'other' factors including hazard characteristics and socio-economic factors that influence perceived risk and have looked at the different ways in which people consider risk. The hazard characteristics discussed in 4.3 are sometimes referred to as 'psychic responses' to the hazard. Mazur (1987) suggests a psychological model of perceived risk which is reproduced in Figure 1.

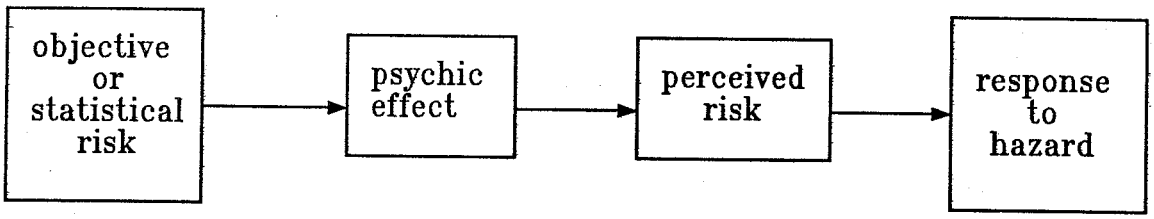

Figure 1. Psychological model of perceived risk.
Source: Mazur, 1987.

The importance of this model is that it reminds us that perceived risk is usually associated with an action (a decision) which will itself have an associated series of outcomes. Risk estimates, whether expert predictions or lay perceptions, are input to a decision-making process.

Mazur points out that there are two effects here: the person's 'verbalised rationale' and the action of response. These may appear at times to be inconsistent. This is a common problem with any approach involving questioning individuals about their attitudes. There does not seem to be any general way of avoiding this bias or of

necessarily predicting it. Mazur suggests an adaption of the psychological model which he calls the sociological model of perceived risk (Figure 2).

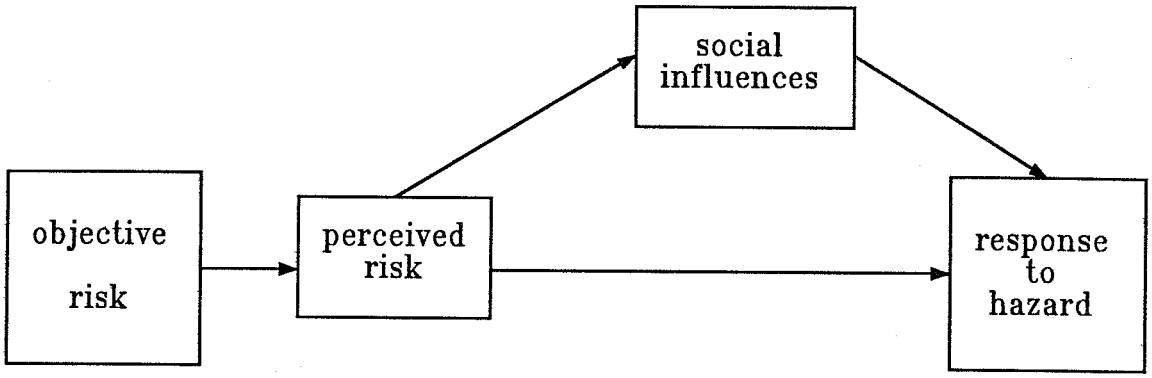

Figure 2. Sociological model of perceived risk.
Source: Mazur, 1987.

This model allows for rationale being subsidiary to social influences and implies that changing behaviour requires changing social influences (eg smoking).

Mazur postulates that social influences may be a more important determinant of response to a hazard than risk perception. This allows that reported perceptions may be merely post hoc rationalisations formulated to be consistent with the response and that in order to change people's behaviour we need to somehow change the social influences surrounding them. This recognition of peer pressure influences is commonly used in many advertising campaigns.

4.6 Political agendas

The primary purpose of making risk estimates is to provide the best information to a decision maker for the purpose of enabling a decision to be made. In many circumstances decisions have to be made in the face of severe uncertainty. Disagreements between experts and lay persons resulting from decisions often occur not because of bias or subjectivity but because of the political implications of the decision. That is, decision makers may use information selectively with certain aims (Tham, 1979).

Starr (1985) contends that public acceptability is dependent more on public trust in hazard managers than on quantitative measures of such risk. This is a common theme in a number of papers and is noted also by Johnson and Baltensperger (1987) in conjunction with hazardous waste and nuclear power plant sitings.

In order for the risk decision-making process to gain credibility with the public it must be seen to be open and fair. Experts and decision makers must to be careful to present and evaluate evidence in such a way that the process is seen to be transparent by the public. Credibility is gained with difficulty and easily lost.

5.0 Methods used to calculate perceived risk

In Chapter 3 we discussed approaches to the study of perceived risk and acceptable risk and noted that the most commonly used approaches are those known as revealed preferences and expressed preferences.

These approaches have been applied in a number of different ways. As stated earlier, the method of revealed preferences requires using the analysis of historical data to infer preferences. This method is linked primarily with acceptable risk studies. The main problem with this approach is that it is very difficult to obtain accurate, complete and appropriate data. Several attempts to repeat the early work by Starr (1969) and Starr *et al.* (1976, 1980) failed to duplicate his results. The techniques used for this purpose included the analysis of publicly available statistics of mortality and basic data analysis techniques.

In the area of expressed preferences a number of different but related techniques have been used, including psychometric scaling, simple social surveys and attitude surveys.

Different groups have tended to associate themselves with particular techniques, for example, the work of Fischhoff and Slovic's group at Decision Research, Oregon, is primarily in the area of psychometric scaling, with additional information being gained from simple social survey questions. Otway and the group from IIASA, Austria, have applied the Ajzen and Fishbein attitude survey techniques (and also provided good critical comment in other areas as well).

Some skepticism has been expressed about the results of social surveys of this nature, however, as Tait (1988) notes, opinion polls do provide information of value, as if they did not, they would not continue to be funded. The difficulty with such polls is not in the collecting of the data, but in the approach to interpretation, and the level of sophistication of statistical techniques applied.

The remainder of this Chapter describes some of the specific methods used by researchers under the headings of the type of approach used.

5.1 Psychometric scaling

Psychometric techniques are employed with the aim of understanding the probability of risk perceptions when these perceptions are extended to quantitative factors such as attributes, consequences, seriousness, controllability etc. Participants are asked to rate a set of hazards on a range of risk characteristics according to a severity scale.

In principle, psychometric studies can be used to obtain estimates of perceptions of risk sources enabling preferences for risk reduction procedures to be assessed and attitudes and perceptions of policy options to be explored. Kraus and Slovic (1988) state that these studies have shown that perceived risk is both quantifiable and predictable. However, there are severe methodological and practical difficulties involved. These are mainly associated with the need to have large samples requiring a high level of complexity. Getting people to understand choices means that large numbers of questions are required and it is often difficult to get subjects to answer the questions.

Krewski *et al* (1987) note that the main studies in this area show two systematic biases in judgements of frequency. These are:

(1) individuals overestimate the probability (frequency of occurrence) of low probability risks and underestimate the frequency of high probability risks; and

(2) individuals exaggerate the frequency of some specific risks and underestimate others.

The claim is that these errors result from biases relating to the heuristics used by lay people to estimate risk. These heuristics were explored by Tversky and Kahnemann (1982) and have been discussed by a number of other authors (including Slovic and Fischhoff). They are referred to as availability, representativeness and anchoring (see Section 4.3).

One of the problems with interpreting the results of psychometric scaling studies is trying to present the results, which often involve 50 or more hazards, and up to 20 characteristics. There is commonly a great deal of correlation between these characteristics and therefore factor analysis is used to analyse the data. This statistical technique combines attributes in groups to improve their explanatory power. However, the use of factor analysis is itself very subjective depending on the groupings selected by the analyst. It draws conclusions which are often unstable and which cannot be generalised over populations or risk sources (Otway and Thomas, 1982). From personal experience we endorse this finding.

Slovic *et al* (1986) argue that the approach of Otway and Thomas is unnecessarily cynical and that an understanding of how people think about risk is important for informing policy even if it cannot answer all questions. They believe that the psychometric work done to date provides a beginning of a psychological classification system for hazards.

Psychometric scaling studies are effective at identifying similarities and differences between social groups, with respect to risk perceptions. The main feature of the perceived risk estimates obtained by this technique is that individuals have shown that they are able to effectively estimate risk in terms of statistical risk of mortality (when restricted to this) but that when they are asked to make risk estimates with greater freedom, their responses reflect wider concerns and other factors (than mortality). This point which has been mentioned before needs to be stressed. Risk is a compound measure of probability and magnitude. Lay people's estimates of the magnitude of risk differ to expert's estimates because of the different factors taken into account in the concept of magnitude. On the other hand lay people have shown that they can estimate the probability of a particular event occurring quite effectively if they are given sufficient (appropriate) information.

