Risk Assessment or Risk Management?

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Summary

Risk analysis is shown to be an integral part of the process of management. Risk management is introduced and described in accordance with the Australian Standard on Risk Management AS 4360. A computer program currently under development to estimate the risks in apartment buildings is briefly described. Finally, some data relevant to an understanding of the risks due to fire in apartment building is presented and used to obtain some understanding of the effectiveness of fire safety systems in reducing risk.

Introduction

Risk assessment is a concept that is often spoken about and used without reference to a context. But risk assessment is futile if the context in which it is performed (or discussed) is not clearly defined and well understood. So, what is risk assessment, and how and in what context is it useful?

Risk assessment may be defined as a process of **risk analysis** and **risk evaluation**, that is a systematic use of available information to determine how often specified events may occur and the magnitude of their consequences, and the determination of risk management priorities by comparing the level of risk against predetermined standards, target risk levels or other criteria[1]. The implication of this definition is that objectives and standards or targets must be established for use in assessing risks and in determining priorities in managing them.

In the fire safety context, at a regulatory level the objectives of building regulations are often quoted as the safety of the occupants, facilitating fire fighting and avoiding spread to other buildings. Other objectives may be relevant, depending on the interests and whims of the building owner or occupier, etc. Viewed in a risk management context (see below) it may be recognised that the deemed-to-comply requirements of building regulations simply represent an attempt at risk management.

An important concept usually explicitly recognised in engineering design, risk management and risk assessment but often not well defined (and even more often not explicitly defined) in building regulations is that of **objectives.** Objectives being what it is intended to achieve as a result of the process being undertaken. As soon as objectives are defined another important concept immediately becomes apparent - **effectiveness,** that is how well the measures put in place actually achieve the objectives. Most of us understand very well that few, if any, of our ideas and actions are 100% effective in achieving the objectives we have in mind. So an ability to measure or assess effectiveness is important in comparing design options and in trying to improve our performance.

A basic requirement in assessing both risks and effectiveness is **data** - information on what has happened, how often, why, what effect various means of prevention or mitigation had, etc. This information is needed whether a risk management approach is formally adopted or not, because if information on what actually happens (and why) is not used there is no substantive basis for any measures, whether required by regulation or adopted through engineering design or risk management.

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Risk management is a concept that provides a **rational context in which** to carry out ri assessment. The Australian Standard on Risk Management (AS 4360)[1] has recently been revis and it provides a relatively simple but very useful framework for risk management which discussed in more detail in the following section.

Risk Management

The Australian Standard on Risk Management[1] defines **risk** as the chance of something happeni that will impact upon objectives and states that risk is measured in terms of consequences a likelihood. It defines **risk management** as the "term applied to a logical and systematic method establishing the context, (and) identifying, analysing, evaluating, treating, monitoring a communicating risks associated with any activity, function or process in a way that will enab organisations to minimise losses ..."

The most important aspect of this definition is that risk management is a **process** not an event. Th is, risk management is not something that is done and then forgotten or assumed to last forever, it a process that requires continuing observation and awareness, and continuing evaluation of chang in the environment and the risks that exist. This is reflected in the flowchart model of ri management that is included in the standard and reproduced in Figure 1.

