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Risk Ranking of Buildings for Life Safety

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Abstract

A risk assessment model has been developed in the form of a checksheet using a risk ranking system to assess the fire risk of buildings in terms of life safety. This involves a simple points system which assigns scores to various hazard and protection features of a building. These scores are then manipulated using addition and multiplication to arrive at an overall risk score for the building. The final value which represents the risk of the building is obtained using the definition of risk where risk is equal to the product of the likelihood of a fire occurring and its consequences. The proposed model which focuses on risk in terms of life safety can be extended to include property protection, environmental impact and social impact. It was found that the influences that human behaviour has on the fire risk within a building are significant and very difficult to quantify.

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1. Introduction

1.1 Objective

This project has been developed for the New Zealand Fire Service to assess the fire risks associated with a building. The purpose of this project has been to develop a system which identifies hazards within a building and the risks associated with those hazards. The end product is a checksheet which fire fighters can fill out while walking through a building. The checksheet attempts to convert the processes that a fire fighter uses when assessing a building for fire risk into a form that can be used by persons with less experience.

The end product of the checksheet will be a number representing the fire risk in terms of life safety of the particular building under assessment. When compared with other buildings that have been assessed using the same system a relative risk scale will be the result. The fire risk of a building will only be relative to other buildings that have been assessed. This will identify which buildings are of a high risk to life safety in a local district.

1.2 Uses for Model

1.2.1 Fire Service Resource Allocation

A risk assessment model which results in the quantification of the fire risk in a building can be of much use to the Fire Service. By assessing the fire risk of buildings in an area, a hazard map can be developed showing up all the high risk areas and concentrated problem areas. This can be achieved by taking the results of the model and laying them out in a map of the district. The different results could be displayed as different colours or as numbers, or on a computer database system.

Mapping the fire risk areas provides knowledge of where the high and low fire hazard areas are assuming that the model used gives reasonable results. This can ultimately lead to the improved allocation of fire fighting resources within the Fire Service on a local, regional or national scale. Also the results of the fire risk assessment model could be useful in reassessing the optimum number of fire stations in a district and their best locations so as to meet the level of hazard associated with a local area.

1.2.2 Fire Engineers

There is potential for this model to be used by fire engineers to identify which components of a building make it unsafe. The fire engineer can use the assessment to see which parts of the building cause the risk ranking to be low or high. This could be useful when needing to rapidly identify hazards in buildings. Fire engineers can also reassess a building after an upgrade of the fire safety. This would show how much less fire risk there was in terms of life safety.

1.2.3 Insurance Companies

Insurance companies assess premiums based on risks. This model could be used to enable insurance companies to assess the fire risks associated with a building. This model investigates the fire risks of a building in terms of only life safety. In the future it can be further developed to look at fire risks associated with property protection. At this further development stage this model would probably be more interest for insurance companies because property protection is the major concern for building insurance.

1.2.4 Building Inspectors

In the future this model could form part of a quality standard which buildings must comply to for fire safety approval. There is therefore a potential for building inspectors to be able to use this model to assess buildings to see that they meet certain quality standards.

2. Hazard and Risk

2.1 Definitions

In developing a system that can be used to assess the risks and hazards associated with a particular complex or building it is important to have an understanding of the terminology used. Defining the terms "risk" and "hazard" helps to keep the problem at hand in focus. It also emphasises the difficulty in quantifying risk and hazard. Once one has an understanding of what fire risk and fire hazard is, progress can be made toward developing a model which can assess the 'amount' of potential danger in a building.

Risk and hazard have a variety of definitions which all tend toward the same meaning. This project deals with fire risk and fire hazard definitions found in the Fire Service dictionary (Narayanan, 1996).

Risk is defined as the likelihood of occurrence that will have an impact upon objectives. It is the product of the consequences and likelihood.

RISK = frequency of event * consequence.

Hazard is defined as an object or physical situation with a potential for causing harm to life, health or property.

Fire risk is defined as the probability that a fire, which has impact on life, health or property, will occur.

Fire hazard is defined as fire that has the potential for causing harm to life health or property.

2.2 Hazard Versus Risk

It is necessary to have a clear view of the difference between hazard and risk.

A hazard is an object or situation with the potential to do harm. A hazard exists or it does not. Its existence is factual, not a matter of interpretation.

Risk on the other hand, is the probability that a particular hazard will cause harm. The magnitude of the risk is related to the harm done, ie., how many people are killed or injured, what environmental damage is done, what are the costs in terms of damage to plant, lost production time, the need to employ temporary staff, a reduction in workforce or public credibility, or legal proceedings and increased insurance premiums (Klein 1996).

There can be much confusion between risk and hazard. Many think that risk is the probability of an occurrence and that hazard is the consequence. This is incorrect. The risk is a combination of the probability of an occurrence and it's consequence. An event which has a low probability of occurring but has a significant consequence may have a similar risk as an event which happens frequently but with small consequences. Therefore to quantify risk, the probability of an event occurring must be combined with its consequences otherwise it will have no real meaning in terms of the size of the risk. The hazard however is a situation with the potential for causing harm with no consideration of how often the situation occurs.

As an example, an oil refinery would be classified as a high hazard premises due to the likely severity of a fire occurring therein but in reality would be a low risk, as historical data would show that risk management activities make it unlikely that a fire will actually occur (NSWFB).

It is difficult to talk about risk and hazard without knowing about the circumstances involved. So far the discussion on risk has just involved two components, probability and consequences. The magnitude of risk relates to these two components. However the perception of risk relates to its context. The consequences of a fire are different depending upon the context from which it is viewed. For example the consequences of a fire vary when viewed from the following contexts:

Life safety
Property protection
Environmental impact
Social impact

When assessing a building in terms of life safety, there is a great concern for the people in the building. What they are doing, how many of them are present, are they asleep or awake. These factors all make a difference to the risk which the occupants are susceptible to.

If assessing a building in terms of property protection, such factors as the building materials, how large the building is and what items are inside it become more important.

When considering the fire risk of a building in terms of environmental impact factors such as the potential smoke production into the atmosphere and the toxic water runoff from firefighting become important issues.

If assessing the fire risk of a building in terms of social impact there is concern for the role of the building in the community. There would need to be consideration as to whether the loss of that building or the items within it by fire would have an impact on society. If so the magnitude of the impact would need to be assessed.

The assessment of the fire risk in a building depends on the circumstances of a potential fire scenario and the context within which the risk is being assessed.

3. Review of Existing Models

The following risk assessment models that have been reviewed are all risk ranking models. A risk ranking model attempts to rank a building by assigning scores to particular features of the building and then manipulating those scores by some arithmetic function to give a final risk score for the building.

3.1 Gretner Method

M. Gretner of the Swiss Fire Prevention Service began to study the possibility of an arithmetical evaluation of fire risk in buildings in 1960. He developed a model which uses the explicit concept of risk as the expectation of loss given by the product of hazard probability and hazard severity(Watts 1995). It is based on the following simple formula.

$R = A \, x \, B$

Where
R = fire risk
A = probability that a fire will start, and
B = fire hazard, degree of danger, or severity.

The Gretner method is based on these two probabilities. The fire hazard is calculated as a ratio of the potential hazard to the protective measures rather than a sum.

$B = P/(N \, x \, S \, x \, F)$

Where
B = fire hazard
P = potential hazard

N = standard fire safety measures

S = special measures, and

F = fire resistance of the building

Potential hazard, P, is the product of hazard elements whose magnitudes are influenced on the one hand by the building contents, ie., materials and merchandise present, and on the other hand, by the building itself.

As with most other schedule approaches, the values for these individual factors are not based on statistics, but are empirical figures resulting from a comparison of analyses of fire risks for which fire protection measures are either common or required by law (Watts 1995).