The main area of research in perceptions to date has addressed the question as to why risks from some activities are treated differently to risks from other activities, examining mean ratings. This question does not address the wider issue of why individuals differ in their judgements. An area of omission in the literature is that of individual response to single technologies.

5.2 Social surveys

Social surveys have been less commonly used than other techniques to examine risk perceptions. The reason for this is that responses tend to be generalised and it is harder to obtain useful quantitative estimates. They usually involve questioning individuals for information about their perceptions of specified hazards. Typically questions on risk perceptions are asked in conjunction with questions on other areas of interest. In such cases the risk perception information may be subsidiary to the main purpose of the study.

Lindell and Earle (1983), provide an example of a study designed primarily to gain information on risk perceptions. Blackford (1989) used questions on risk perceptions as part of a study seeking information on people's expectations and perceptions regarding the causes, responsibilities, control and options for flood management. A major purpose of the study was to determine people's willingness-to-pay for greater flood protection.

5.3 Attitude surveys and behavioural intentions

> "*Attitude is the concept commonly used to describe how people feel about things*"
> Otway and Thomas, 1982).

Attitude theory is concerned with the prediction and understanding of human behaviour. As Fishbein and Ajzen (1975) point out, there are very many ways of measuring an 'attitude' ranging from single responses to complex modelling approaches. Thomas (1981) uses the argument that rational choice under uncertainty depends on the individual's interpretation of the consequences and that risks issues are usually perceived, not in isolation but along with perceptions of possible benefit, to suggest a convergence with attitude theory as described by Fishbein and Ajzen (1975). This claim is based on the grounds that the approach provides a conceptual framework and a methodology for studying the ways that individuals view the world.

Using the terminology of Fishbein and Ajzen, and considering risk perception as an attitude, salient determinants are beliefs (subjective probabilities) about hazards. A belief represents the cognitive images that a person possesses about a given object or the association between an 'attitude object' and an attribute ("the use of coal leads to air pollution", Thomas, 1981). It is a probability judgement whether the attribute is or is not associated with the perception of an object. A strength of belief is the probability the individual assigns to the association.

Ajzen and Fishbein (1980) model a relationship between attitudes, strength of belief and salient beliefs (evaluations of beliefs within the individual's span of attention at any one time).

Otway's group at IIASA used this approach in the late 1970s as a means of researching people's perceptions about energy systems. It involved open-ended interviews where people were asked to scale their attitudes towards five energy systems and 39 attributes (or consequences) which were associated with a set of 39 belief statements. Respondents were then asked to rate the 'truth' of each of these belief statements. Fishbein was himself directly involved with this work.

It is possible to use mailed questionnaires for this approach, but the best results are obtained from personal interviews. In the Austrian example, interviews were used and considerable explanation had to be given on how the rating scale worked. This is common to most such studies which means that the time required to perform even a moderate study is very lengthy. The statistical analysis techniques are complex and factor analysis is sometimes used as well.

A major criticism of the Fishbein and Ajzen approach is that beliefs are aggregated and community attitudes are derived modally. The shortcoming here is that individuals are most likely to give different weightings to the 'basket' of beliefs that they are evaluating and that this is not taken account of in the aggregation process.

However, the questionnaire techniques applied by Ajzen and Fishbein are generally very useful, and can be combined with other approaches to give useful results.

5.4 Other methods

New techniques for deriving information about risk perceptions are being studied. Tait (1988) refers to the "common theme" of these approaches as being firstly "the need to find ways of getting respondents to provide information in their own way", and secondly, "the need to analyse the data in such a way as to allow valid generalisations to be drawn". Taped interviews are being explored as an approach to the former.

The multidimensional scaling technique developed by Vlek and Stallen is an analysis technique which produces a multidimensional spatial mapping of relationships. This was used by Lee (1981a) to compare different hazards or sets of people on a range of dimensions. In this example, Lee was analysing the perceptions of two groups of people towards sporting activities. The analysis is referred to as multidimensional scalogram analysis (Lingoes, 1973). Johnson and Tversky (1986) compared factor analysis and similarly presented material derived from a set of 18 hazards. They found that the space obtained from multidimensional scaling differed from the factor analytic space.

Contingent valuation (Bishop and Heberlein, 1985) risk-related studies have been used to consider values for one or two hazards. One of the difficulties with contingent valuation (in common with other techniques discussed here) is in presenting the data in a suitably simple form for people to understand sufficiently to enable them to make informed responses. People are asked how much they would be willing-to-pay (or willing-to-accept) if a particular activity were allowed to go ahead. In typical non-market valuations a respondent might be asked how much he would be willing-to-pay for a recreational resource to remain in its natural state. Demand curves are derived from the individual information gained. Intuitively this would appear to be a good way of getting around the need to aggregate individual perceptions to obtain societal estimates of perceived risk. In practise the estimates obtained seldom provide more than upper or lower bounds to the problem.
Analysis of variance has been used occasionally in a limited fashion for modelling

perceptions of individuals. The first example reported is Slovic and Lichtenstein (1971). A further example appears in Anderson (1981). Results give sets of across-hazard and inter-hazard combinations for comparison. The main limitation is that sometimes the analysis gives combinations that do not exist in reality. The method works if all the characteristics of the hazard are included, but this is obviously difficult to ensure. A further limitation is that people are asked to judge abstract profiles which may have little real meaning. However the approach does force people to look at risk in association with a defined set of characteristics in a similar way to psychometric surveys and attitude studies.

6.0 Acceptable risk (or how safe is safe enough?)

"What is an acceptable risk? Who determines it? And how do they do it?"
(Greenberg, 1984)

Definitions

"The acceptable level is the level which is 'good enough', where 'good enough' means that you think the advantages of increased safety are not worth the costs of reducing risk by restricting or otherwise altering the activity."
(Fischhoff, Slovic *et al.*, 1978)

"The occurrence of risk in the past is not evidence of acceptability.... There never was any historical or social 'acceptability' of risk (in the workplace) . . . . current levels of risk represent the best bargain organised labour can achieve at any given time."
(Samuels, 1979)

"Law cannot determine acceptable risk. Acceptable risk is a socioeconomic political question. A better means of determining acceptable risk would benefit the legal system but must derive from social process."
(Green, 1979).

Acceptable risk is based on the assumption that "there is a non zero level of probability of occurrence of an accident below which the public as a whole is willing to accept the risk; at this level there will be no bar to direct involvement or endorsement of the activity".
(Royal Society, 1983)

"In a democracy, no program can survive long without general public acceptability. . . . public perception that the program is undesirable can eliminate it."
(Lave, 1984)

> "*Risk acceptance reflects the results of balancing positive and negative consequences and their probabilities by forming a general evaluative judgement of the riskiness of a certain object or activity.*"
> (Renn and Swaton, 1984)

This series of definitions represents a number of ways in which risk researchers have attempted to characterise acceptable risk. The first characterisation of acceptable risk derived from Starr's work with the revealed preference method. His results gave the first explicit recognition of acceptable risk.

None of the definitions is complete. Previously we suggested that perceived risk has three elements: awareness, knowledge and values. It should be noted that the only researcher who does not assume knowledge (and implicitly awareness) is Lave (1984). Many risks are accepted in ignorance of the existence and value of the risk.

Fischhoff, Lichtenstein *et al.* (1981) modified their earlier definition (above) by saying that acceptable risk is a useful descriptor for a type of decision-making process but that it is not appropriate as a term to describe the results of the process. That is, risks are not acceptable but options are.

One of the things that most of these definitions have in common is that they refer to acceptable risk in the context of a decision process. This moves away from some of the earlier descriptions where acceptable risk was thought of as an independent concept which could be transferred or compared fairly straightforwardly between different types of activities.

Early discussions of the concept of acceptable risk centre around whether it existed or not. In 1979, Rowe (Goodman and Rowe, 1979) described a set of conditions which he believed supported the existence of acceptable risk. They are:

(1) risk that is perceived to be so small as to be deemed negligible;
(2) risk that is uncontrollable or unavoidable without major disruption in lifestyle;
(3) acceptable risk levels established by a credible organisation with responsibility for health and safety;
(4) historical levels of risk that continue to be acceptable; and
(5) risk that is deemed worth the benefits **by the risk taker.**

He refers to these respectively as the threshold condition, the status quo, the regulatory condition, the de facto condition and the voluntary balance condition. This illustrates the fact that acceptable risk is certainly not a single dimensioned

concept. We do not believe, however, that these conditions necessarily support the existence of acceptable risk. The types of risks referred to here can also be termed 'accepted', 'necessary', 'unavoidable' or 'tolerated' risks and these are discussed later in this Chapter.

