Risk Assessment and Risk Communication in Civil Engineering

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Summary

This paper summarises parts of a study carried out by Working Group WG32 of CIB into presently applied methods of risk management related to civil engineering and building structures. The complete study is reported in CIB Publication 259. The report gives an overview of advanced and simplified risk analysis techniques and criteria for risk acceptance. Then attention is given to the aspects of communication with the public and the authorities. Finally a number of practical cases are discussed. The cases are used to evaluate the theoretical issues of the first chapters. This conference paper concentrates primarily on the acceptance and communication aspects.

Keywords: Risk management, risk analysis, risk acceptance, risk communication

1. Introduction

To an engineer, the "risk" associated with a hazard is a combination of the probability that that hazard will occur *and* the consequences of that hazard. Consequences to be considered include injury or loss of life, reconstruction costs, loss of economic activity, environmental losses, etc. In all cases, the safety issue has to be addressed either explicitly or implicitly. When *explicitly* addressed, safety targets are set in terms of the *maximum acceptable risks*. However, it is not the engineer who makes the decision about acceptance of riskful civil engineering activities. Decisions are being made by politicians who on their turn are influenced by the press, the public opinion, pressure groups and so on. As a consequence there is a need for communication about risks between the various parties involved. The Working Group WG 32 has prepared a discussion note on this theme [1] and this paper presents a summary.

2. Risk Analysis

In risk analysis, the following steps two major can be distinguished:

(1) **Hazard identification and definition of relevant hazard scenarios**
In this step all hazards and corresponding hazard scenarios have to be identified. A hazard is defined as a set of conditions that may lead to undesirable or adverse events. Identification of hazards and hazard scenarios is a crucial task to a risk analysis. It requires a detailed examination and understanding of the system. For this reason a variety of techniques have been developed to assist the engineer in performing this part of the job (e.g. PHA, HAZOP, fault tree, event tree, decision tree, causal networks, etc) [2,3].

(2) **Estimation of probabilities and consequences**
Risk is commonly expressed in terms of probability and consequences of the undesired events. In a quantitative risk analysis, for every possible hazard scenario E_{ij} following hazard H_i, the possible consequences D_{ij} and corresponding yearly probabilities $P(E_{ij})$ are estimated.

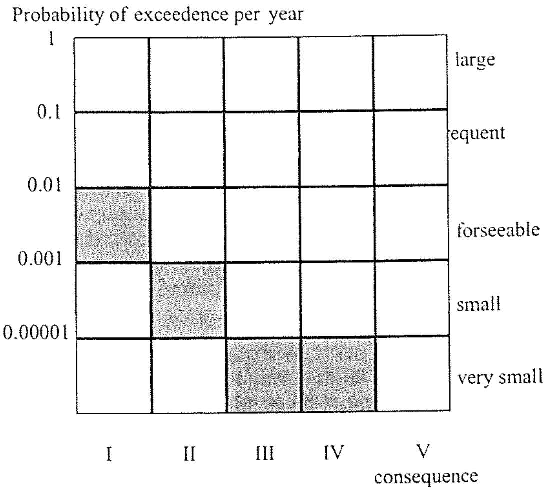

Fig 1 Frequency-consequence-diagram

The damages D_{ij} may be: casualties, injuries, psychological damage, monetary values or environmental values. In most cases a selection has to be made. The probability estimations $P(E_{ij})$ are usually at least partly based on judgement and may for that reason differ quite substantially from the actual failure frequencies. The result of the quantitative estimates of consequences and probabilities is often presented in the form of a *frequency-consequence-diagram*, character-ised by classes of frequency and classes of consequences (Fig. 1). For communication purposes the classes are often described in words. In such a diagram one may also indicate the regions that are acceptable and which are not.

If damages can be expresses in numbers, we may present the risk as the mathematical expectation of the consequences of an undesired event. In the case of disjoint events E_{ij} we have a yearly risk for the j-th risk item:

$$R_j = \Sigma\, P(E_{ij})\ D_{ij} \qquad (1)$$

If all damages have the same dimension we may end up with one number expressing the yearly risk: $R = \Sigma\, R_j$. If the damages are not of the same dimension, one needs weighing factors in order to make the various components comparable to each other and to relate them to the measures that must be taken for possible risk reduction. [4]

3. Risk acceptance criteria

Given a risk it has to be decided whether it will be accepted or not. The acceptance limits for a given disaster usually originate from three different angles:

(1) Individual acceptable level of risk
Individual risks are usually expressed as Fatal Accident Rates (FAR) [6-8]. They can be expressed as an annual fatality probability or as the probability per time unit of a person being killed when actually doing the specific activity. An almost unavoidable risk is the probability of dying from natural causes. In developed countries this probability for a person under 60 years of age is about 10^{-3} per year. The probability of losing one's life in normal daily activities, such as driving a motor car or working in a factory, is in general one or two orders of magnitude lower than the normal probability of dying. Activities such as mountaineering entails a much higher risk. These numbers may be reflected as an implicit risk acceptance model. Of course, people do not have those numbers actually in mind, but there seems to be a pattern that for activities considered as attractive and done voluntary much higher risks are accepted as for unvoluntary activities. This means that we may use these numbers to set up limits. The FAR numbers indicate 10^{-4} as some reference number. For some riskful activity one might then have the requirement:

$$P(\text{casualty}) < \beta \; 10^{-4}. \qquad (2)$$

Beta depends on the degree of voluntariness and the profit. The lowest acceptance value (say $0.01<\beta$ 0.1) can be found for activities which are involuntary and of little profit for the person at risk.

(2) Socially acceptable level of risk
The social acceptance of risk to human life is often presented in the following from ISO 2394.

$$P(N_d>n) < A\, n^{-k} \qquad (3)$$

This requirement should hold for all n. Here N_d is the number people being killed in one year in one accident. The value of A may range from 0.001 /year to 1/year and the value of k from 1 to 2 (see Fig. 2). High values of k express the social aversion to large disasters. The probability $P(N_d>n)$ depends on the probability of failure and on the factors that determine the number of fatalities in case of a failure. In many applications the ALARP principle is used. The upper line in figure 2 may be considered as unacceptable and the lower limit as negligible. For activities giving risks between a reduction of the risk should be sought if economically reasonable. The choices of the ALARP limits are a matter of national safety policy.

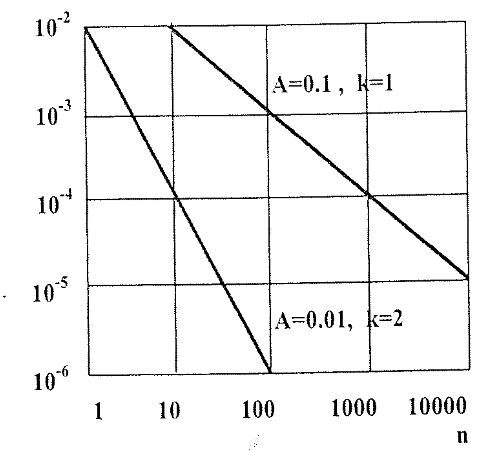

Fig. 2 The "P<An $^{-k}$ *requirement" presented as "F-N-curve".*

(3) Economic criteria
In the third acceptance criterion the problem is schematised as a mathematical-economic decision problem by expressing all consequences (losses as well as benefits) in terms of money [9]:

$$C_{tot} = C_o + \Sigma\; P_{Fi}\; D_i \,/\, (1+r)^i \qquad (4)$$

where C_o is the sum of the investments and net capitalised profits, r is the real rate of interest, D_i the damage costs in year *i* and P_{Fi} the probability of failure exactly in year i. So for higher damage a smaller optimum failure rate should be taken as might be expected. Note that S_i includes all costs after failure: it includes direct damage, cost of repair, but also all future failure costs of the repaired structure (if any). The cost *S* may or may also involve a term related to a monetary value of the casualties involved [10].

4. Risk communication

4.1 The fundamemtal problems

The basic reason for risk communication is to inform all those with an interest in decision-making about the possible consequences of various options. This is not to say that communications are always aimed at decision-making. The general public as a whole, for example, are rarely in the position to make decisions involving risk, since professionals or politicians normally make such decisions on their behalf; but they will nonetheless often be affected by those decisions. Since the public's opinions do (at least, in a democracy) matter, the actual decision-makers will want to keep them informed, at least to some extent. The public *have an interest in* risk, even though they might not always *be interested in* it.

The fundamental problem in risk communication with the public is that the public apparently do not usually interpret "Risk" in the same way as do engineers. It seems that the everyday, layman's concept of "Risk" is a very complex concept which is very difficult to identify but which can sometimes be closely associated with "Threat", so that Hazards with high consequences are then highly ranked despite having extremely low probabilities of occurrence. Two examples from may serve to show the differing attitudes that the public can take.

- **Ronan Point collapse, 1968.** 5 deaths. This occupied the news media for several days, and had ramifications not only in the UK but throughout the world generally. Consequences included the modification of building codes & regulations and contributed to a fundamental change in the public's attitude towards high-rise accommodation.
- **Traffic accidents**. Very approximately, 1,000+ people a year are killed in the UK in traffic accidents. An accident involving 5 fatalities usually makes the local news but not normally the national news other than in a relatively minor way.