This model requires values for five different factors, those being A, P, N, S and F as defined above. To obtain values for A, the probability that a fire will start and B, the fire hazard is quite a task when trying to deal with little or no statistical data. Trying to assign values to the standard fire safety measures and also special measures and also differentiate between the two is difficult. Also, quantifying the fire resistance of a building is difficult. Therefore the Gretner method is felt to be too complicated to apply to in this situation. There is a range of factors to be dealt with and it is felt that it would be very time consuming and difficult to deal with all the factors so that they would be suitable in a large variety of different buildings. For these reasons the Gretner method has not been used here.

3.2 Dow's Fire and Explosion Index

The Dow Fire and Explosion Index is a risk assessment model designed specifically for the Dow Chemical Company. This model "is a useful screening tool to quantify the expected damage from potential fire, explosion and reactivity incidents and to identify equipment that could likely contribute to the creation or escalation of an incident" (Watts, 1995).

It is very specific towards the chemical industry and there is much emphasis on explosions and reactions. "The key feature of the method is to identify the dominant combustible material in the unit being studied and assess its thermodynamic properties" (Watts, 1995).

The method then calculates hazard factors, material factors and then damage factors. The methods of calculating the risks of the identified hazards are representative of a risk ranking system. This model was found to be useful in that it uses a method of assigning values to various variables depending on their dominance within the building.

3.3 Australian Fire Service

Two models were reviewed from Australia. They were the New South Wales Fire Service Risk Mapping Classification System and also the Queensland Mapping System (NSWFB). Both models use a checksheet which a firefighter would fill out while assessing the building. They take into consideration the number of stories a building has, it's floor area and the construction materials of the building. Also, building age into consideration and whether or not it has fire protection systems in place.

Both models use the risk ranking technique of assigning a score to various categories of the building features.. The scores are then summed at the end to give a resultant risk value for the building. Appendix 1 shows copies of the Australian models reviewed.

There is no explanations available as to why the various categories are used, where the assigned values came from or what they are based on. Both the models have used subjective judgement to develop the numbers used but have not described the reasoning behind those choices.

In developing a model for life safety, one would need to consider the occupants in the building. Both these Australian models have briefly considered occupants. The only allowance for occupants in a building is an occupant hazard category. This allows the occupants to come under low, medium or high categories. The category is chosen from a list of building occupancies which list only the types of building, eg., laundries, leather goods factories, railway sheds, motels. There is no provision for the varying number of occupants or their age or capabilities.

It is felt that a model which gives a building a risk ranking in terms of life safety should take more features into consideration to try and develop a more accurate estimation of the risks involved. There is of course an unlimited list of building features which can be considered which would be impossible to cover with one risk assessment model. However the Australian models which have been reviewed do not consider the potential for a fire to start, its growth potential or the detailed characteristics of the building's occupants.

3.4 Rapid Fire Risk Assessment

Gillet, 1994 discusses a model called Rapid Fire Risk Assessment. This model has a different format to that previously mentioned. The user follows through a series of tables and selects the appropriate boxes and assigns the corresponding score which is given at the bottom of the table. At the end the scores are combined and the user ends up with two scores. One relates to the likelihood of fire and the other to the severity of the consequences. The likelihood of fire table is shown below in Table 3-1. The consequences table is shown below in Table 3-2.

SIMPLE FIRE RISK ASSESSMENT LIKELIHOOD

Factor	High	Normal	Low	Not Sure	Score
Fire Load					
Likelihood of Ignition Likelihood of Escalation					
Block likelihood total mark =					

Score High = 3
Normal = 2
Low = 1
Not sure = 2 on Ignition and Escalation
Not sure = 3 on Fire Load

Table 3-1 Simple Fire Risk Assessment Likelihood

SIMPLE FIRE RISK ASSESSMENT CONSEQUENCES

Factor	High	Normal	Low	Score
Harm to people				
Harm to environment				
Harm to buildings and equipment				
Harm to business				
Block likelihood total mark =				

Score High = 3
Normal = 2
Low = 1

Table 3-2 Simple Fire Risk Assessment Consequences

These two scores are looked up in a final table and a single final number is given. This number is between one and ten. The higher the number, the more severe the fire risk. This final table is shown as Table 3-3.

SEVERITY OF CONSEQUENCES

Very Severe	6	8	9	10	10
Severe	5	7	8	9	10
Moderate	3	5	7	8	9
Slight	2	4	5	7	8
Very Slight	1	2	3	5	6
	Very Low	Low	Normal	High	Very High

LIKELIHOOD

Table 3-3 "Rapid Fire Risk Assessment" consequences versus likelihood matrix.

This model was found very useful however and some of the concepts have been used in the development of the new model. For instance the method of combining the ignition sources and flammable materials has been used. This is very simplistic but effective in obtaining a rapid assessment of the fire risk of a building using little information and no statistical data. It works through the various features of a building and ranks them as high medium or low according to their relative influence on the safety of a building. This is simple but better than nothing at identifying hazards and their associated risks.

This model is said to be used effectively by some professionals and judged credible by peer review. However the methods used are not very precise. There is little consideration to the number and type of occupants, or what fuel loading is involved. There is no explanation of the methods used in developing the tables in the model or the justification of the scores assigned to them.

3.5 Summary

These models which have been reviewed have all been useful in the development of a new model. They all use the risk ranking technique as the best way of obtaining a quick fire risk assessment with the limited data that is available. The reviewed models have not been used for the purposes of this project for a variety of reasons. Either they are too specific in their intended purpose to be suitable or too brief in detail.

For these reasons a new model has been developed to meet the objectives of this project. Some of the methods from the models reviewed have been incorporated in this new model as they were found to be useful in terms of risk assessment of buildings.

4. Model Development

4.1 Risk Ranking Systems

The model being developed is a fire risk ranking system. Using professional judgement and past experience, fire risk ranking assigns values to selected variables representing both positive and negative fire safety features. The selected variables and assigned values are then operated on by some combination of arithmetic functions to arrive at a single value, which is then compared to other similar assessments or to a standard (Watts, 1995).

The model is arranged so that credits are assigned to each of the hazard features and charges assigned to the protection features. The user works through a checksheet and ticks the appropriate boxes. After the checksheet has been completed the positive credits and the negative charges are summed. This total which represents the magnitude of the hazards within the building is then multiplied by a number representing the probable fire severity. The probable fire severity is obtained by combining the likelihood of ignition with the fire growth rate of the materials present. There will be a resultant dimensionless number representing the fire risk in terms of life safety.

4.2 Life Safety versus Total Risk

As previously mentioned the risk associated with a building can vary widely depending on the perception of that risk, ie. the context in which it is viewed. The initial development of the model was to result in one number which gave the overall fire risk of the building being assessed. However it has since been discovered that it is very difficult to obtain an accurate number representing the risk in terms of life safety as well as in terms of property protection, environmental impact and social impact. These are very different issues and are affected by fire in different ways. For example if considering life safety when developing a model it would be important to consider the number of occupants, any disabilities they may have, and the growth rate of fuel. One would not need to consider whether the runoff from water applied to the fire went into a stream and destroyed wildlife, nor would one need to consider how much property was lost in terms of money value. If the risk was being assessed in terms of environmental impact however then the runoff hazard would be an issue of more importance. The property loss would be of high importance if concerned about property protection. It is very difficult to lump all these issues together and come up with one overall number which represents all of them.

For these reasons, the new model is focusing on identifying the positive and negative safety features of a building relating to life safety.

5. Factors Affecting Life Safety.

The model includes the some of the following variables. These are discussed with the intention of giving the reader an understanding of the importance they have on life safety and whether they are included in the model or not.

