1 Introduction

Engineering risk arises from uncertainty. This may be due to incomplete knowledge or understanding, to the appearance of unforeseen events that may be of commercial, political or social origin, or to an inability to control a developing situation. Such events, if they happen, may result in loss or harm to people, property and the environment. Even when risks are reduced, avoided or transferred, there is always some residual chance that things may go wrong, occasionally badly wrong.

We normally think of a risk being the chance that some adverse thing might happen of the consequence should it do so. Specifically, with engineering risk, we mean the practical likelihood of a specific hazard being realised through engineering activity given the actual workplace practices, management priorities, constraints and pressures[1]. Taking risks, however, may lead to gain, and this anticipated gain is normally the incentive for undertaking risky ventures.

Indeed, absolute safety is an impossible dream. Even doing nothing is risky. Many lives were lost in fording New Zealand rivers before they were bridged. Yet our attempts to overcome such risks often bring others we may not have considered. Bridges can and do fail. Further, we cannot even say that the only perfectly safe bridge is the one that has not been used. The collapse of the Westgate box-girder bridge under construction at Melbourne, and the destruction by fire of an Apollo spacecraft on the launching pad both illustrate that failures can occur before things are used for their designed purpose. The management of risks throughout the complete lifespan of a project from initial conception onwards is thus an important aspect of modern business and engineering enterprises.

Although a lack of safety can lead to tragedy, there is sometimes a comic side to relieve its seriousness. Smith[2] relates the story of a sphere which normally held liquid propane and was being filled with water to expel any oil vapours. Unfortunately, the supporting legs could not stand the weight, water being heavier than oil, and the sphere fell over. A mobile crane was brought to raise the sphere, but the crane's jib could not withstand the load, and collapsed sideways over the sphere, causing further extensive damage.

Considerable effort has been expended in recent decades to devise ways of assessing and monitoring risks to put a measure on their real value, so that we can minimise or avoid the major ones, leaving untreated the minor ones of little consequence that we may be prepared to live with, at least for the time being. While such techniques have yielded demonstrable progress in a reduction of accidents and increase in safety, perceptions often remain that technological risks are too great and increasing.

The reality of a risk does not derive simply from such so-called "objective" measures. Newby[3], in his address for the 1997 Jubilee Lecture of the Institution of Chemical Engineers in London, quotes the word of an American social psychologist, W I Thomas:

> *"Things which are perceived as real will be real in their consequences"*

We perceive risk through the accumulated wisdom of our forebears and our own experience and those of the society in which we live. Such informal measures were adequate when society was relatively static and new experiences were rare. While there is little doubt that the world is a healthier and safer place for most of its inhabitants than a century ago, there is more uncertainty through seemingly ever-increasing rates of political, social and technological change. These changes, noted Newby[3], have left individuals feeling threatened with a sense of greater unpredictability and increased vulnerability. The past is no longer a simple template for the future. Moreover, few in society unquestioningly believe that our pursuit of new knowledge and gain of new skills will bring about human progress and happiness. This loss of confidence has its expression in an enhanced perception of risk and a suspicion of expert opinion, with the rise of independent groups presenting alternative viewpoints.

The perception of risk is a social belief. A proposed medium-density fibreboard plant in the Dunedin area did not gain a resource consent because of the perceived risks of emissions, even though the quantitative assessment showed these risks to be minor and their long-term environmental impacts to be negligible. *The thing that was perceived to be real was real in its consequenc*e. Real are the perceptions of the risks of living near high-tension power lines, of irradiating food, of the introduction of genetically-modified organisms, or even of the visits of nuclear-powered warships. Such perceptions do influence political and social policy, and ultimately shape the pattern and pace of technological change, regardless of technical measures of risk. *Today, the communication of risks can be as important to a successful outcome of an engineering project as the treatment of the actual risks.*

Within business and commerce, risks usually will be measured in monetary terms. Even here the perception of risk and the perceived effect of failure on the corporate image can be as important as financial estimates.

Just as individuals and organisations set themselves personal thresholds of tolerable risk, so too communities develop informal but real perceptions of thresholds of societal risk[4]. Accidents and failures that cause large-scale damage or multiple fatalities are almost always followed by a public outcry, often leading to some kind of inquiry into the cause and the steps needed to prevent a re-occurrence. We are risk-averse, particularly whenever the risky venture is outside our control. As a society, we appear to seek the elimination of high-severity risks that might be experienced in an average lifetime.

Risk perception involves a range of social and cultural values and attitudes towards hazards and their benefits. Different people will perceive a given risk differently, depending on their value systems they hold and the benefits they derive, and view it within different contexts. Thus it is impossible to reduce the perceived risk into a single objective function, such as a mean probable fatality rate, or some product of likelihood and consequence. The human condition is of wider compass.

This does not mean that quantitative measures of engineering risk are useless, and the assessment and control of hazards should be left to adversarial debate in resource consent hearings or the judgement of the Environment Court. Rather, the reality of so-called "objective" risk assessments has to be set alongside the reality of perceived risk in formulating policy. Engineering-risk assessments play a vital role in the wise use of resources and in the development of a project from its conception to its "death". Only by quantitative measures can we ascribe priority to alternative risk-reduction strategies or monitor improvements in safety, health and the environment.

Elms[5] has written:

> *"Engineering is goal-oriented, rather than truth-oriented ... in that it has an end in mind."*

Engineering has often regarded the end in providing for society's perceived needs as justifying the means, but no longer is that the case. The IPENZ Code of Ethics now looks towards sustainable management and care for the environment with minimal adverse side-effects. Consideration of means and the evaluation of associated risks at all stages of a project are thus essential components of engineering endeavour.