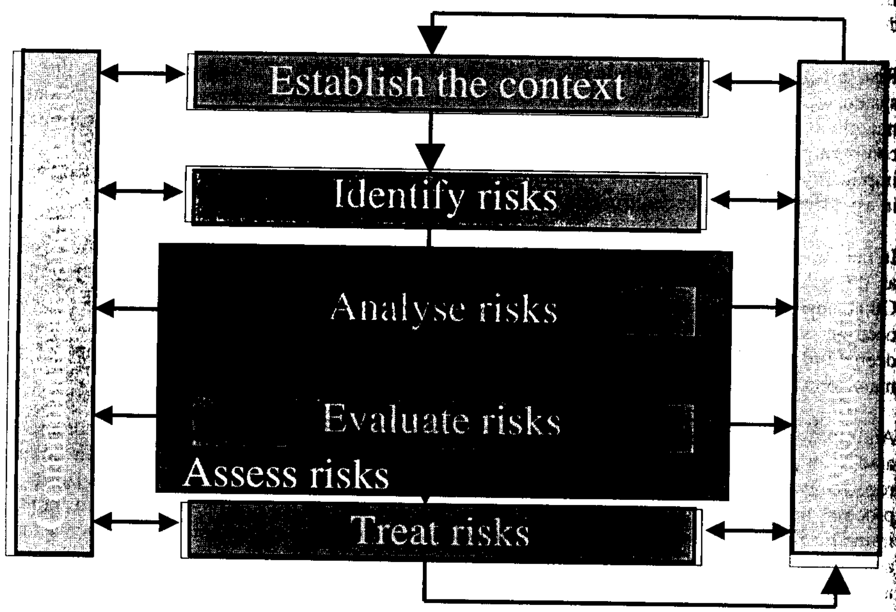

Figure 1 Overview of the Risk Management Process

In the standard **establishing the context** includes such activities as establishing the strategic organisational and risk management context, developing criteria for assessment of risks an deciding on the structure to be used in the risk management process.

In **identifying the risks** there are two questions that are relevant:

- What can happen?
- How can it happen?

The two major aspects of **analysing the risks** as shown in Figure 2 are estimation of the likelihood of events and estimation of their consequences. The two of these are combined to estimate the levels of individual risks and the overall level of risk. In analysing risks the best available information sources and techniques should be used. Suggested **sources** include:

- relevant past records
- experience
- experiments and prototypes
- engineering or other models

Suggested **techniques** include:

- structured interviews with experts
- multi-disciplinary groups of experts
- evaluations using questionnaires
- computer and other modelling
- fault and event trees

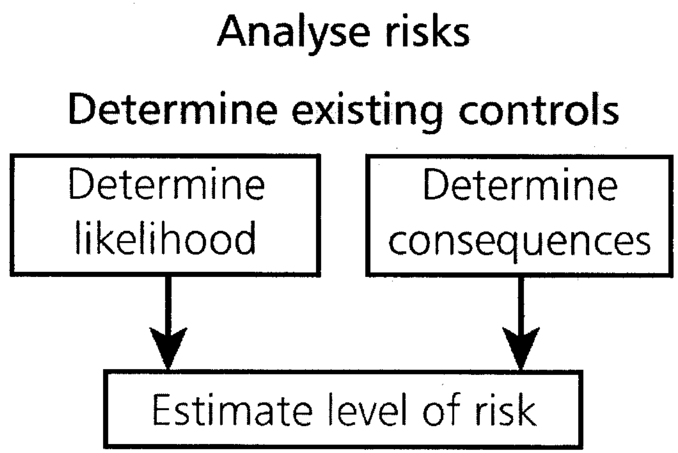

Figure 2 Estimating the Level of Risks

Once the levels of risks have been determined these need to be **evaluated**, essentially by comparing with criteria as to whether each risk and the overall risk is acceptable or not and, if not, against each other to establish priorities for treating the risks.

In **treating the risks** several steps are suggested in the standard:

- identify and evaluate treatment options
- select suitable treatment options
- prepare and implement treatment plans

Important aspects of the risk management process as envisaged in the standard are clear objectives, and a continuing processes of communication, consultation, monitoring and review. In the fire engineering context, the objectives mentioned in the introduction (above) are often of primary concern but additional objectives such as minimisation of property damage, no contamination o contents and continuity of business may also be relevant. It is obviously important that while ev the risk management process is intended to be effective that communication, consultatio monitoring and review continually take place, lest circumstances or the risks change and the proce becomes ineffective.

Risk Assessment

Risk assessment can be undertaken in many different ways and at levels of relative simplicity great complexity and depth, but it is important to note that whatever the level of sophistication t result is an estimate, not a fact.

In the fire engineering context many approaches have been published[2-5]. One of the more compl is CESARE-Risk[6], a computer based risk-cost assessment model that has been under developme for several years and which is currently undergoing testing for application to apartment buildings.