<u>Probability of Fire</u>

Ignition probability

-flammable substances present

-ignition source eg. smoking

Fire growth

Fuel load

<u>Hazards and Related Consequences</u>

Occupants

Number of occupants

Aged, immobile or young occupants

Sleeping people present

Human behaviour

Building

Number of stories

Quality of escape routes

Building age

Fire and smoke spread

Floor area

Hazardous substances

Management Practices

Housekeeping

Wedged open doors

Evacuation procedures

Evacuation drills

Staff training

Protection

Sprinklers

Smoke alarms

Heat detectors

Manual call points

Brigade connection

Management practices

5.1 Probability of Fire

Recalling the definition of risk from chapter 2, risk is the product of the probability of an event and its consequence. The factors presented in this section relating to fire make up the probability part of the risk model. When combined, these factors relate to the likelihood of a fire occurring. The sections following ie., Occupants, Building, Management Practices and Protection combine to form the hazards and their related consequences in the event of a fire.

5.1.1 Ignition

The likelihood of ignition relates to a combination of whether there is an ignition source and whether flammable materials are present. If there is an ignition source the likelihood of ignition also depends upon whether there is any controls in place or not. For instance a fireplace would be considered an ignition source. If there was a spark guard in place then any flammable materials have some protection against sparks which might cause ignition. The spark guard effectively reduces the likelihood of ignition.

Secondly the user must decide whether there are flammable materials present. If so are they near a potential ignition source. In the case of the fireplace, if the floor has a carpet covering then the likelihood of a spark igniting it is higher than if it were a bare wooden floor or a concrete floor. A stack of newspapers in front of the fireplace is even more hazardous.

In deciding whether something is an ignition source the user of the model must judge it appropriately. Appliances and electrical devices are designed to certain safety standards and when being used for their intended purpose would not be considered as a likely ignition source. They are however sometimes faulty and can start fires. Appliances should be considered as a controlled ignition source. However in the case where a potential ignition source such a heater is being used to dry clothes the likelihood of ignition becomes much higher and would be considered an uncontrolled ignition source.

Potential ignition sources in a building are often the results of human behaviour as in the last example. This is a difficult area to deal with. Objects in a building may have a low likelihood of ignition which is easily made high by the behaviour of one person. When assessing a building the user should try and deal with potential ignition sources as they are seen or as they are likely to be in the normal operation of the building. Human behaviour is discussed later.

It is impossible to specify all of the situations which cause a high likelihood of ignition. The user must ask themselves whether there are ignition sources present. Then the user must decide if there are adequate flammable materials near by so that the combination of the ignition source and the adjacent flammable materials constitutes a significant hazard. This can be done with the help of Table 5-1 which is taken from the Rapid Fire Risk Assessment model (Gillet, 1994).

Ignition Sources	Flammable Materials	Likelihood of Ignition
Rarely Present	Rarely Present	Low
Rarely Present	Controlled Flammables	Low
Rarely Present	Uncontrolled Flammables	Medium
Controlled Ignition Source	Rarely Present	Low
Controlled Ignition Source	Controlled Flammables	Medium
Controlled Ignition Source	Uncontrolled Flammables	High
Uncontrolled Source	Rarely Present	Medium
Uncontrolled Source	Controlled Flammables	High
Uncontrolled Source	Uncontrolled Flammables	High

Table 5-1 Likelihood of Ignition Classifications

The terms given in the table above are explained as follows.

Ignition Source Rarely Present.

This category is fairly self explanatory. If the building being assessed has no ignition sources when in normal use then this is the category to use. Almost all buildings have light fittings. For this model they are not considered as an ignition source. A bedroom containing a radio and an electric clock would come into this category.

Controlled Ignition Source.

This category applies to buildings containing ignition sources that are not likely to be a problem. This would include appliances, heaters, computers, fireplaces with a closing door.

Uncontrolled Ignition Source.

This category includes situations where there are open flames present such as lab Bunsen burners, open fire places, or flying sparks. Any other situation which the user deems as a likely ignition source would fall into this category.

Flammables Rarely Present.

An area with virtually nothing to burn would fall into this category. A workshop containing objects such as tools and non flammable equipment would apply to this category. The user must assess the objects within the building and decide whether they are likely to burn if ignited. If the answer is no then this category would apply.

Controlled Flammables.

This category covers situations where flammable materials are present but they are not likely to easily ignite. This would include wooden furniture, filing cabinets, books on a bookshelf. Under certain conditions these items would burn but the likelihood is not high.

Uncontrolled Flammables.

This category covers buildings containing flammables which are likely to easily ignite. This would include loose papers, polyurethane foam covered furniture, curtains etc. If there are flammable materials close to an ignition source in an uncontrolled manner then they would come into this category.

5.1.2 Fire Growth

The growth rate of combustibles is important to life safety. Fast growing fires will produce smoke at a greater rate than slow growing fires. It is the smoke which is initially produced that is most important to life safety. A slow growing fire will produce low amounts of smoke initially giving occupants more time to escape. The concentrations of smoke that occupants breathe in may be lower than in a fast growing fire, thus reducing the likelihood of injury or death.

The growth rate of the fire is split into four categories, slow, medium, fast and ultra fast. Based on the predominant fuels in the building and the way in which they are arranged the user will select the appropriate category. Table 5-2 gives the growth rate categories to be used.

Predominant Fuel	Fire Growth Rate
Little or no fuel. Items which will rarely ignite or develop into fire.	Slow
Objects which do not easily ignite but would burn given sufficient ignition. Items of metal or heavy wooden construction. Minimal plastics or foam. Tidy bookcases, filing cabinets.	Medium
Typical bedroom or office rooms. Loose papers, general furniture, curtains, light wooden items, polyurethane foam coverings.	Fast
High dominance of rapid burning objects. Items which produce high volumes of smoke rapidly. Storage of polyurethane covered furniture, plastics, foams, clothing.	Ultra Fast

Table 5-2 Fire Growth Rate Classifications

5.1.3 Fuel Load

Fuel load is not as important as the growth rate of the combustibles. Generally there will be enough combustibles to sustain a fire which could potential cause injury or death. Fuel load however is more of a concern to property protection. A building containing enough fuel to burn for days is significant to property loss. With life safety fire risk there only needs to be sufficient fuel to burn for a matter of minutes. For this hazard factor the user needs to ask, is there enough fuel present to sustain a fire that could compromise the lives of the people in the building. Usually the answer will be yes. In some cases it will be the opposite such as engineering workshops where there may be little or no fuel. If this is the case then it will be detected by the model in the sections allowing for likelihood of ignition and fire growth rate. Therefore there is no provision for the fuel load within a building in this model.

5.2 Occupants

5.2.1 Number of Occupants

It is far easier to evacuate a building when there are few people occupying it than if it contains a large number of people. Hence there is a lesser risk of injury or death to occupants due to lack of delays and queuing. Also a low number of occupants in a building means a relatively low number of people exposed to the hazards in that building. The risk associated with the number of people occupying a building is divided into four categories. It is designed so that the higher the number of people at risk, the greater the corresponding risk value. The categories are as given in Table 5-3.

Number of Occupants	**Occupant Category**
Up to 2	Low
3 to 5	Medium
6 to 20	High
Over 20	Extreme

Table 5-3 Occupant Number Classifications

The first category is a low number of people at risk. This is up to 2 people. Society seems to tolerate a fire which results in one or two people being injured or killed in a fire. Where multiple deaths occur there is more interest from society. The 6 deaths resulting from the New Empire Hotel fire on the 4th February 1995 caused great upset to society. In the above table, the high classification incorporates buildings where between 6 and 20 people are present. The moderate classification is where a building contains 3 to 5 occupants. This number of people at risk is still quite low but considered high enough that a category between low and high should exist. The extreme category of over 20 people is to take large groups of people into consideration. A fire resulting in the loss of more than 20 people is unlikely but would be considered a disaster by society.