Gough (1988a) describes some of the work by Rothschild and Inhaber. A section of that report is repeated here to illustrate some of the early approaches to acceptable risk which are no longer considered appropriate. Rothschild (1978) reported in the Listener, implied that the concept of acceptability must be related to other risks which are implicitly accepted by individuals. He sets his acceptable risk explicitly at 1:7500 per year of exposure, using car accidents in 1974 as a reference point. His approach was based on work by Inhaber (1978[1] and 1981), and the Rasmussen report (United States Atomic Energy Commission, 1974). In a similar manner the Rasmussen report confidently predicted that nuclear accidents will occur at a rate of 1 in 1,000,000 for accidents involving 1000 or more fatalities (based on a group of 100 reactors) and goes on to equate this to the risk of a meteor striking a major United States city and causing the same number of casualties.

This work has been severely criticised on a number of grounds. The criticism has highlighted the difficulties involved in transferring risk acceptance from one activity to another without taking account of the factors involved in risk perceptions, and the implicit subjectivity attached to the perceptions of different types of risk. Rothschild, Rasmussen and Inhaber have shown an alarming dependance on statistics derived from quite questionable sources, and have disregarded the need to quantify risk with regard to all the factors involved in risk magnitude. These numbers are quite meaningless in terms of the risks faced by individuals and groups as part of their everyday existence.

6.1 What is acceptable risk?

In the remainder of this publication we consider acceptable risk determination as a decision process of which the outcome is a benchmark which risk analysts, regulators and managers may use to measure the risk of an activity against.

If we adopt the tenet that the determination of acceptable risk is a type of decision-making process (in the same way as risk assessment) but not a product of

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[1]Inhaber (1981) is a revised version of Inhaber (1978), a limited circulation publication which is not readily available.

that process, we are proposing that once a hazard or potential harm has been identified then a decision must be made as to which level, if any, should be allowed to persist, or be deemed 'acceptable'. Related to this are equity issues revolving around the distribution of risks and benefits and the question of 'acceptable to whom?'

We know that different groups define and use the concept of acceptable risk in different ways. For example:

(1) risk analysts seek to define acceptable risk;

(2) risk regulators use the risk analysts information and apply social criteria and judgements to establish acceptable risk levels for society;

(3) managers try to match their processes to the levels set by the regulators; and

(4) the public at large struggle to understand levels of acceptable risk imposed on them and to match these with those levels that they derive from their own perception of the risk.

Risks exist in our society and are 'accepted' under different circumstances. This has, in the past, led people to believe in the existence of a (universal) acceptable level of risk. We have already mentioned that some proponents of acceptable risk believe in a single risk measure that, with minor adjustments, can be used to cover all risk. Other analysts recognise that the factors affecting perceived risk, and thus acceptable risk, mean that risks are viewed differently in terms of acceptability. For example, a single measure of acceptability in terms of numbers of deaths or injuries is not acceptable to the public and nor is it desirable.

The term 'acceptable risk' itself requires amplification. Risks are 'accepted' (or become acceptable) under different circumstances according to people's perceptions of the risk (a fact not recognised by Rothschild and Inhaber). Estimated levels of (technical) risk that are unacceptable in the workplace (by workers) may be commonly accepted by the same people in their private life.

People apparently voluntarily accept comparatively high risks of death and injury by driving cars on holiday weekends, but again, apparently irrationally oppose the siting of LPG facilities (on paper a much safer consideration).

In both these cases, applying the availability heuristic we could say that factors affecting perceived risk and acceptable risk are the voluntary nature of the activities, the dread aspect, the catastrophic consequence (in the latter case), fear of the unknown and other motivations not necessarily associated with risk.

A number of alternative descriptors for some of these types of 'acceptable' risk have been developed, which reflect more accurately the characteristics of the particular hazard. These descriptors include 'accepted' risk, 'necessary' risk, 'tolerable' risk and 'unknown' risk. They are not altogether uniquely defined, and there are overlaps between some of them. They are useful in that they provide a way of looking at the concept of 'acceptable' risk according to some of the social factors associated with the type of risk being considered.

6.1.1 Accepted risk

In our everyday life we meet, face and apparently accept risks all the time. This fact has been used by authors such as Inhaber, Rothschild and Rasmussen as evidence for the existence of acceptable risk. What they have ignored is that these risks or hazards which we encounter have certain characteristics which are evaluated by individuals and groups when considering risk. We have previously discussed the probability and magnitude aspects of risk. The characteristics of the magnitude of the consequences of risk are the size, the timing and the extent of the potential harm. In attempting to define an acceptable risk, the above authors have considered only the probability aspect of the measure. They have not considered the hazard or the social context of the magnitude component.

Earlier, we suggested that there is no such thing as an acceptable risk, and that options are acceptable, but outcomes are not. When individuals evaluate risk they do so on the basis of societal preferences and the outcome of this process is accepted risk, where the perceived personal benefits are seen to outweigh the perceived risks.

6.1.2 Necessary risk

Necessary risk is related to accepted risk. It is incurred when consideration is given to additional socio-economic factors such as employment, income or age. Necessary risk is risk which is considered unavoidable because of these factors or because it is not possible to reduce the risk.

The political process is a very important part of necessary risk and accepted risk. Decision makers are faced with the responsibility of judging that a particular risk level is necessary for certain socially desirable conditions to be met.

6.1.3 Tolerable risk

Tolerable risk depends primarily on the idea of the benefits outweighing the risks. The risk will never be accepted, but it will be tolerated for a particular activity or for a specified time period.

Moore (1988) describes the term 'tolerable risk' as originating from the Sizewell B Inquiry in Britain. "A tolerable risk is not the same as an acceptable risk as people may tolerate a certain level of danger associated with a particular risk but that does not mean they will ever accept it." The term derives from comments by Sir Frank Layfield Q.C. (1987) that "although acceptable risk is often used in balancing risks and benefits, it does not adequately convey the reluctance with which possible substantial risks and benefits may be tolerated".

Tolerable risk therefore indicates that people judge the benefits from accepting a particular risk to be sufficient to outweigh the potential costs. This risk may be considerably higher in absolute terms than an individual or group would be prepared to tolerate under different circumstances. Usually such risk is associated with a specific time period (such as air travel) or socio-economic factors such as the lack of viable options for work (also implying a fixed time period after which the individual expects to be able to leave).

If decision makers wish to use tolerable risk to best advantage they must be prepared to provide the public (or the group at risk) with full information about the operation of the activity, safety measures and areas of uncertainty.

O'Riordan (1987) also pursues the line of tolerable risk and suggests that the conventional approach to tolerable risk rests on four basic principles:

(1) ignorance in terms of which risks are known and which are not;
(2) the de Minimis principle which states that residual dangers will be tolerable if there is no better approach and if the process through which this is accepted are transparent, accessible and accountable;
(3) the comparison test that dangers are tolerated if they are seen to be lower than other familiar processes; and
(4) the justification test which relates benefits to dangers.

6.1.4 Unknown or apparently acceptable risk

Uncertainty is a very important factor in the consideration of acceptable risk and risk comparisons. Some apparently 'accepted' risks are totally unknown or unsuspected. The classic example used to illustrate this type of risk is the case of the Love Canal in New York State, where development took place on the site of a disused chemical dump as a result of inadequate monitoring. The people living in the area were subjected to considerable risk from chemical poisoning until public concern finally forced the issue to the surface. Further evidence to hand from British experience is beginning to suggest that there is a danger of leukemia from very low levels of radiation which have previously been considered harmless: levels such as might be experienced by people living in close proximity to nuclear power plants. There is also the current concern linking cancer in children to radiation absorbed by their fathers working in high radiation areas in nuclear power plants (The Press, 1990).

Unknown risks change character as their presence becomes known.

6.1.5 Safety

> "*Safety is a thing of the past, a thing is safe if its risks are judged to be acceptable.*"
> (Lowrance, 1976)

When scientists use the term 'safe' to describe a risky situation, they are doing is describing 'permitted' (accepted) or 'tolerated' levels of risk. Safety cannot be measured in this context. Risk can be measured on a statistical basis, but safety is a

matter of judgement (as seen in the risk assessment process, Section 6.3). What we mean by this is that safety is a relative concept, usually dealing with people in particular situations. When we talk about the safety of a building or the safety of a bridge we are talking about the relative risks of that building or bridge failing.

The concept of **levels** of risk leads to the relationship between acceptable risk and safety. So far, we have deliberately avoided the use of the terms 'safe' and 'safety' because they carry an implicit reassurance of 'absoluteness'. In practice, safety is a subjective, relative measure which is a function of risk management. The determination of a 'safe' level of exposure is equivalent to setting an acceptable level of risk.

6.1.6 Threshold conditions

In recent years the determination of acceptable risk has turned towards the development of quantitative models which are used to set numerical levels below which any estimated risk is said to be acceptable. These levels are known as thresholds, and for health risks they are commonly derived from dose-response studies using either animals or humans. For technological hazards such as nuclear power and LPG installations, where raw data is not readily obtainable, the process is more difficult and uncertain.