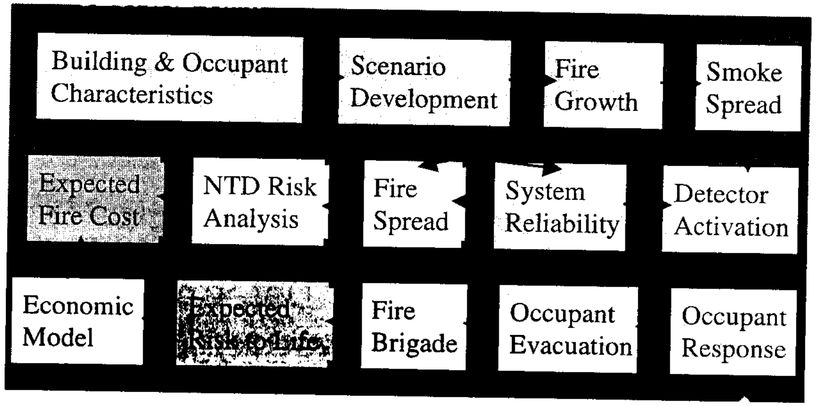

Figure 3 CESARE-Risk - Basic Structure

The basic structure of CESARE-Risk is shown in Figure 3. The program considers many facto including the following:

- building, apartment and room geometry, etc
- occupant numbers, groups, types, locations, etc
- 384 scenarios:
  - various doors and windows open and closed (probabilities)
  - 3 fire types: smouldering, flaming, flashover (statistics)
  - slow, medium and fast fires (adding low, medium and high temperature; short, medium and long durations)
- Monte Carlo simulations:
  - reliability
  - flame spread
- fire brigade interaction with occupants and effect on fire
- fire growth: fast one zone model
- smoke spread: two zone and network models
- detectors/alarms: ten system combinations

Further details of CESARE-Risk and other risk assessment methods can be found in the references.

Data Relevant to Fire Risk Management in Apartment Buildings

The following data is amongst that which is being used to test and assess CESARE-Risk. It illustrates the type of data that is available and useful in building fire risk management and engineering design. This data is for apartment buildings and is obtained from the USA NFIRS database for the years 1983 to 1993 except 1986. It represents 420,315 reported fires in which 3,111 civilians died and with US$3,230 billion estimated property losses. Thus there were 7.4 civilian fatalities per 1000 fires and $US7,700 average estimated property loss per fire.

It appears from a careful examination of the recorded fatalities and from examination of coroners records of similar fires in Melbourne, Australia that probably above 90% of the fatalities were in the apartment of fire origin. It is particularly noteworthy that 82% of fatal fires had a single fatality (representing 63% of fatalities), 12% had two fatalities (18% of fatalities) and 4% had 3 fatalities (9% of fatalities). Thus 90% of fatalities occurred in one, two or three fatality fires - if the number of fatalities is an issue, then it is these fires that are the most important to address, not just those with larger numbers of fatalities.

It also appears that more than 10% of fatalities are suicide, about 10% of fatalities are children lighting the fire and becoming intimately involved, over 30% of fatalities involve alcohol abuse, and over 35% of fatalities are over seventy years of age (a much higher percentage than their proportion of the population). These figures are very important in realistically assessing how effective fire safety systems can be in reducing fatalities.