The number of occupants in a building is to be taken as the number of people who would normally occupy the building or the firecell during its intended use.

5.2.2 Aged, Immobile or Young Occupants

Aged persons are generally less mobile than the average person. They also have a higher tendency to have hearing problems. These factors can contribute to problems in an emergency situation such as slower reactions to a fire and slower egress from the building. Research shows that fires in rest homes result in far greater deaths than any other building (Narayanan & Whiting, 1996). For this reason the model allows the user to note whether the building contains aged or immobile occupants. It is up to the user of the model to judge whether the age or the mobility condition of the occupants would cause delays in a fire situation which would increase the danger to the occupants. For example, rest homes and care institutions containing disabled people would be considered as buildings with increased risk to the occupants.

The high number of deaths in rest home fires indicates that the risk to the occupants is significantly higher in the case of aged people. The increased risk to disabled or immobile people is also considered to be significant as mentioned by Shields, 1995.

Buildings containing a high proportion of children is also considered to increase the risk. Very young children have difficulty perceiving that there is danger in a fire situation. When they do perceive danger they do not always react by trying to escape. Quite often children try to hide from the danger. Firefighters have been known to find children hiding behind furniture or hiding in closets. It is for these reasons that young children are considered a higher risk than adults. Buildings such as creches, kindergartens and other childcare institutions which have a high proportion of children are the types of situations being referred to here. Schools and places where children have had some fire evacuation training are not considered to be an increased risk. This is because the children would be more able to perceive danger and if they have been trained to evacuate in a fire situation then they would know how to react. The user must assess the situation and decide if there is a high proportion of children present and if so whether they would cause significant delays in an emergency evacuation.

A building containing a minority of aged or disabled people or children would not be considered to increase the danger to the occupants if there is a majority of able people present to assist. For instance, an office containing 10 people, 2 of which are aged, disabled, or children would not be considered a problem. As mentioned previously, it is up to the judgement of the user of the model to assess the potential danger.

Aged, disabled occupants and children are accounted for in this model in Table 5-4.

Aged, Disabled Occupants and Children	**Result**	
Are aged, disabled or immobile persons or children present such that they would cause significant delays in an emergency evacuation?	Yes	Bad
	No	Good

Table 5-4 Aged, Disabled Occupants and Children Classification

5.2.3 Sleeping Occupants

In a building where the occupants may be sleeping such as hotels, apartments, hospitals, rest homes etc., the response time is expected to be longer in an emergency situation. Where there is an automatic detection system present, sleeping occupants take longer to respond to the alarm signal than if they are awake. The alarm firstly has to wake them from their sleep. The time to do this varies depending on the "heaviness" of the occupants' sleep. Those under the influence of drugs or alcohol may not wake to the sound of a fire alarm. Secondly, once awake, the occupants take time to comprehend the alarm sound and realise that they have been woken by the alarm. They must then get out of bed and investigate the alarm before evacuating the building. All of this could take some time and will usually take significantly longer than if the occupants are awake at the time of the alarm.

If there is no automatic alarm system the occupants may not wake up during a fire until it is too late. Noise of roaring flames or windows breaking may wake occupants but this also means that the fire is well developed and the egress route may be overwhelmed by fire and smoke.

Whether occupants are sleeping or not can make a significant difference to the chances of them surviving in a fire. Early warning detection systems which sound an alarm also play an important role in the survival of sleeping occupants. Protection features of a building are discussed later.

Sleeping occupants are accounted for in this model in Table 5-5.

Sleeping Occupants		**Result**
Is this building intended for sleeping purposes or do the occupants of this building sleep here?	Yes	Bad
	No	Good

Table 5-5 Sleeping Occupants Classifications

5.2.4 Behaviour of Occupants

The behaviour of people can be the main cause of hazards in safe buildings. These behaviours are very difficult to quantify. There is an almost endless list of possibilities, for example:

- Locking of fire exits at night clubs.
- Drunk or drugged people cooking and leaving pots on the stove.
- Falling asleep while smoking.

- Using heaters too close to flammables
- Use of sparking equipment such as welders and grinders too close to flammables.

These human factors are often the cause of fatalities within relatively low hazard buildings. These sorts of things are extremely difficult to assess with this type of model. Therefore there will be no provision for human behaviour in the checksheet.

5.3 Building

5.3.1 Number of Stories

The number of stories a building makes a difference to the time needed for escape. It is obvious that a high rise building will involve more problems for occupants escaping that a single story building. A multi level building contains stairs which are used by occupants in an emergency. Even if the building had elevators, these are not to be used as a means of escape in the event of fire.

For this reason there is a hazard factor relating to the number of stories the building has. A single story building has no stairs and will be in a separate category to those buildings with stairs. For this model a single story building with a mezzanine floor will be considered as a two level building.

The hazard categories for the number of stories will be low, medium and high. They are divided as shown in Table 5-6.

Number of Levels	Hazard Category
Single Level	Low
2 to 4 Levels, includes mezzanine floors	Medium
5 or more Levels	High

Table 5-6 Number of Levels Classifications

The low hazard category is for buildings of only one level. Here there are no stairs to other levels. The medium category is for buildings of 2 to 4 levels. This grouping has been used as an intermediate category. A building of 2 to 4 levels is a multi level building but is not considered as a high rise. Anything 5 levels and above is considered as a high hazard for this model.

5.3.2 Exits

The quality of exits of a building relates to their location, distribution and ease of use. With the help of Table 5-7 the user will assess the quality of the exits in the building.

Exit Assessment		Exit Quality
Do the occupants have an alternative means of egress in a fire situation?	Yes	Good
	No	Bad
Are there long or confusing exitways such that occupants would have difficulty escaping?	Yes	Bad
	No	Good
Does the building have a sufficient number of exits for the size of the building and it's occupants?	Yes	Good
	No	Bad

Table 5-7 Exit Quality Assessment

The above table is designed to give the user flexibility when assessing the exits. The user is guided by the questions as to what to look for. The user must keep in mind the use of the building and the nature of the occupants. The main question being answered by using the above table is, "Are the exits adequate for the safe and efficient egress of occupants during an emergency?"

5.3.3 Building Age

This model attempts to take into account the factors which are hazards in a building. Often an old building will be more hazardous than a new one. This is because modern building codes require buildings to meet certain fire safety standards. Hazardous features of old buildings such as concealed spaces, open shafts, lack of fire stopping will be covered under the smoke and fire spread section. Therefore no provision will be made in this model for building age.

5.3.4 Fire and Smoke Spread

The construction of a building can have a great influence on how smoke and fire can spread throughout a building. This section enables the user to assess the concealed spaces, open shafts and penetrations within a building with regard to their potential influence on life safety. When completing this part of the model the user should keep in mind whether the risk to occupants' lives could be affected by the various features of the building. This can be achieved with the help of Table 5-8.