In some definitions, a threshold is described as the level of exposure or toxicity below which there is no harm to humans. This is in fact quite different to the definition that involves an acceptable level of risk, but the two are sometimes used interchangeably.

The question in most cases is whether a threshold involving a level of no harm in fact exists. Animal tests are very expensive and time consuming, particularly at low levels of exposure or toxicity. They also pose increasingly complex ethical questions. Therefore, in most cases models are used to extrapolate (simple straight line extrapolation is common). Current thinking suggests that these approaches are not valid and that there is no evidence to support them.

6.2 Acceptable risk and perceived risk

The discussion of different ways in which we can look at acceptable and accepted risk has demonstrated that acceptable risk and perceived risk are not different types of risk. Perceived risk has been defined as "that risk seen intuitively by individuals". Perceived risk is thus an estimate of real risk. Acceptable risk on the other hand has been described as a descriptor for a type of process "but not the product of that process". Perceived risk influences the acceptable risk decision-making process and provides one criterion for evaluation of the risk. Perceived risk is also a determinant of accepted risk, necessary risk and tolerable risk, which are outputs from the decision process also.
Acceptable risk depends on perceived risk and perceived benefit. Its determination requires a balance of risks and benefits in the marketplace. In considering whether acceptable risk exists as a unique entity, Fischhoff, Slovic *et al.* (1978), state that people do not believe that this state of balance has been achieved.

6.3 Acceptable risk and risk assessment

Gough (1988a) stated that the determination of acceptable risk is an integral part of the process of risk assessment. Acceptable risk problems are decision problems because they require a choice between different courses of action, but they differ from other decision problems in that one of the available alternatives involves as a consequence, a threat to life or health. This threat may be either direct, with obvious consequences, or indirect, being a threat to something that we value as a part of our quality of life.

Risk assessment has two main components: risk determination (identification and estimation) and risk evaluation. Risk evaluation involves societal evaluations of the acceptability of the risk options. Therefore acceptable risk decision making is a part of risk assessment.

Samuels (1979) puts this slightly differently, stating that there are two separate but legitimate issues with respect to acceptable risk:

(1) the measurement of risk; and

(2) the determination of acceptability.

Of these, the first is an empirical judgement and the second is an ideological judgement.

Setting acceptable risk levels can be seen as equivalent to the risk assessment process. Firstly, the risks need to be identified, secondly they need to be estimated and thirdly they need to be evaluated against society's values, beliefs and aspirations. The first two steps of this process involve the analyst or scientist and the third step is a political or ideological judgement as described by Samuels.

Once we have identified a hazard (or possible adverse outcome) and estimated the risk we must then determine whether it is socially acceptable and if so, at what level. But in considering this the analyst is no longer working as a scientist. This type of decision should be made through the political process. Rall and Niehs (1980) stress that this decision should be based upon scientific data and clearly articulated social and economic values.

The product of risk assessment is therefore a collection of information about the effects of an activity from which analysts and regulators (politicians) are required to determine a level of 'acceptable' risk **for that specific activity or situation.** This is particularly applicable in the area of health hazard where risk assessment is used often in conjunction with animal tests to assess the risk to humans from particular chemicals or toxic agents that the public is exposed to either in the workplace or through their environment. In the United States, a number of government agencies perform and fund research in these areas of toxic effects. One of the main difficulties is that to date this type of risk assessment model has only been developed for cancer (Greenberg, 1984).

Risk assessment and the establishment of acceptable risk levels (through regulatory processes) generally involve recourse to political decision-making processes. Some of the literature suggests that the two can be divorced, and that risk assessment is a scientific process and acceptable risk is a political issue (Clarke, 1988). Where risk issues are involved this is generally incorrect. Risk assessment is, and should be, politically influenced.

6.4 Acceptable risk and risk management

Risk management is the implementation phase of the risk assessment process. It involves communicating the decision to analysts, management and the public and putting in place the institutional and managerial arrangements required. If the risk assessment decision process determines a level of risk that is considered acceptable for the situation being studied, then a further part of risk management is the process which monitors the results of implementation and reports back to the decision

making body as to its effectiveness. Risk management within an organisation or operation also involves seeking ways of reducing risks (risk mitigation).

Lave (1984) lists the following criteria as relevant for evaluating risk management strategies:

(1) level of residual risk;
(2) efficiency in risk reduction;
(3) administrative simplicity;
(4) equity; and
(5) public acceptability.

The task of risk management then is to ensure that risks remain between the boundaries defined as acceptable. As Lave points out, the first four of these criteria may be met and yet if the fifth (public acceptability) is not, then conflict will occur. The determination of risk levels that are 'acceptable to the public' is crucial.

Current policy in the United States is to separate risk assessment and risk management. In this case, the challenge for the risk assessor is to communicate "all the information needed by the risk manager in such a way that its implications will be readily understood" (Paustenbach, 1989). The reasoning behind this separation is probably an attempt to ensure the independence of the risk assessment process. The difficulty, as pointed out by Paustenbach is that unless the communication process is given very careful attention then the risk manager may be unaware of information critical to the correct operation of the system.

7.0 Methods used for calculating acceptable risk

In this discussion we have been looking at acceptable risk and its relationship to perceived risk and risk perceptions. In Chapter 3 we looked at the different approaches that have been taken to the study of perceived risk and acceptable risk and noted that revealed preferences had been used by Starr to infer the existence of acceptable risk and some estimates of value.

Discussion of acceptable risk then concentrated on the concept of acceptable risk determination as a decision process. We also looked at alternative concepts such as accepted risk, necessary risk and tolerable risk, which are more appropriate than acceptable risk in many cases.

Acceptable risk is not the product of the acceptable risk decision process. The product is an acceptable option or a benchmark against which analysts and managers can measure levels of risk. It is applicable only in the specific context in which it is determined.

In recent years, the determination of acceptable risk has turned towards the development of quantitative models which are used to set numerical levels below which an estimated risk is said to be acceptable. A common approach is to place 'known' risks on a scale and to rate the acceptability of 'new' risks by estimating their equivalent numerical value and placing them alongside this scale.

In his classic paper, Rowe (1980) lists four methods for assessing risk. All of these approaches are used for the setting of acceptable risk levels. Fischhoff *et al.* (1980) describe them as follows:

(1) risk aversion, which involves the maximum reduction of risk possible with little or no comparison with other risks or with benefits, of which standards of zero tolerance and dose-consequence threshold levels are examples;

(2) risk balancing (corresponding to Rowe's risk comparison method), assumes that some level of risk above zero is acceptable and defines the level through comparison with appropriate reference cases, such as similar technologies, natural background levels or risk previously determined to be acceptable;

(3) cost effectiveness (of risk reduction), seeks to maximise the reduction of risk for each dollar expenditure on safety - acceptable risk may be set by breaks in the slope of risk reduction efficiency for a given hazard or by allocating public funds among hazards for maximum risk reduction to society as a whole;

(4) cost(-risk)-benefit balancing, recognises some level of risk above zero, acceptable risk is defined by balancing the benefits of an activity or technology against the level of risk it presents - the risk tolerated increases proportionately with the magnitude of the benefits involved.

None of these approaches provides an adequate solution to the question of risk acceptability and it must be remembered that risk to human health is only one value dimension of acceptability; a variety of other considerations (equity, impact upon institutions, ecological impacts) may assume greater importance in any given case. Also, societal values change and what is viewed as being safe today may be viewed as being unsafe tomorrow (as previously discussed with regard to the setting of limits on occupation levels of radiation).

There is a clear difference between setting levels of acceptable risk for specific circumstances and determining acceptable risk in general terms. Acceptable risk levels are the product of the acceptable risk decision-making process, and they are acceptable only in terms of the process involved in their determination and the social evaluation associated with it. Judgements on acceptability involve the consideration of perceived risks and benefits in the light of feasible alternatives.

Moving therefore from these 'objective' approaches to the setting of acceptable risk levels we enter the area of psychometric risk acceptance analyses. The shortcomings of the objective approaches are that they do not take full account of the dimensions of risk which include: the temporal limits, who is affected, how people respond to reduce risk, the difference between accepted and acceptable risk, and the way in which individuals arrive at decisions. Psychometric and sociological studies that estimate perceived risk increase our understanding of how particular benefits are seen by individuals and specific groups.

Starr (1969) and Starr *et al.* (1976) reject the disregarding of any risk below a particular level and claim that models should take account of tradeoffs between risk options to establish risk benefit tradeoffs. Their approach involves the use of revealed preferences. Otway and Cohen (1975) followed this approach but were unable to duplicate Starr's results and concluded that the methodology and results were very sensitive to the assumptions made and the data used. Starr, himself, put a

great many provisos on his results. The use of revealed preferences and expressed preferences to improve understanding of risk perceptions has been discussed in Chapter 3.