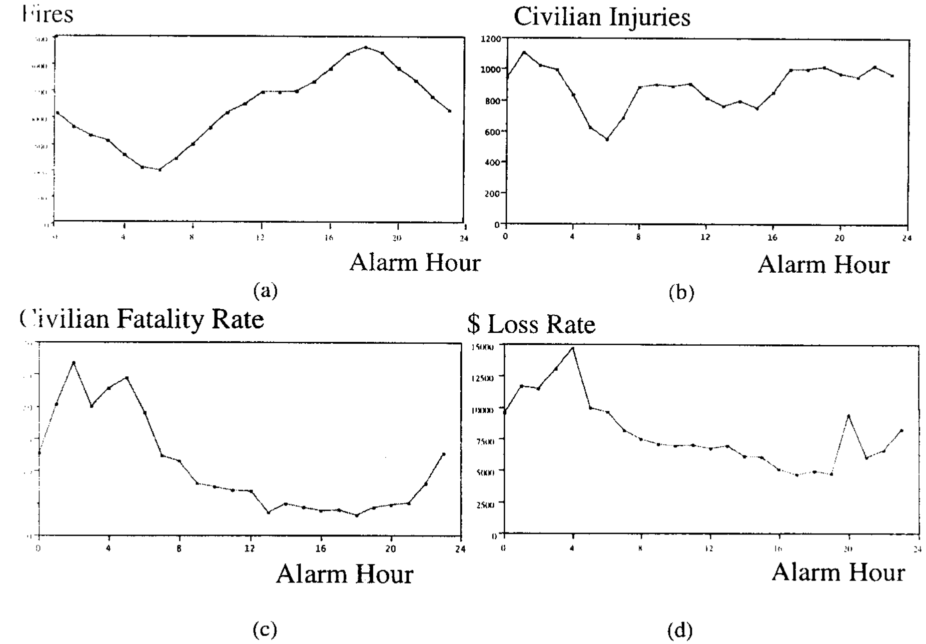

Figure 4 USA Fires in Apartment Buildings - Effect of Time of Alarm

Another aspect of the data is the variation with time of day (Figure 4). It can be seen in Figure 4 (a that the number of fires per hour varies greatly through the 24 hours, from a minimum at about 5 o 6 am to a maximum nearly three and a half times as great at about 6 pm. However the civili injuries per hour do not vary nearly as much and vary quite differently through the 24 hour perio (Figure 4 (b)). A similar effect can be seen in the civilian fatality **rate** (the number of civili fatalities per 1000 fires, Figure 4 (c)) with the fatality rate being about 25 fatalities per 1000 fir during the hours just after midnight and about five fatalities per 1000 fires for most of the dayli and early night-time hours. The estimated $ loss rate varies somewhat similarly but not to the sa degree (Figure 4 (c)).

Table 1 USA Fires in Apartment Buildings (Unsprinklered) - Effect of Area of Fire Origi

Area of Fire Origin	Fires	Civilian Fatalities (and Fatality Rate)
Lounge area	23590	771 (32.7)
Sleeping areas	42227	736 (17.4)
Kitchen, cooking area	111870	288 (2.6)
All others	138550	561 (4.1)

Notes: Rate per 1000 fires

An examination of the area of fire origin of these fires shows that the greatest number originate the kitchen but this does not mean that these fires are the most important if it is civilian fatalities the focus of our interest (Table 1). Reference to Table 4 reveals that far more fatalities occur fires that originate in the lounge and sleeping areas and the rate of fatalities that occur in fi originating in these areas are about 12 and 7 times as great respectively.

An examination of this data and similar data for fires in retail premises in the USA reveals that it recorded that detectors do **not** operate:

- in 50% of retail fires
- in 37% of apartment fires

(in both cases the fire is judged to mostly be too small, but both are lower at night)

and that sprinklers do **not** operate:

- in 70% of retail fires
- in 60% of apartment fires

(in both cases the fire is judged to mostly be too small, but both are lower at night)

So one question we should constantly ask ourselves is : How effective are fire safety systems?

- sprinkler systems
- smoke detector systems
- protected construction (fire resistance levels)

If we define **effectiveness** as a combination of two factors, efficacy and reliability then we can begin to obtain some interesting insights using the statistical data introduced above.

Defining **efficacy** as the degree to which a system achieves the specific objective under consideration given that it operates when required, it is obvious that the efficacy of a system can be different depending on the objective set. For example, if a fire safety system (such as sprinklers, smoke or heat detectors or fire resistant barriers) is intended to prevent fatalities it would be 100% efficacious if there were no fatalities, and 0% efficacious if the fatality rate was not reduced compared with otherwise situations in which sprinklers were not used. It is foreseeable that the efficacy with regard to another objective, for example avoidance of property damage might be quite different.

Defining **reliability** as the probability that the system operates when required, a fire safety system would be 100% reliable if it operated as required every time it was required (although such reliability is unlikely to be achieved in real applications) and 0% reliable (completely unreliable) if it never operated when required. Under this definition reliability is obviously unaffected by the objective and thus is the same regardless of the objective.

Thus **effectiveness** as a combination of efficacy and reliability depends on the objective under consideration, and therefore is not necessarily the same for each objective.