Smoke and Fire Spread Assessment		**Result**
Do concealed spaces exist such that fire or smoke spread could occur within the building in the event of a fire? If so, are they likely to significantly increase the risk to occupants' lives?	Yes	Bad
	No	Good
Do open shafts exist such that fire or smoke spread could occur within the building in the event of a fire? If so, are they likely to significantly increase the risk to occupants' lives?	Yes	Bad
	No	Good
Do holes or penetrations exist such that fire or smoke spread could occur within the building in the event of a fire? If so, are they likely to significantly increase the risk to occupants' lives?	Yes	Bad
	No	Good

Table 5-8 Smoke and Fire Spread Classifications

5.3.5 Floor Area

A building with a large floor area could be considered as more of a fire risk than one with a small floor area just because of the greater size. A large building could be considered more of a risk because it is probably likely to have more ignition sources than a smaller building of the same nature. Consider two office buildings. One twice the size of the other, both with similar contents and equipment. The larger office would probably have more computers, heaters and other potential ignition sources. For this reason it could be considered more of a fire risk. The larger office may also have more occupants. The occupant load of a building is covered previously.

There are however reasons why a large building may be less of a fire risk than a small building. If the two office buildings mentioned above both have the same number of occupants then the larger building would have its occupants less densely spread out than the small building. Therefore there would be less chance of queuing to get out the door, hence less risk of being injured. It could be argued however that being in a small building would mean that occupants would become aware of the fire earlier than those in a large building and therefore could escape quicker. Also, occupants in a large building are not necessarily spread out evenly. Company meetings, group activities and crowd gatherings can easily form uneven concentrations of people.

A large building would probably have more alternative exits than a small one therefore reducing the risk to life safety. On the other hand the distance one has to travel to escape may be much shorter for a smaller building therefore reducing the risk to life safety. These advantages and disadvantages of exits are covered earlier so will not play a part here.

When considering a fire in a building with a large open floor area, it can be argued that the upper layer of heat and toxic smoke would descend slowly compared to a building with a small floor area. This is due to the upper layer being allowed to spread over a large area before hitting the walls and descending toward the floor.

However the height of the ceiling and the size of the rooms within a building are more important in terms of the descending smoke than the floor area of the whole building.

There are both positive and negative features relating to the floor area of a building. They are difficult to quantify and compare. Such features of the differences in floor area are felt to have been covered reasonably in other sections mentioned previously. These features are such things as the quality of the exits, potential ignition sources, number of occupants. For these reasons there will not be a provision in the model allowing for the floor area of a building.

5.3.6 Hazardous Substances

Some substances which are present in buildings can increase the fire risk to life safety. Stored chemicals that may give off highly toxic fumes, paints, explosives and certain gases can cause increased injuries in a fire situation. Where these items are present they should be incorporated into the model. The user must decide whether any of the items in the building are hazardous substances.

Polyurethane and materials that have an ultra fast fire growth rate could be seen as being hazardous substances. These are covered in the section on fire growth rate so should not be considered as hazardous substances.

Allowance for hazardous substances is shown in Table 5-9.

Presence of Hazardous Substances		**Result**
Are hazardous substances present in the building which significantly increase the risk to life safety?	Yes	Bad
	No	Good

Table 5-9 Allowance for hazardous substances

5.4 Management Practices

5.4.1 Housekeeping

Housekeeping practices within a building can have an effect on the fire risk of a building in terms of life safety. For example the obstruction of exitways. If corridors and hallways contain stored equipment, boxes, furniture or other obstructions, these can be hazards in the event of an emergency. They may not seem like hazards in the everyday use of the building because they may be easy to avoid or walk around. However in an emergency there may be many people trying to egress the building through an exitway simultaneously and if it is cluttered with obstructions then delays are easily caused. These delays could be very critical if occupants are trying to evacuate a building which is on fire. For this reason the provision is made for the neatness of exitways as shown in Table 5-10.

Also, general housekeeping can be important in the workplace. For example, a wood turning workshop would be expected to have a lot of wood shavings on the floor. If the housekeeping was to sweep the shavings into a metal bin with a lid every day there would be less risk of a fire starting than if the shavings were just swept into a pile in the corner once a week. The point being made here is that the general neatness and tidiness of a building can have on effect on the likelihood of fire and also the magnitude of existing hazards. This type of housekeeping practice is difficult to incorporate into this model. Therefore there will be no provision made for the general neatness of a building.

5.4.2 Wedged Open Doors

It is well known by those in the fire safety community that door wedges can make a big difference to the safety of a building. For this study a wedge is defined to mean any device used to hold a door open. Smoke stop doors are designed to stop the flow of smoke to other parts of a building. If these doors are wedged open in the event of a fire they can be the cause of smoke movement throughout a building. This can lead to the unnecessary injury and death of occupants. An example of this is the New Empire Hotel Fire on the 4th February 1995. Smoke stop doors were wedged open at the time of the fire. This led to unnecessary smoke and fire spread throughout the top floors which caused multiple deaths.

It is difficult to account for wedged open doors in this model. Wedged open doors increase the risk to life safety of a building significantly. The model could take this into account but the purpose of this model should be remembered. The purpose of this model is to assess the fire risks of buildings in terms of life safety. A very safe building can instantly become unsafe by putting a wedge under the doors. This is a management practice causing the safety of a building to be reduced.

The objective of this model is to assess the fire risk of buildings in terms of life safety so the fire service can eventually allocate resources accordingly. Fire fighting resources should not be concentrated around buildings with poor management practices. It would be better to educate those using wedges possibly with the help of penalising those who do not comply.

However it is felt that the wedging open of doors is a management practice which is known to increase the risk of fire and smoke spread significantly. Therefore there is a provision for wedged open doors in this model. This provision is shown in Table 5-10.

5.4.3 Evacuation Procedures

This section is to allow for management practices which are in place which reduce the risk to life safety in a building. Provision is made here for an evacuation scheme existing in the building. An evacuation plan consisting of regular trial evacuations and training of occupants is considered to reduce the risk to life safety by giving them some preparation in emergency evacuation procedures.

Some buildings may have evacuation plans because they are required to in order to comply with fire safety regulations but may they not carry out regular trial evacuations. Regular trial evacuations are considered to be valuable to the safety of the building occupants. They train the occupants to recognise the fire alarm and the correct procedures involved in egressing the building. This would therefore familiarise the occupants with the exits and the checking procedures involved.

For the reasons outlined above the provision for evacuation procedures in this model is split up into two categories. The first one allows for whether or not a building has an evacuation procedure which has been approved by the fire service. The second allows for whether or not the occupants of the building participate in regular evacuation drills. These are shown in Table 5-10.

5.4.4 Staff Training

Staff training involves the training of staff in emergency procedures. This can involve training of building occupants to become floor wardens who check that all occupants are moving out of a building in an emergency evacuation. Also the training of the occupants of the procedures involved when a fire alarm is raised. If the building occupants are trained in how to act in the event of a fire alarm then there is less likelihood of panic or confusion. For this reason it is felt that the fire risk to occupants in terms of life safety is reduced by having staff training of emergency procedures. This is covered in Table 5-10 which takes staff training into account.

	Management Practices	
House Keeping	Are there obstacles or obstructions in corridors or exitways such that occupants could be significantly impeded or delayed during an emergency evacuation?	Yes No
Wedges	Have fire doors or smoke stop doors been held or wedged open such that fire or smoke could spread to other parts of the building?	Yes No
Evac Procedure	Is there an evacuation procedure in place which is approved by the Fire Service?	Yes No
Trial Evacs	Are trial evacuation procedures regularly updated and evacuation drills carried out on a regular basis?	Yes No
Training	Are staff or occupants of the building trained in emergency and evacuation procedures?	Yes No

Table 5-10 Allowance for Management Practices

5.5 Protection

5.5.1 Sprinkler Systems

Sprinkler systems are extremely effective at reducing the fire risk within a building. While they do not reduce the likelihood of a fire starting, they actively help to control a fire. Research shows that there have been very few injuries or deaths in sprinklered buildings compared with unsprinklered buildings. To date there has only been one death in a sprinklered building (Narayanan & Whiting, 1996).