Part of the process of determining a level of acceptable risk involves examining the difference between people's perceived risk and the technologist's estimated risk. As there is no obvious way of dealing with these differences it is perhaps useful to look at ways in which we can measure perceptions as a means of better understanding the way in which these differences arise.

People do not necessarily reject technical risk estimates. Macgregor and Slovic (1986) looked at the perceived acceptability of three different approaches to making safety decisions. They were cost-benefit analysis, risk analysis (including quantitative risk assessment) and the setting of standards (regulation). The expected value risk analysis was judged the most acceptable method and industry standards (because of the non obvious basis of the decisions made on acceptability or safety) was the least acceptable. The reason for the preference for the risk analysis approach was that the methodology could be clearly seen and the approach understood. The lesson for risk analysts is that transparency of process is critical to the credibility of the decision-making process and hence the acceptability of the decision.

7.1 Risk aversion

The risk aversion approach to setting acceptable risk levels attempts to reduce risk as much as possible. There is no attempt to compare risks and benefits. The main difficulty with this approach is that it is really not possible to eliminate risk entirely, and because of the lack of anything to compare the residual risk against, it is difficult to make any judgement as to the efficacy of the approach in a particular circumstance.

The use of dose-consequence studies to set thresholds of acceptable risk is a particular application of this approach. Threshold levels of risk are set, below which it is considered that the level of risk is effectively zero. The major difficulty is that the methods used to set these threshold levels usually require extrapolation from measured higher dose-response levels to these very low levels. In specific circumstances it has been found that these extrapolations may be quite inaccurate. The particular example of current concern is the case of exposure to very low level radiation. Low levels of exposure previously considered 'safe' have recently been shown to have potentially dangerous effects.

This type of extrapolation is necessary because it is virtually impossible to construct credible experiments for very low levels of exposure. Such experiments require very large numbers of experimental subjects thus incurring high costs in terms of time and money.

7.2 Risk comparisons

As Whipple (1986) points out, "one basic way to consider the acceptability of a risk is to compare it with other risks".

The risk comparison approach to setting acceptable risk levels involves setting maximum and minimum levels of risk using known and accepted risk levels as a scale of reference. The 'new' risk is then estimated and deemed acceptable or unacceptable according to where it lies on this risk scale.

Risk comparison was the approach used by Rothschild to determine the acceptability of nuclear power. He compared the calculated risk of a nuclear power plant explosion with the risk of death on the road. This illustrates the care which must be taken when using risk comparisons to assess acceptability. It is very important that the 'new' risk being examined is compared with an appropriate reference risk with similar characteristics. This is essential for public acceptance of the estimated 'riskiness' of the new activity.

Risk comparison is a form of extrapolation and there are a number of obvious difficulties associated with its use. As we have already stated, the setting of any acceptable risk level involves a number of value judgements. If objective risk estimates and referents are used, there is considerable subjectivity involved (even ignoring the problems of taking account of all aspects of magnitude). There is a danger that the risk analyst and expert may forget the subjective nature of "objective" estimates.

Risk comparisons can be useful, particularly when the risks being compared have similar characteristics, but it is important to recognise that comparing risks that totally dissimilar in nature is dangerous. Risks can be measured in a lot of different ways and reflect a lot of different attitudes (in terms of perceptions). Individual risks must be treated differently to group risks. Some risks have characteristics which expectation and individual risk measures fail to capture and it must be born in mind that risks are not acceptable, but technologies or processes are.

7.3 Cost effectiveness of risk reduction

Cost-effectiveness analysis is used to compare alternative means of achieving the same reduction in risk. Risk-cost comparisons are used to compare the relative costs of risk reduction either by controlling a substance at different levels or by reducing alternative types of risks. Typically, measures of cost include dollar per life or dollar per accident avoided. Estimates of risk must therefore also be expressed in the same units. This is sometimes difficult to achieve.

In common with the risk comparison method, different types of risks cannot be compared.

7.4 Cost-risk-benefit analysis

Cost-benefit analysis provides an accounting framework for evaluating and comparing projects, but it does not directly provide insight into the acceptability of risk values (Starr and Whipple, 1980).

Cost-benefit analysis can be used to assess acceptable risk. It is, however, more commonly used in the form of risk-benefit analysis where risks are accounted as costs. Lay people judging acceptability have been shown to use a form of individual risk-benefit assessment where they compare their perceived risk against their perceived benefit.

Risk-benefit analysis suffers from the same limitations as cost-benefit analysis, foremost of which is the problem of equity. The major unsolved problem in calculating risks and benefits is the reconciliation of the differences between the individual, group and societal perspectives (Engelmann and Renn, 1979). As a result of this divergence, rational decisions at each of these levels are not necessarily consistent. This is because of the distribution of direct and indirect risks and benefits, which returns us to the problems of NIMBY ('not in my back yard') and NIABY ('not in anybody's back yard').
Starr suggests that risk-benefit analysis can be used in particular situations for the allocation of resources for safety, where a fixed budget is available for risk reduction, the setting of standards (or performance targets) and in societal risk-taking decisions where the level of decision making is quite specific.

The problem with units becomes more apparent when you realise that people make individual judgements of acceptability by weighing up the perceived risks and benefits without needing to quantify their estimates, let alone worry about commensurate units. For decision making at a group or societal level more explicit accounting is required.

7.5 Equity issues

The question of equity was introduced in Section 7.4, but it is important enough to require re-iteration. In any form of cost-benefit analysis or cost-risk-benefit balancing exercise, a major area of concern is equity. Many risk decisions involve situations where the distribution of the risks and benefits is such that the benefits accrue to one societal group while the costs are borne by another. A simple example is that of a chemical plant that produces noxious fumes. The benefits accrue to the company and indirectly to the consumers of the products produced while the costs are born virtually entirely by the residents adjacent to the plant.

As Engelmann and Renn (1979) point out, "the rational decision of the individual or of a group is not necessarily consistent with the rational decision of society". They list four reasons for this:

> "(1) the direct benefit and the direct cost are of little relevance to the individual citizen;
> (2) the indirect advantages and disadvantages are of immediate significance to the adjacent citizens;
> (3) (as a rule) the indirect advantages and disadvantages are not equally distributed; and
> (4) the altruistic cost and benefit considerations of the individual citizens of a group will not necessarily be in conformity."

As a means of reconciling these different viewpoints, they recommend a three-stage process of individual, intermediate (group) and social cost-benefit evaluation, combined in a dynamic, interactive framework. This is a complex solution which is unlikely to prove practical in most real-world situations.
Acceptable risk depends upon who will be affected in terms of costs and benefits. The dilemma becomes not what is an acceptable risk, but what is a fair or equitable risk? To whom is the risk acceptable: the policy makers, or those who have to bear the risk? How can we increase the fairness of risk?

One of the more interesting studies in this area is reported by Fischhoff, Slovic *et al.* (1978) where psychometric techniques were used to elicit estimates of perceived risk, acceptable risk and perceived benefit. The study group was an educated informed section of the League of Women Voters. The most interesting result was the consistent relationship between perceived benefit and an acceptable level of risk. This is consistent with our early conclusion that you cannot separate determination of acceptable risk from the expected benefit.

8.0 Implications for risk perception research.

One conclusion of Slovic's work in the area of risk perceptions (Slovic, Lichtenstein *et al.*, 1979) is that lay people need to be better informed, to rely less on unexamined and unsupported judgement, to be aware of the qualitative aspects that condition risk judgements and to be open to new evidence. Experts need to recognise their cognitive limitations, to temper assessments with the qualitative aspects that temper lay judgments and to somehow create ways in which this modifying process can find expression in hazard management.

This review of the literature includes an examination of perceived risk and acceptable risk and a discussion of the approaches and specific techniques which have been used to study and measure these concepts. Individual researchers are optimistic about the results they have achieved and have used these results to support the case for continuing research in the area. Some concern about the way in which the results of this work have been used have been expressed by other researchers. There is no doubt, however, that differences between lay perceptions of risk and expert predictions of risk do exist, and that these differences affect the way in which individuals and groups react towards risk: whether they accept it, tolerate it or consider it necessary. If we wish to improve the risk decision-making process and to reduce conflict in environmental decision making, then the more information we can give decision makers about the way people respond to risk the better.

8.1 Changing attitudes towards perceived risk.

In 1979, General Motors held a symposium entitled "Societal risk assessment: how safe is safe enough?". In one of the papers reported from this symposium, Kasper (1979b) presented some conclusions about risk decision making. He stated that it was unlikely that calculated and perceived risk measures would ever co-incide, but suggested changes to the decision-making process to "make things easier". These were firstly a change in attitude, which recognises that not only the public needs to change, but that experts need to work at improving their image so that they are believed again. Secondly, he proposed a change in the process of decision-making so that all affected parties should be included as early as possible.