Why should two incidents, involving the same number of fatalities, cause such differing reactions? Is it, for example, that the public are used to traffic accidents, but are not used to having buildings fall down? If so, then it might be possible to gauge the public's reaction to an adverse event by looking at frequency of occurrence. Or is it due to a feeling of lack of control? Or is it due to the way that incidents are reported (an important factor, here, is the role of the media in shaping public opinion)? Or something else?

Another fundamental difficulty is that the public tends to judge a message about risk not so much in terms of the information that it contains but, rather, in terms of their view of the communicator. The public is well aware of the large influence of judgement on the risk estimations. So a major factor, here, is the public's view of the *credibility* and *trustworthiness* of the communicator. These are qualitative terms which are very difficult to define, but include other concepts such as [11] *factual, knowledgeable, expert, public welfare, responsible, truthful*, and good "*track record*". It is generally accepted that credibility and trust can take a long while to build up, but can be quickly and easily destroyed by ineffective or inappropriate communication. Factors which can destroy trust in a communicator include *omissions, exagerations, distortions, self-serving statements*.

4.2 Communcation forms

Communications from the public
The form that the public's communications might take varies according to the circumstances. It is, however, commonly aimed at politicians and usually attempts to make use of the news media. Hazards such as the planned construction of a chemical works in the local neighbourhood or the routing of a train, carrying hazardous material, over local lines typically give rise to protest meetings, marches, petitions, organised letters to politicians. Expressed concerns normally concentrate on hazards and consequences rather than risk.

Communications to the public
Communications to the public are rarely about risk per se but usually about various threats or hazards and -sometimes- their probabilities. In public domains, there can be some very basic discussion of probabilities in the immediate aftermath of a major incident such as an explosion or rail crash. More commonly, however, any discussion about long-term threats, such as those from smoking or from traffic levels, is a mixture of qualitative and quantitative information.

Communications by Professionals
Professionals are the main group of people who might normally be expected to be trained, albeit sometimes at an elementary level, in risk identification/analysis. As such, they are more amenable to a more mathematical means of communication than other groups -although even this may depend to a certain extent on the profession involved. Methods of communication tend towards the more formalised approaches:

Role of the news media
The news media are usually viewed as being central to communications generally, and risk is no exception. The media play two essentially different roles: as a **passive** transmitter of someone else's message (as when they repeat a press release), or as an **active** producer, or interpreter, of a message. Their messages often reflect the concerns of the public and other sectors of society, but are not necessarily unbiased. The demands acting on the daily media mean that they must inevitably tend to emphasise the short-term and so want to report immediate events such as accidents or just-published reports into areas perceived as being of public concern. Discussion about longer-term implications can [12] find their way into Editorials, the weekly press and discussion programmes.

4.3 The basic rules of Risk Communication

Covello and Allen [13] formulated seven basic rules of good communications:
- accept and involve the public as a legitimate partner; *A basic tenet of risk communication in a democracy is that people and communities have a right to participate in decisions that affect their lives, their property, and the things they value.*
- plan carefully and evaluate performance; *Risk communication will be successful only if carefully planned.*
- listen to the public's specific concerns; *If you do not listen to people, you cannot expect them to listen to you. Communication is a two-way activity.*
- be honest, frank and open; *In communicating risk information, trust and credibility are your most precious assets.*
- co-ordinate and collaborate with other credible sources; *Allies can be effective in helping you communicate risk information*
- meet the needs of the media; *The media are a prime transmitter of information on risks; they play a critical role in setting agendas and in determining outcomes*
- speak clearly and with compassion. *Technical language and jargon are useful as professional shorthand. But they are barriers to successful communication with the public.*

Given the above analysis on the communication item, these rules can be fully subscribed by the CIB Working Group.

5. Closure

In formulating and quantifying risk acceptance criteria, the engineering profession has to deal with clients, politicians, press and public. The communication about these matters is a very complex subject involving highly technical information, psychology, presentational skills etc. The difficulty is that most laymen in the field of risk analysis do have completely different views on risks. The emphasis is much more on the magnitude of the consequence then on abstract notions like probability and frequency. Especially in low probability high consequence events go often beyond the imagination. People are often too optimistic about risks they are accustomed to but overreacting to new and unknown risks. The fact that probabilities in most risk analysis projects are partly and sometimes even strongly based on judgement rather than data is another complicating factor. In addition, the memory of the public is short: things that just happened get much more attention then disasters of some years ago. It is believed to be the engineers task to bring some logic and consistency in the decisions. Based on this background idea, the CIB Working Group 32 has written a report [1] on the framework of risk management and risk communication in order to help the profession to deal with these matters. This paper gives a summary of some parts of the report.

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