Sprinklers both detect the fire in most cases and control the fire also. This prevents the fire from spreading and hence producing more lethal smoke. Therefore sprinklers have a great reducing effect on the fire risk to life safety within a building. In this model provision will be made for sprinklers being present in a building and will have a high reducing effect on the risk because they are considered the most effective protection feature.

Other automatic fire controlling systems such as foam or gas dispensing systems are to be considered as having a similar effect as sprinklers. This is because they serve the purpose of activating automatically in the event of a fire and attempt to control the fire. Other automatic systems which control the fire which are present are to be considered as sprinkler systems for this model as they reduce the fire risk to life safety significantly.

Allowance for sprinklers is shown in Table 5-11.

Presence of Sprinklers		**Result**
Are sprinklers or other automatic extinguishing devices present throughout the building?	Yes	Good
	No	Bad

Table 5-11 Allowance for Sprinklers

5.5.2 Smoke Alarms

Smoke alarms are effective in providing early detection of fire or smouldering. They are most effective in sleeping occupancies where occupants are alerted in the early stages of the fire rather than being woken by noise or smoke from the fire. The extra time provided by the early warning from smoke alarms can be critical in saving lives.

A study by J.R Hall (Hall, 1996) states that homes with smoke detectors have slightly more than half the risk that a death will occur if a fire occurs compared to homes without smoke detectors. "Or to put it another way, smoke detectors cut the risk of dying if a home fire occurs by 40-50%."

Out of the homes that have smoke detectors, 20% of them have smoke detectors which do not work due to batteries missing, dead batteries or disconnected batteries. (Hall 1996) So even if an occupancy has smoke detectors, they may not necessarily work. This is difficult to take into account in this model because a smoke detector may be functioning correctly at the time a building is assessed. The batteries may then be removed or may not be renewed at a later date causing the detector to become useless.

Smoke detectors that are hard wired, ie., powered by the mains power supply, are considered to have the same benefits as battery powered detectors. They are likely to be operational at all times unless there is a fire at the time of a power shortage. Smoke detectors which are hard wired will be incorporated into this model the same way as battery powered detectors.

There is less information available on buildings with smoke detectors in which the occupants are not sleeping in terms of the reduced risk. Smoke detectors in these buildings would give early warning of fire enabling the occupants to try and extinguish it or to escape. This early warning to the fire is still considered very important and valuable even in buildings where occupants do not sleep.

Buildings with smoke detectors present are considered as being at a significantly lower risk than those without for this model. They are not weighted as highly as sprinklers because they do not control the fire, however they are weighted higher than heat detectors because of the early warning provided. The issue of smoke detectors being present but not working due to batteries dead or missing is not taken into account in this model.

Allowance for smoke alarms is shown in Table 5-12.

Presence of Smoke Alarms		**Result**
Are smoke alarms present throughout the building which are in good working order?	Yes	Good
	No	Bad

Table 5-12 Allowance for Smoke Alarms

5.5.3 Heat Detectors

If only heat detectors are present, the fire is detected but not controlled as in the presence of sprinklers. The signature of the fire they detect is its heat. This usually means that the fire is significantly developing at the time of detection. In other words the warning signal is informing occupants that there is a smoke producing fire already established in the building which is continuing to grow. The time available for occupants to try to extinguish the fire or escape is often much lower than the time available in a building with smoke detectors. A building with smoke detectors however detects the smoke of a fire in the early stages of growth. This gives the occupants more time to extinguish the fire or escape.

For this model heat detectors are considered to reduce the fire risk of a building. This is because they detect the fire and warn occupants by way of audible alarm. This is especially important in sleeping occupancies. Heat detectors are not considered as effective as sprinklers or smoke detectors because they do not control the fire or give early warning to the occupants.

Allowance for heat detectors is shown in Table 5-13.

Presence of Heat Detectors		**Result**
Are heat detectors present throughout the building which are in good working order?	Yes	Good
	No	Bad

Table 5-13 Allowance for Heat Detectors

5.5.4 Manual Call Points

A building with manual call points as the only fire protection system is considered to be slightly less risk to life safety than a building with no fire protection at all. Manual call points allow occupants who discover a fire to raise the alarm by activating the call point. They do not however detect fire automatically. Therefore occupants who may be asleep or unaware of a fire in the building will not be alerted automatically.

Manual call points are considered to have some effect in reducing fire risk in terms of life safety. The weighting associated with them is less than sprinklers, smoke detectors and heat detectors. In the case of a building having a combination of manual call points and other detection systems, all will be taken into account and apply to the resultant risk value for the building.

Allowance for manual call points is shown in Table 5-14.

Presence of Manual Call Points		**Result**
Are manual call points present throughout the building which are in good working order?	Yes	Good
	No	Bad

Table 5-14 Allowance for Manual Call Points

5.5.5 Brigade Connection

Where a fire alarm system is connected to the Fire Service the fire risk to that building is considered to be reduced. The Fire Service can take between 5 and 20 minutes to arrive at the scene of a fire and in many cases the fatalities have occurred before they arrive. However there are also cases where building occupants are rescued by firefighters. This was the case at the New Empire Hotel Fire on the 4th February 1995. At this fire, occupants were rescued from balconies by firefighters. Had they not been rescued they may well have added to the fatalities which occurred on that night.

It is for these reasons that the presence of fire service connection reduces the risk associated with a building in this model.

Allowance for a brigade connection is shown in Table 5-15.

Presence of Fire Service Connection		Result
Does the building have a wired connection to the fire service?	Yes	Good
	No	Bad

Table 5-15 Allowance for Brigade Connection

6. Assignment of Scores

The tables in this chapter show the scores assigned to each of the factors which play a part in the model. These tables are all part of a final checksheet which is shown in the Appendix 1. The scores are combined using a combination of multiplication and addition in order to follow the definition of risk. The manipulation of the scores is shown in the next chapter.

The scores assigned to the various factors are based on subjective judgement. The reasoning behind the importance of each one in terms of life safety has been explained in the previous chapter. The scores assigned have not yet been tested or verified. This would be the next step in the development of the model, however time did not allow this.

6.1 Probability of Fire

6.1.1 Probable Fire Severity

The likelihood of ignition from Table 5-1 in the previous section is combined with the fire growth rate from Table 5-2 to give a probable fire severity. The combination is in the form of a matrix. This effectively multiplies the score for the ignition likelihood with the score for the fire growth rate. This multiplication is used because the two factors involved are dependent variables. This means that both must happen at the same time for a fire to occur. ie., If something ignites but the fire does not grow then there is little hazard. For example, paper in a rubbish bin may ignite but if there is no other fuel to burn or the fuel has a very slow fire growth rate then the hazard would be less than if there was rapid burning fuel present. A rapid burning fuel would produce large volumes of smoke at a rapid rate and therefore would be more of a hazard.

On the other hand if there is fuel which is fast burning but there is little likelihood of ignition then the likelihood of a severe fire is low. The combination of ignition likelihood and fire growth rate of fuel available to obtain a probable fire severity is shown in along with the assigned scores.

	Growth			
Ignition	Slow	Medium	Fast	U. Fast
Low	1	2	3	4
Medium	2	3	4	5
High	3	4	5	6

Table 6-1 Probable Fire Severity.

6.2 Occupants

6.2.1 Number of Occupants

The assigned values for the number of occupants are shown below in **Error! Reference source not found.**.

Number of Occupants	Occupant Category	Score
Up to 2	Low	4
3 to 5	Medium	6
6 to 20	High	8
Over 20	Extreme	10

Table 6-2 Number of Occupants Scores

The number of occupants in a building is to be taken as the number of people who would normally occupy the building or the firecell during its intended use.