What is important about these two recommendations is not what they say, but that whilst they appear imminently reasonable and sensible, their message is still as relevant today as it was ten years ago. The discussion reported at that time was interesting in that it basically consisted of experts hotly defending their own records, thus re-inforcing the necessity for the first recommendation.

At a later meeting of the Royal Society on the assessment and perception of risk in 1981 (Warner and Slater, 1981), participants supported the suggestion that greater credibility should be given to perceived risk and risk perceptions, and expressed the belief that this was in fact occurring. Prior to that time there had been a general feeling amongst experts that lay people were unable to understand technological risks and that therefore they should not be involved in decisions about risk. Risk perceptions were treated as 'irrational' and irrelevant. However, despite the inception of this welcome, apparent change in attitude, progress over the past eight years has been slow, and the development of ways to incorporate public perceptions has proved difficult.

8.2 Limitations of current research

Covello (1983), in a survey of perceived risk literature, suggested that there were three major limitations in the perceived risk literature, namely that:

(1) most studies focus on individual and not group perceptions of risk;
(2) few studies have examined the relationship between risk perception and actual behaviour (i.e. response to hazard); and
(3) few attempts have been made to relate the literature on risk perception to the literature on the perceived risks of natural hazards.

In the same paper, Covello made a number of points about the limitations of the risk perception studies that he reviewed. These can be summarised as that:

(1) most reported findings are based on studies of small, select, unrepresentative groups;

(2) there has been little work on the influence of organisational and social structure factors on risk perceptions;

(3) risk perception studies in common with nearly all survey research are subject to biases connected with the way people respond and the way in which the questionnaire is constructed;

(4) there have been few attempts to relate actual response with reported perceptions; and

(5) few attempts have been made to relate technological risk perceptions with natural hazard perceptions.

This review was written in 1983, shortly after major controversy between risk researchers, sparked by a paper in *Risk Analysis* by Otway and Thomas (1982). This latter paper adopted a cynical view of research into risk perceptions and suggested that motives behind some of this research may have political overtones (Section 8.3, and Appendix D).

The points made by Covello are not necessarily criticisms. They are observations which need to be kept in mind when evaluating the work done by risk researchers. It should, however, be noted that very little subsequent work has been done to rectify the deficiencies identified here.

A further important point made by Covello (1983), which is very relevant to the New Zealand situation, is that most of the research on risk perceptions has centred around controversy over the use of nuclear power. The main feature of this debate has been that the conflict is generally a **value** conflict as opposed to an **interest** conflict, which is unlikely to be resolved by increased information. In New Zealand we need to be aware of these differences between the types of conflict that are likely to arise.

In the area of risk conflicts, the use of surrogates is a common feature. Conflicts presented as interest based may prove to be value based, with issues clouded by surrogate aspects of the problem. One of the reasons for this is that there is generally a great deal of uncertainty involved in these conflicts and therefore risk issues can be used to motivate sectors of the community previously unconcerned. Real fears exist in many of these cases despite them being discounted by experts. Incidents such as Brown's Ferry, Three Mile Island, Bhopal and Chernobyl do not increase the public's faith in experts' ability to identify and control hazard.

To date, research into the resolution of risk conflicts has not produced any significant breakthroughs. Research is now concentrating on risk communication which is assuming greater importance as technical expertise and an awareness of the importance of public perceptions increases.

8.3 The future for risk perception research

> *"Risk research especially in the area of risk perceptions is being used as a panacea with which to address what are essentially societal and political matters ....*
> *Risk research is being used as a tool in a discourse which is not concerned with risks per se, nor with the cognitive processes by which people misperceive the risks of new technologies, but whose hidden agenda is the legitimising of decision-making institutions and the equitable distribution of hazards and benefits."*
> (Otway and Thomas, 1982)

We have considered the list of limitations of risk perception research as outlined by Covello (1983). Deriving from about the same time, Slovic *et al.* (1982b) suggest an agenda for risk perception research. It reads as follows:

(1) what are the determinants of perceived risk? (what are the concepts by which people characterise risk?);
(2) how and why do layperson's perceptions of risk differ from those of experts?;
(3) what information is needed to foster enlightened individual and social behaviour with regard to risk issues?
(4) what is the role of judgement in technical assessments of risk?;
(5) how do people perceive the benefits of risky technologies?;
(6) what determines the relative acceptability of hazardous technologies; and
(7) what makes a risk analysis "acceptable"?

Some of these questions have been addressed (notably the question as to how and why expert and lay perceptions vary), but very few clear answers are apparent. Otway and Thomas (1982) expressed concern about the reasons behind the fostering of risk perception research. They suggested that risk analysis (and perceived risk research) was being used as a political tool, and that it had little validity in its own right (see quote at the beginning of this section). This point of view sparked a very important debate as to whether perceived risk research was valid.

Therefore, in New Zealand, we need to be very clear as to **why** we are studying risk perceptions and how they have an impact on the acceptable risk process. We need to set our own objectives for this research.

O'Riordan (1982) suggests that we need to link risk perception studies more to the emerging critique in the wider arena of societal values and particular technologies, and less to the narrow area of probability consequence judgements and evaluation. This may be particularly important in connection with environmental risk studies where perceptions are closely tied with values. We need to consider ways of adapting processes to incorporate changes in the value structures underpinning risk perceptions since these alter over time. We also need to look at the influences effecting these changes.

Risk perceptions are a key issue in risk conflict situations. We have already discussed the need for experts and decision makers to improve communication with lay people so that the processes by which acceptable risk decisions are made is transparent to the public. It is not expected that the lay public will understand the full technological aspects of risk analysis, but the process by which these estimates are derived, and the decision-making process involved with the assessment can and should be open and comprehensible.

Risk communication is likely to be an important part of any future research into risk perceptions and acceptable risk. As stated by Slovic (1986), "the objective of informing and educating the public about risk issues seems easy to attain in principle, but in practice may be difficult to accomplish". To effectively communicate risk issues, analysts and communicators must have a good understanding of the way in which risk issues are perceived by the public and be prepared to modify their way of doing things to allow the public greater input into the decision-making process.

Bidwell *et al.* (1986) suggested a five-point strategy to be adopted by decision makers to improve the decision-making process and make it more credible to the public. These were to:

(1) emphasise outcomes;
(2) take the initiative;
(3) build legitimacy;
(4) maintain credibility; and
(5) seek consensus.

These actions all form part of a risk management strategy and whilst some of them may appear difficult to implement they are important objectives for decision makers and managers.

Continuing with the theme of risk communication, Slovic (1986) makes a number of points, which have been arrived at through risk perception research. They are that:

(1) people's perceptions of risk are often inaccurate;
(2) risk information may frighten the public;
(3) strong beliefs are hard to modify; and
(4) views are easily modified by presentation format.

The implications for risk communication efforts are that risk perceptions and behaviour are determined not only by mortality and accident statistics, but by a number of other factors. Slovic (1987) further adds that "the most important message from this (risk perception) research is that there is wisdom as well as error in public attitudes and perceptions", and that by using broader criteria to judge risk than those used by the scientific community lay people may conceptualise risk in a "richer" fashion.

This is an important conclusion for a society that is becoming increasingly concerned with quality of life and the maintenance of a 'quality' environment.

Fischhoff and Lichtenstein (1982b), concluded that informing people via warning labels, media programmes etc. is not sufficient. What is required, is "to institute material into school curricula to improve people's judgmental skills and decision strategies for coping (with risk and uncertainty)".

8.4 Conclusion

This publication has described current thinking about perceived risk and acceptable risk, discussed the main approaches to estimating them and examined their usefulness within the risk decision-making process incorporating risk assessment and risk management.

In Section 4.1 we asked the question why study perceived risk? We believe that the main reason for this is so as to provide analysts and decision makers with information that can be used to improve the quality of the risk decision-making process by clarifying and focusing public interest and concerns. Transparency of process is the key to the credibility of the decision-making process and hence to the credibility and acceptance of the decision.

Scientists have in the past taken the attitude that lay perceptions of risk are due to ignorance and irrationality on the part of the public. Early attempts at reconciling lay perceptions and scientific estimates tried to bring lay perceptions closer to expert predictions by providing greater information to the public. This was shown to be counter-productive in many cases, illustrating a misunderstanding of the reasons for the divergence. Conflict resolution cannot in some cases be achieved because of the value structure of the conflict.

Some of the reasons for divergence between expert and lay estimates of risk were discussed in Section 4.1. One of the key issues is that people are not concerned solely with mortality or physical injury. Many other (rational) factors affect their perceptions of risk. Therefore, expert predictions and lay perceptions are both valid contributors to the risk decision-making process, which includes decisions involving 'acceptable' or 'tolerable' levels of risk. Both sides have something to contribute and communication is a two-way process.