For example, using the USA apartment fire statistics it turns out that the civilian fatality rate (per 1000 fires) is:

- 9.4 without sprinklers, detectors or protected construction
- 2.6 with sprinklers only
- 8.7 with detectors only
- 7.4 with protected construction only
- 6.8 with detectors and protected construction
- 1.3 with sprinklers and detectors
- 2.3 with sprinklers and protected construction
- 2.8 with sprinklers, detectors and protected construction

Some of these figures should be used carefully as there are relatively few fires in some categories, but the overall trend is unmistakable - sprinklers appear to be much more **effective** in reducing the civilian fatality rate than detectors or protected construction.

A similar examination of the estimated $ loss rate reveals the following:

- $8450 without sprinklers, detectors or protected construction
- $3610 with sprinklers only
- $6810 with detectors only
- $5520 with protected construction only
- $2430 with detectors and protected construction
- $5160 with sprinklers and detectors
- $1850 with sprinklers and protected construction
- $2710 with sprinklers, detectors and protected construction

Thus, again it appears that sprinklers might be more effective than the other systems, but perhaps not to the same degree as for the civilian fatalities.

One more aspect of the data is revealing: in reported fires in apartments in the USA (from 1983 to 1993, except 1986) between 1 am and 4 am there were 25,497 reported fires of which 395 resulte in one or more fatalities (a total of 573 fatalities). Thus in 98.5% of these fires there were n fatalities. Surveys of fire engineers, regulators and others involved in fire engineering reveal th most people expect fatalities in a far greater proportion of fires, on average people expect fataliti in about 50% of fires - a gross over-estimate.

It is relevant to question why this occurs and how reliable are our perceptions of the degree of ri that fire in buildings represents. If our expectations do not accord with reality then we may app disproportionate measures to the problem, compared with other risks we face as individuals and societies. A thorough understanding of the risks we face due to fire and the effectiveness of th various means we can used to prevent or mitigate them is essential to good risk management.

Conclusion

Risk assessment is a small part of risk management, and it is risk management that is a usef means of addressing fire safety (and many other risks). However, risk assessment is an essenti part of risk management.

Risk management is a process that must be undertaken throughout the life of a building to ensu that risks are identified and managed not just when the building is built, but throughout its intend life. There is much data available that may be used to help in risk management, but greater a more effective use needs to be made of such data, and better data (more complete, more reliabl would be beneficial.

When risk management is undertaken, and the fire safety system in a building is viewed as a whol it becomes obvious that there is no point in great refinement in modelling or analysing one aspect fire safety when others lack refinement (this observation applies whether a risk approach is adopte or not).

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Fire Physics a Personal Overview

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Instead of an approach discussing fundamental phenomena, we discuss three applications:

1. Interpretation and Modeling of the (Australian) early fire hazard test
2. Heat fluxes, excess pyrolysate and flame heights from fully involved enclosure fires.
3. Radiation from turbulent fires.

These cases represent a wide application spectrum of an approach that pursues the development and use of key *flammability properties* (obtained from small-scale tests) in calculating fire growth and fire intensity in fires.

Key flammability properties can be obtained from calorimeter tests such as in the cone calorimeter and lateral flame spread measurements as in the LIFT apparatus. Flammability properties include thermal properties of unpyrolyzed material and char, ignition parameters and properties of the gaseous effluents after pyrolysis starts. Properties of the gaseous products include their composition, soot formation rates, toxicity and corrosion effects. We use these properties to predict the burning of a material in the Early Fire hazard test which may be considered as an intermediate scale test. [see for details references 1,2,3,4,5,6].

Interaction of fire development in enclosures with the inflow of fresh air from openings is discussed in the second application. The effects of room geometry (cubic like or corridor like) on the intake of fresh air is taken into account in predicting burning inside the enclosure when fully developed conditions are established. Because not all material is burning inside the room, excess pyrolysate and flame extension outside the room is also calculated. Dimensional arguments are employed to determine the relevant quantities using experimental data for determination of constant parameters and validation [7.8].

The last application illustrates how flame radiation in fires can be estimated using measured soot formation rates from materials based on the characterization of smoke point height for a given material. Soot is the main contributor of radiation heat fluxes in fires that are the main cause for the great hazard of fires in buildings, industry and forests.
Turbulence is modeled using k-e –g modeling with a simple soot formation kinetic equation. Results of calculation and experiments are presented for turbulent buoyant jet flames and pool fires. [9,10,11,12]