6.2.2 Aged, Immobile or Young Occupants

Aged, immobile and young occupants are accounted for in this model in Table 6-3.

Aged, Disabled Occupants and Children	Result	Score
Are aged, disabled or immobile persons or children present such that they would cause significant delays in an emergency evacuation	Yes (bad)	4
	No (good)	0

Table 6-3 Aged, Disabled Occupants and Children Scores.

6.2.3 Sleeping Occupants

Sleeping occupants are accounted for in this model in Table 6-4.

Sleeping Occupants	Result	Score
Is this building intended for sleeping purposes or do the occupants of this building sleep here?	Yes (bad)	4
	No (good)	0

Table 6-4 Sleeping Occupants Scores.

6.3 Building

6.3.1 Number of Stories

The scores assigned to the various categories of the number of floors are shown in Table 6-5.

Number of Levels	Hazard Category	Score
Single Level	Low	0
2 to 4 Levels, includes mezzanine floors	Medium	3
5 or more Levels	High	5

Table 6-5 Number of Levels Classifications.

6.3.2 Exits

The quality of exits of a building relates to their location, distribution and ease of use. With the help of Table 6-6 the user will assess the quality of the exits in the building. The assigned scores are shown as follows

Exit Assessment		Quality	Score
Do the occupants have and alternative means of egress in a fire situation?	Yes	Good	0
	No	Bad	2

Are there long or confusing exitways such that occupants would have difficulty escaping?	Yes	Bad	2
	No	Good	0

Does the building have a sufficient number of exits for the size of the building and it's occupants?	Yes	Good	0
	No	Bad	2

Table 6-6 Exit Quality Assessment.

The main question being answered by using the above table is, "Are the exits adequate for the safe and efficient egress of occupants during an emergency?"

6.3.3 Fire and Smoke Spread

The scores assigned for the fire and smoke spread features of a building are shown in Table 6-7. When completing this part of the model the user should keep in mind whether the risk to occupants' lives could be affected by the various features of the building.

Smoke and Fire Spread Assessment		**Result**	**Score**
Do concealed spaces exist such that fire or smoke spread could occur within the building in the event of a fire? If so, are they likely to significantly increase the risk to occupants' lives?	Yes	Bad	2
	No	Good	0
Do open shafts exist such that fire or smoke spread could occur within the building in the event of a fire? If so, are they likely to significantly increase the risk to occupants' lives?	Yes	Bad	2
	No	Good	0
Do holes or penetrations exist such that fire or smoke spread could occur within the building in the event of a fire? If so, are they likely to significantly increase the risk to occupants' lives?	Yes	Bad	2
	No	Good	0

Table 6-7 Smoke and Fire Spread Classifications.

6.3.4 Hazardous Substances

The assigned score for the presence of hazardous substances that significantly increase the risk to life safety in the event of a fire is shown in Table 6-8.

Presence of Hazardous Substances		**Score**
Are hazardous substances present in the building which significantly increase the risk to life safety?	Yes	3
	No	0

Table 6-8 Allowance for Hazardous Substances.

6.4 Management Practices

The assigned scores for management practices are shown below in Table 6-9.

	Management Practices		Score
House Keeping	Are there obstacles or obstructions in corridors or exitways such that occupants could be significantly impeded or delayed during an emergency evacuation?	Yes	1
		No	0
Wedges	Have fire doors or smoke stop doors been held or wedged open such that fire or smoke could spread to other parts of the building?	Yes	4
		No	0
Evac Procedure	Is there an evacuation procedure in place which is approved by the Fire Service?	Yes	-2
		No	0
Trial Evacs	Are trial evacuation procedures regularly updated and evacuation drills carried out on a regular basis?	Yes	-1
		No	0
Training	Are staff or occupants of the building trained in emergency and evacuation procedures?	Yes	-1
		No	0

Table 6-9 Allowance for Management Practices.

6.5 Protection

6.5.1 Sprinkler Systems

The provision for the presence of sprinklers within the building and the assigned score is shown in Table 6-10.

Presence of Sprinklers		Score
Are sprinklers or other automatic extinguishing devices present throughout the building?	Yes	-6
	No	0

Table 6-10 Allowance for Sprinklers.

6.5.2 Smoke Alarms

The assigned score for the presence of smoke alarms in working order is shown in Table 6-11

Presence of Smoke Alarms		Score
Are smoke alarms present throughout the building which are in good working order?	Yes	-4
	No	0

Table 6-11 Allowance for Smoke Alarms.

6.5.3 Heat Detectors

The assigned score for the presence of heat detectors in working order is shown in Table 6-12

Presence of Heat Detectors		Score
Are heat detectors present throughout the building which are in good working order?	Yes	-2
	No	0

Table 6-12 Allowance for Heat Detectors.

6.5.4 Manual Call Points

The assigned score for the presence of manual call points in working order is shown in Table 6-13

Presence of Manual Call Points		Score
Are manual call points present throughout the building which are in good working order?	Yes	-2
	No	0

Table 6-13 Allowance for Manual Call Points.

6.5.5 Brigade Connection

The assigned score for the presence of a wired connection to the Fire Service which is connected to the fire alarm panel is shown in Table 6-14

Presence of Fire Service Connection		**Score**
Does the building have a wired connection to the fire service?	Yes	-2
	No	0

Table 6-14 Allowance for Fire Service Connection.

7. Manipulation of Scores

7.1 Explanation

This chapter shows how the scores which are obtained using the tables in the previous chapter are manipulated and combined to finally result in the risk value which represents the whole building. The number obtained for probable fire severity represents the likelihood of a severe fire occurring in the building. In the definition of risk,

ie., **Risk = probability x consequence,**

the **probability** component is represented here by the number obtained for the probable fire severity.

The probable fire severity comes from Table 7-1. This is the exact same table as shown in the previous chapter.

	Growth			
Ignition	Slow	Medium	Fast	U. Fast
Low	1	2	3	4
Medium	2	3	4	5
High	3	4	5	6

Table 7-1 Probable Fire Severity

The scores from the other tables which represent the **consequences** are combined using addition to obtain a number representing the overall **consequences** associated with a building as the result of a fire. Finally the two numbers, the **probability** value and the **consequence** value are multiplied together to result in a final number which represents the total fire **risk** of the building in terms of life safety.

For example, if the value for probable fire severity is 4 and the total value for the consequences associated with a building is 6, then 4 multiplied by 6 is 24. For this example building, the risk to life safety is 24. This number is a non dimensional number which, when compared with other building risk values gives the risk of the building relative to other buildings.

7.2 Hazards and Consequences

The scores associated with the hazards and consequences which are those relating to the occupants, the building, management practices and protection are all added to give a value representing the consequences of a fire in the building in terms of life safety. All the scores have been assigned to the various factors based on their relative influence on the risk to life safety. The following list of tables is part of the final checksheet. It is shown here to help explain the way the numbers are added for each of the building hazards.

Occupants

Number of Occupants

No. Occupants	Category	Score		
0 to 2	Low	4		
3 to 5	Medium	6		
6 to 20	High	8		
over 20	Extreme	10		
	Score Used			a

Aged, Immobile, Children

	Score		
Yes	4		
No	0		
Score Used			b

Sleeping Occupants

	Score		
Yes	4		
No	0		
Score Used			c

Building

No. Stories

No. Stories	Category	Score	
1	Low	0	
2 to 4	Medium	3	
over 5	High	5	
	Score Used		d

Exit Quality

Alternative Egress?

	Score	
Yes	0	
No	2	
Score Used		e

Confusing Exits?

	Score	
Yes	2	
No	0	
Score Used		f

Sufficient Exits?