Douglas and Wildavsky (1982a) have shown that cultural influence on risk perceptions including the types of risk different cultures choose to study. Other authors including Whyte (1982) have stressed the fallacy of trying to apply results out of context. We must therefore be particularly careful in New Zealand not to use overseas results without extremely careful screening and local testing.

People accept or reject risk according to their perceptions. We cannot say that x is an acceptable risk, however, we can state that x is an acceptable level of risk for a particular activity and specific situation. People accept or tolerate different, sometimes quite high levels of risk, according to the circumstances surrounding the risk, their perceptions of the risk and other sociological factors.

Perceived risk research cannot be divorced from the decision-making process. Risk decisions are almost always politically influenced, therefore understanding of the decision-making process is a critical aspect of this work. We therefore conclude by listing a series of conclusions representing a general consensus among risk researchers.

They are that:

(1) perceived risk is a necessary input to the risk decision-making process;

(2) that in order for the public to accept the risk decision-making process, that process must be open and fair;

(3) that risk communication is a two-way affair and that channels of communication between analysts, decision-makers and the public need to be improved; and

(4) that experts need to be more prepared to explain the processes by which they reach their conclusions to the public.

Along with this, there is a feeling that although current techniques for estimating perceived risk are inadequate, they provide useful information and that the most appropriate direction for the future is to work towards developing combinations of current approaches which can be tested to improve the methodologies.

Glossary

ACCEPTABLE RISK
: risk that is judged by society to be acceptable

ACCEPTED RISK
: risk that is apparently accepted by society, for example, driving a car

ACTUAL RISK
: scientifically calculated or experienced risk (usually statistical risk or predicted risk)

HAZARD
: a harm or negative outcome

PERCEIVED RISK
: risk as seen intuitively by individuals or societal groups

PREDICTED RISK
: risk as measured by systems models using historical data

REAL RISK
: risk that will be determined by future circumstances, and which therefore cannot be measured

RISK
: probability of the occurrence of harm (Freedman, 1987), compounded with the magnitude of the harmful event

RISK ASSESSMENT
: risk determination and evaluation

RISK DETERMINATION
: risk identification and estimation

RISK ESTIMATION
: the calculation of the probability of occurrence and the magnitude of the possible outcomes

RISK EVALUATION

the determination of the significance or value or the risk, including study of risk perception and the tradeoff between perceived risk and perceived benefits

RISK FACTOR

something that causes a risk (Freedman, 1987)

RISK IDENTIFICATION

the identification of all possible sources of risk and the possible outcomes from particular actions

RISK MANAGEMENT

the making of decisions involving risk and implementation of these decisions

SAFETY

an action is safe if its risks are judged to be acceptable

STATISTICAL RISK

risk measured statistically using currently available data

UNCERTAINTY

a lack of knowledge arising from changes that are difficult to predict or events whose likelihood cannot be accurately predicted

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Appendix A

Bibliographic Search

The files searched were accessed using the DIALOG Information Retrieval Service.

Nine specific databases were accessed.

The initial search string used was:

"technical" and "risk",	or
"risk" and "management",	or
"risk" and "perception",	or
"acceptable" and "risk",	or
"perceived" and "risk",	or
"risk" and "preference",	or
"assessment" and "risk".	

In some cases very large numbers of entries were listed. When this occurred the search string was restricted to the perceived risk, risk perceptions and acceptable risk areas. In some cases, the search was limited to 1980 onwards.

The databases searched were:

FILE 8	COMPENDEX PLUS
FILE 11	PSYCHOINFO
FILE 37	SOCIOLOGICAL ABSTRACTS
FILE 40	ENVIROLINE
FILE 41	POLLUTION ABSTRACTS
FILE 49	PAIS INTERNATIONAL
FILE 68	ENVIRONMENTAL BIBLIOGRAPHY
FILE 228	BRITISH OFFICIAL PUBLICATIONS
FILE 292	GEOBASE

There was a considerable amount of duplication between some of the files, and the most useful ones were ENVIROLINE, POLLUTION ABSTRACTS and GEOBASE. PAIS INTERNATIONAL AND ENVIRONMENTAL BIBLIOGRAPHY were moderately useful.

Appendix B

Survey design

The next step in this project will involve testing questionnaire approaches by means of a series of pilot surveys. These surveys will be directed towards testing and developing *techniques* for studying and estimating perceived risk. They will also look at ways in which people accept and tolerate risk.

This emphasis on techniques means that the samples used will be small and (probably) unrepresentative. Therefore, the results obtained may not be useful themselves as estimates. The objective is to compare different ways of approaching the question of estimating perceived risk rather than obtaining estimates to be used.

The statistical techniques to be used will include:

(1) psychometric scaling, following the work of Fischhoff, Slovic *et al.* of Decision Research, Eugene, Oregon;
(2) attitude surveying, following Otway and Fishbein, IIASA, Austria; and
(3) willingness-to-pay surveying (incorporating willingness-to-accept).

All analysis will be performed on an IBM-style PC, using the statistical package SYSTAT.

The survey techniques to be used will include telephone surveying, personal interviews and mailed questionnaires.

The areas selected for sampling will include representative communities of the Lyttelton Harbour Basin. There are specific environmental and health risks in this area associated with the present and proposed systems of sewerage disposal.

It is hoped to be able to perform a retrospective study to examine current perceptions of either the microwave tower erected by Telecom in the lower area of Victoria Park on the Port Hills or the LPG pipeline and storage facility in Lyttelton.

Accompanying this work will be a brief statement on the purpose of studying perceived risk, and a proposal for its use as a risk management tool. This links with the decision-making process study reported on in Gough (1989).

Appendix C

Examples

Although there has been a great deal of research interest in the area of perceived risk and acceptable risk over the past 12 years, the number of studies specifically aimed at obtaining estimates of perceived risk is small. This appendix contains a selection (non-exhaustive) of some of the more interesting studies encountered during this literature survey.

Brief notes on the purpose of the studies, the way in which it was conducted, and some of the main conclusions reached are given. These studies will be used as a basis for the pilot surveys proposed for the next step in this research project.

Slovic *et al.* (1985) report on three psychometric scaling studies. In these studies, respondents were asked to rate a set of hazards according to a range of risk characteristics. The primary objective of the projects was to explore the relationships between risk characteristics. A smaller set of characteristics was derived using factor analysis. These risk characteristics were related to risk perceptions.

The first study was conducted over nearly three years between 1976 and 1978 and involved League of Women Voters (76), college students (69 and 38), Active Club members (47) and professional risk assessors (15) as respondents. The numbers in brackets refer to the numbers in each sample. In this first study the respondents were asked to rate perceived risk, adjusted risk and nine risk characteristics for each of 30 hazards.

There were two main parts to the study. Firstly, respondents were asked to rank risks from different activities and secondly, they were asked to rate specific risks according to some of the factors (listed in Section 4.3) as affecting perceived risk. The two sets of information were correlated and analysed.

The main criticism of this study was that the results obtained cannot be extrapolated to the general population because of the socio-economic characteristics of the groups used as subjects.

The second study conducted in 1979 involved a sample of 175 college students who were asked to rate perceived risk, adjusted risk, desired regulation and 18 risk characteristics for each of 90 hazards.

The third study in 1980 used 34 college students who were asked to rate perceived risk, adjusted risk, desired regulation and 18 risk characteristics for each of 81 hazards.

These studies have also been reported in Fischhoff *et al.* (1978, 1980, 1981, 1985) and Slovic *et al.* (1979, 1982, 1985, 1986) and other publications. The 1978 paper gives examples of the questions and rating scales used for the first study.

An important conclusion reached by the authors is that "psychometric scaling can quantify similarities and differences among groups with respect to risk perception and attitudes". Non-expert judgements differed markedly from experts judgements where estimates of risk were concerned (however, they were similar when estimates of frequency of injury or death were requested).

Although a number of different groups were studied, no attempt was made to obtain any sort of 'representative' sample. All groups concerned were highly educated and geographically centralised. The authors believe that their work, as well as providing a forecast of public response, provides a useful basis for comparing risks.

These studies as reported in this paper provide a good guide for the application of psychometric scaling methods.

Thomas (1981) reports on a study conducted by IIASA between 1977 and 1978. The survey was directed towards the choice of energy options and nuclear power in Austria. A stratified sample of 224 respondents was used, and people were questioned about their beliefs. Thirty-nine belief statements were used and respondents were asked to "scale their attitudes" towards five energy systems".

Lindell and Earle (1983) describe a survey of 229 respondents in 17 different geographical groups across the United States. They were characterised as predominantly high income, highly educated males in the 30-60 age group. The expectation was that this sample would be politically active and express diverse opinions.

A further sample of 396 respondents was selected on the basis of association with risk in industrial facilities.