The incentive for writing the original IPENZ book was a growing concern for the liability of engineers in an increasingly critical and litigious world. The then President of the Institution, Eric Ireland (1983-4), noting that some spectacular failures had figured prominently in newspapers or had been featured on television, appointed a task committee to study the subject of engineering uncertainties and risks and prepare a publication that might be used as a reference for the engineering profession and those associated with it. Their work set out to review the nature of engineering risk. To address the particular concern with liability, the publication contained several appendices dealing with matters of law and insurance which were prepared by professional advisers to the editorial committee.

Since the publication of that book, as noted in the Preface, the commercial, professional and statutory environment in which professional engineers work has changed considerably. The aggregated body of engineering expertise within the former Ministry of Works and Development has been dispersed; the corporate heirs of the old NZ Electricity Department and Post Office have much leaner in-house infrastructures. The Building Act (1991) and its Regulations (1992) are an example of newer legislation that is outcome-driven, rather than prescriptive in content. The Resource Management Act (1991) has introduced the concept of sustainable management of resources and placed a duty on both principals and employees to avoid, eliminate or mitigate “effects” on the environment. The definition of effects is very wide in the Act, covering both acute and long-term impacts, whether remote or not and whether of short duration or not. Subsequent legislation, such as the Health and Safety in Employment Act (1992) and the Hazardous Substances and New Organisms Act (1996), with the setting up of the Environmental Risk Management Authority in 1998, now provide a new statutory framework for engineering activity beyond the traditional obligation of an engineer to practise her or his profession with reasonable and proper care and skill.

A number of recent infrastructural failures in New Zealand and Australia has also raised concerns about the prudent management of engineering assets and operations. In early 1999, the President of IPENZ, Sir Ron Carter, issued a policy statement entitled, *Risk and Prudence*, on behalf of the Institution (see Appendix B). This statement provides guidelines for organisations that rely intensively on engineering and technology and for which engineering-related risks are a significant proportion of the total risk of conducting business. It recommended that organisations should ideally have at least one Board Member with a recognised professional engineering background. In executive management, there should be a person or persons (as appropriate) having clear responsibility and accountability for engineering and technology matters, with engineering risks being properly evaluated and considered in assessing the overall business risk. Within an organisation’s business activity, there should be a regular audit of performance of its engineering policies, including those applying to engineering personnel, measured against industry’s “best-practice” standards. The statement concludes by noting that adherence to the proposed policy would help those with responsibilities for governance to show that they have acted prudently in managing the engineering resources entrusted to them.

The 1983 report of the IPENZ President’s task committee set out a number of conclusions and recommendations, many dealing with aspects of engineering liability. The thrust of these earlier conclusions reflected the concerns of the task committee, with its engineering members drawn from the ranks of consulting and public works engineers. Subsequently, the Institution has declared, within its revised Code of Ethics, that its members' concern for risk has a wider compass. Engineers have a duty of care to protect life and safeguard people. Specifically, members are required to:

1. **Give priority to the safety and wellbeing of the community and have regard to this principle in assessing duty to clients and colleagues;**
2. **Be responsible for ensuring that reasonable steps are taken to minimise the risk of loss of life, injury or suffering which may result from the work or the effects of a member's work;**
3. **Draw attention of those affected to the level of significance of risk associated with the work;**
4. **Assess and minimise potential dangers involved in the construction, manufacture and use of a member's products or projects.**

The Code also specifies that members shall be committed to the need for sustainable management of resources and seek to minimise adverse environmental impacts of engineering works or applications of technology for both present and future generations.

At the same time, there has been a greater awareness of the need for integrated risk management, in many fields besides engineering, culminating, for example, with the publication of the Australian/New Zealand Standard AS/NZS 4360:1995, and its reissue in revised form in 1999. Further examples of the increasing importance placed on this approach to management include the holding of the Wellington conference in March 1997 on *Integrated Risk Management* under the auspices of the Centre for Advanced Engineering and the issuing of a statement of policy on *Risk and Prudence* in engineering governance by the IPENZ Board, which has been already referred to. It seems appropriate, then, in this book to provide both an overview of the management of engineering risk as well as a more detailed treatment than its predecessor on the nature of engineering risk, its identification, analysis, evaluation and treatment, including the impact of recent legislation on professional engineering practice as a result of political and social perception of risks to persons and the environment from engineering works. The book is thus more of a first guide to the topic of managing engineering risk, written to the template of the revised Risk Management Standard AS/NZS4360:1999, rather than a review of the liability of engineers from the risks they run in the exercise of their profession.

Engineering-risk management is concerned with mechanisms of recognising and facing threats to a technology-based organisation before they have a chance to inflict expensive and possibly irreparable damage. These threats may have a technical origin, but normally the prime cause is poor management of engineering processes and facilities.

References

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3 Newby, H (1997): “Risk analysis and risk perception: The social limits of technological change”, *Proc. Safety & Environ. Protection,* 75 (B3), 133-7.

4 Helm, P (1997): “Risk assessment, methodology, vulnerability, impact and importance”, in Rep. Christchurch Engineering Lifelines Group: “*Risks & Realities*”, CAE, Univ. Canterbury, Christchurch.

5 Elms, D G (1992): “Risk assessment” in D J Blockley (ed.) “*Engineering Safety*”, McGraw-Hill, New York.