The purpose of this study was to determine the minimum distance respondents

would be prepared to live from particular industrial facilities which included oil fired, coal fired and nuclear power stations, oil refineries, insecticide factories and nuclear waste sites.

The results of this survey were collated in the form of perceived risk gradients that differed by facility and social group but which were stable over time. This suggested that the geographical siting may be an important factor in stimulating public opposition to the siting of hazardous facilities (how near is near enough).

Hohenemser *et al.* (1985), reported on a pilot study of 34 college educated people in Eugene, Oregon. Each respondent was asked to score 81 hazards on 11 hazard descriptors. The purpose of this study was to examine measures of 'hazardous' by looking at the way in which lay respondents view hazards. The results were compared with results extracted from scientific literature and discussion with experts. The results included a judgement of perceived risk as a ranking of the perceived risk of dying from each hazard on a scale of one to 100. The most striking conclusion was that perceived risk showed no significant correlation with mortality. This confirms the hypothesis that outcomes other than death are sometimes viewed as greater threats. The paper goes on to discuss applications of perceived risk to risk management.

Macgregor and Slovic (1986) report on the evaluation of three methods for making a consumer product safety decision. The three methods evaluated were cost-benefit analysis, risk analysis and abiding by industry safety standards. The methods were examined for perceived acceptability, logical soundness, completeness and sensitivity to moral and ethical concerns. Five hundred and forty University of Oregon students participated in the study which was conducted in a group setting with presentations being make to groups of 50 respondents. Examples of questions are given. Factor analysis of acceptability scales and decision-making situations was performed. The aim of the study was to "explore a methodology for understanding how people evaluate decision making approaches applied in contexts involving health and safety risks". The results were useful and indicated that risk analysis (risk assessment) was the most accepted decision-making method.

Deluca *et al.* (1986) report on an explanatory model of risk perception which describes independent variables as socio-demographic characteristics and cognitive orientations affecting qualitative aspects of perceived risks and benefits, attitudes and information. These in turn affect the independent variables, which are perceived risk and perceived benefits, leading to a perception of safety standards and actions.

Six technologies were studied: automobiles travel, commercial air travel, nuclear electric power, nuclear weapons, handguns and industrial chemicals. The sample included 1320 respondents from New England and the south-west USA. The questionnaire was conducted in interview form and took an average of 45 minutes to complete. At the time of writing the authors did not feel able to draw any general conclusions as the data was not yet fully analysed. However, they made some general points concerning the nature of responses of different groups.

Full questionnaires are given.

In 1986 Macgill conducted a study in West Cumbria which involved interviews with 462 inhabitants. This is reported fully in Macgill (1987). The purpose of the study was to examine the effects of anxiety on the people who lived and worked in the area of Sellafield in West Cumbria (Windscale).

A social survey approach was used to establish "patterns of belief".

The main conclusions were that the major determinants of perceptions of risk were material benefit, personal investment (in terms of lifestyle), workplace, malign effect (mythology and local beliefs), scientific understanding and the media.

The Federal Department of Health in Canada conducted a survey of 200 people across Canada with the objective of ascertaining the criteria people use to evaluate risks, and to collect data which the Department could use to improve its communication with the public and to develop risk policy. The has been reported by Krewski *et al.* (1987). Respondents were asked to rate 12 activities (risk factors) on a one to seven scale then asked to rate the extent to which 13 characteristics affecting risk perception were relevant to each of the 12 factors. From the information obtained, risk profiles for the 12 risk factors were obtained. The main conclusion of this study was that people do not consider all lives to be of equal value or all forms of death to be equal (which counters Starr's conclusions).

Johnson and Baltensperger (1987) report on a pilot study "intended to compare the relative explanatory power of two personality, two bounded rationality. and three-'social reconstruction of risk' models of hazard perceptions". Telephone interviews with 127 respondents were conducted, and from this sample, 47 were selected for face-to-face interviews. Their conclusion was that individual models were unable to explain the considerable variance in benefit, risk and acceptability assessments, and that a composite model might be required.

McDaniels (1988) describes a contingent valuation study (expressed preference framework) on risk reduction where subjects expressed values were compared with actual and proposed costs of safety regulations. The difficulty in this case was to design a framework for contingent valuation which was simple for respondents to understand and enabled them to make intelligent responses. Four groups in Pittsburgh were surveyed, and 53 usable questionnaire results were obtained. The questions concerned willingness-to-pay (WTP) for death avoided. A second survey of students using an abbreviated form of the questionnaire used in the first survey was also performed. Three different versions of the WTP questions were formulated, and it was shown that the presentation of the question had a significant influence on the answers obtained. A further conclusions was that WTP for death avoided varies significantly over hazard type.

Appendix D

Historical summary

It is rather interesting to note the various stages risk perception research has gone through. This brief summary, written in note form, attempts to outline the main events that have influenced risk perception research.

In **1969**, Starr initiated the debate by looking at acceptable risk and perceived risk.

Over the next 10 years the two main groups of Otway (IIASA, Austria) and Fischhoff (Decision Research, Oregon) first tried to duplicate Starr's work and then to develop their own methods.

In **1973**, Tversky and Kahnemann began exploring the heuristics by which members of the public develop their perceptions of risk. They concentrated on availability, representativeness and anchoring.

In **1976**, Lowrance wrote his book 'Of acceptable risk' where he discussed the various ways in which acceptability exists in society. He describes the types of tests used by statisticians to determine threshold levels for risk (levels below which no measurable harm can be found), and looks at regulatory practise.

Some later authors criticised this book because of the implicit assumption it makes that acceptable risk exists. However, he did raise the very important questions of who should decide on acceptability of risk, for whom, and in what terms and why

In **1977**, Lord Rothschild made his unfortunate speech in which he attempted to compare accepted or tolerated risks to acceptable risk. He branded the public as irrational because they were apparently not prepared to accept risks attached to nuclear power plants at a level (mortality statistics) at which they accepted the risk of death from road accidents.

Between **1975** and **1980**, Otway (IIASA) and Fischhoff (DR) developed their approaches to estimating perceived risk. Both used the expressed preference approach but while Otway's group concentrated on attitude studies, Fischhoff's group used psychometric methods. Both groups also attempted to duplicate Starr's results and failed.

In **1981**, the Royal Society discussion meeting on perceived risk was published. In this, Lee made the point very strongly that the public's perceptions of risk should not be considered irrational simply because they differ from expert predictions of risk. Other authors considered particular types of risk.

In **1982** , Otway and Thomas wrote a paper in which they criticised the risk perception researchers (themselves included). They suggested that:

> ". . . . . risk research especially in the area of risk perception is being used as a panacea with which to attempt to remedy what are essentially societal and political matters. Risk research is being used as a tool in a discourse which is not concerned with risks per se not with the cognitive processes by which people misperceive the risks of new technologies, but whose hidden agenda is the legitimacy of decision making institutions and the equitable distribution of hazards and benefits"
> (Otway and Thomas, 1982)

This appeared in the journal *Risk Research* along with a paper by Slovic *et al.* in which an attempt was made to set goals for risk perception research.

> "This research (studies of risk perception) aims to aid risk analysis and societal decision making by (i) improving methods for eliciting opinions about risk, (ii) providing a basis for understanding and anticipating public responses to hazards, and (iii) improving the communication of risk information among laypeople, technical experts and policy makers."
> (Slovic, Fischhoff and Lichtenstein, 1982)

The important thing about this debate is that it made people start to think about what perceived risk (and along with this) acceptable risk research was actually all about. They started to question whether it was important and why.

In **1983**, the Royal Society published another report on risk. This was called risk assessment but it dealt with perceived risk and acceptable risk and summarises the approaches used to date.

An important development occurred in **1987 arising out of the Sizewell B enquiry in Britain.**

Sir Frank Layfield QC commented that "although acceptable risk is often used in balancing risks and benefits, it does not adequately convey the reluctance with which possible substantial risks and benefits may be tolerated".

O'Riordan (1987) pursued this line and suggests that this tolerance rests on 4 basic principles

(1) ignorance - which risks are known and which are not;

(2) de Minimis principle - residual dangers will be tolerated if there is no better approach and if the process through which this is accepted is transparent, accessible and accountable;

(3) the comparison test - dangers are tolerated if seen to be lower than other familiar processes; and

(4) the justification test - where the benefits are related directly to the possible dangers.

This approach, which requires acceptance of some form of regulatory agency, could be pursued.

This brief summary ignores a lot of the major work done in the area, but illustrates some of the important points. It must be remembered that a lot of other risk researchers with related interests have contributed to the perceived risk and acceptable risk debates.

The current 'hot' issue in risk research appears to be in the area of risk communication, and this research will undoubtably proceed further in the area of risk conflicts. Developments will be reported in future Centre for Resource Management reports and publications.

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