	Score	
Yes	0	
No	2	
Score Used		g

Fire and Smoke Spread

Concealed Spaces?

	Score	
Yes	2	
No	0	
Score Used		h

Open Shafts?

	Score	
Yes	2	
No	0	
Score Used		i

Holes or Penetrations?

	Score	
Yes	2	
No	0	
Score Used		j

Hazardous Substances

Present?

	Score	
Yes	3	
No	0	
Score Used		k

Management Practices

Obstructions in Exitways?

	Score	
Yes	1	
No	0	
Score Used		l

Wedges Under Doors?

	Score	
Yes	4	
No	0	
Score Used		m

Evacuation Procedure?

	Score	
Yes	-2	
No	0	
Score Used		n

Trial Evacuations?

	Score	
Yes	-1	
No	0	
Score Used		o

Staff Training?

	Score	
Yes	-1	
No	0	
Score Used		p

Protection

Sprinklers?

	Score	
Yes	-6	
No	0	
Score Used		q

Smoke Alarms?

	Score	
Yes	-4	
No	0	
Score Used		r

Heat Detectors?

	Score	
Yes	-2	
No	0	
Score Used		s

Manual Call Points?

	Score	
Yes	-2	
No	0	
Score Used		t

Brigade Connection?

	Score	
Yes	-2	
No	0	
Score Used		u

Total **Consequence** Score = a + b + c + d + e + f + g + h + i + j + k + l + m + n + o + p + q + r + s + t + u = _____

This total consequence score is the sum of the factors which relate to the consequences.

7.3 Final Risk Score

The next step is to multiply the value obtained from Table 7-1 which is the probable fire severity by the total consequence score. This gives the risk score for the building.

Risk = Prob Fire Severity x Consequences

For example, if the score for the probable fire severity is 4 (from Table 7-1) and the total score for the consequences is 6 then the risk for the building is, 4 x 6 = 24.

7.4 Meaning of Result

The risk value obtained does not give an indication of whether the building is a high or low risk. This can only be determined by assessing other buildings and comparing the relative risk values for those buildings on a scale. Figure 7-1 shows a the idea of putting the assessed buildings on a relative scale in simple in a simplified fashion.

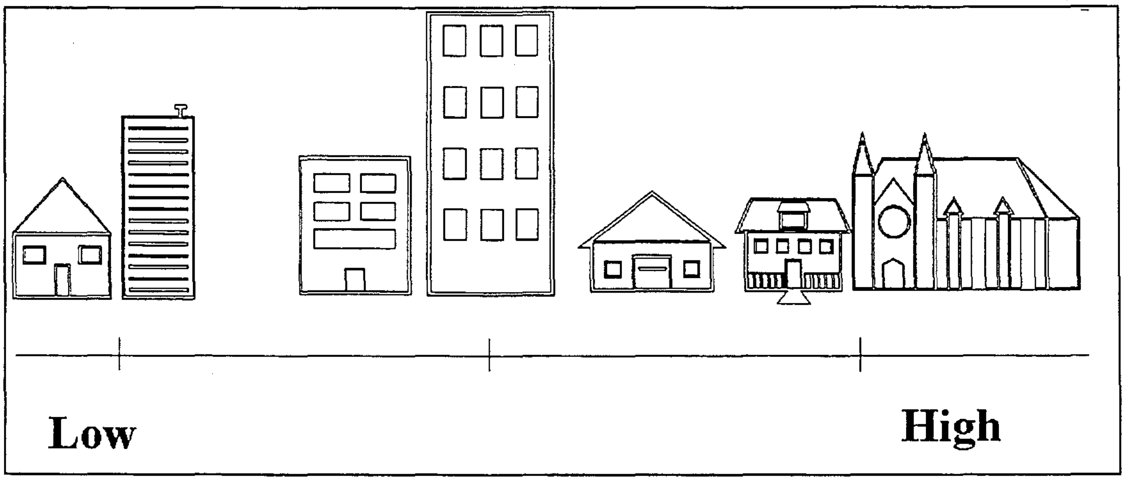

Figure 7-1 Schematic of Fire Risk Scale

The results for the risk of buildings is not necessarily linear. A building with a risk value of 20 is not necessarily twice as much of a risk as a building with a score of 10. The scores assigned to each of the hazards are based on subjective judgement and they are simply added to give a number representing the consequences component of the risk equation. It is impossible to combine such a variety of factors in a way such that the results can be compared linearly. The results are however useful in identifying which buildings stands out as the safest and those which are the highest risk.

8. Using the Model

8.1 Final Checksheet

The final checksheet can be seen in Appendix 1. This is the checksheet that can be taken into buildings and filled out while assessing the building. An example of the model being used to assess a building is also shown in Appendix 1.

8.2 Scope of Assessment

Some buildings may have rooms in them which are of a particularly high risk to life safety compared to other parts of the building. For instance a warehouse may have very little combustible material in the majority of the usable space, but the offices may contain furniture and papers which would rapidly endanger lives in the event of a fire. The assessment should be carried out in the part of the building which would obviously give a higher risk. If there is doubt then assessments should be carried out on those areas of uncertainty separately and the higher resulting risk value taken as the risk for that building.

Where a building is divided into firecells by fire resistant walls a separate assessment should be carried out for each firecell.

8.3 Information Handling

The handling of the results of each checksheet have not been dealt with in this project. One way of storing the results would be to have a database system on computer. This would store all the information on the checksheet and could be looked up at any time. Also extremely useful in this method of data handling is that if the values used in the model are changed at any time the database could be set up so that all the buildings that have been assessed already would be updated to the new values.

The results can be dealt with in a variety of ways by computer. One further step from the database system is the use of G.I.S (Geographic Information System). This is a database system with a special user interface. The location of an area can be shown on the computer screen as a map with the building sites marked. The user can click on a particular site and the information associated with that site shows up. The information could be the results of a risk assessment using this model. Various other data relating to that particular building can also be shown depending on how it is set up. This can be useful when incorporating risk assessments in terms of aspects other than life safety such as property protection, environmental impact and social impact.

9. Conclusions

- A risk assessment model has been developed in the form of a checksheet using a risk ranking system to assess the fire risk of buildings in terms of life safety.
- A simple points system has been used which assigns scores to various hazard and protection features of a building. These scores are then manipulated using addition and multiplication to arrive at an overall risk score for the building.
- The final value which represents the risk of the building is obtained using the definition of risk where risk is equal to the product of the likelihood of a fire occurring and its consequences.
- The proposed model which focuses on risk in terms of life safety can be extended to include property protection, environmental impact and social impact.
- It was found that the influences that human behaviour has on the fire risk within a building are significant and very difficult to quantify.

10. Future Research

10.1 Testing of Model

The next stage of the development of this model is to test it. This means that the model should be applied to a variety of buildings and the results analysed. In order to test the model it would have to be applied in situations such as the following.

1. Test the model on various buildings of the same nature and compare the results.
2. Test the model on various types of buildings and compare the results
3. Have various different people test the model on the same buildings and compare the results.
4. Compare the results of this model to the results using other existing models.
5. Compare the results of the model to statistics on fires in buildings.
6. Compare the results of the model to the assessment of the risk of buildings by personal judgement.

The results of testing the model would hopefully help to identify which areas need further development.

10.2 Other Aspects of Risk

There are many parts of this project that should be studied in further detail so as to improve the accuracy of assessing the fire risk in a building.

10.2.1 Property Protection

The fire risk of a building in terms of property protection could be assessed using similar techniques as those used in this model. There would be more emphasis on the building materials and the fuel load within the building. This aspect of risk assessment would be of interest to the insurance industry for the assessment of premiums based on the fire risk to property. It is an area which could be studied in detail as a future research project.

10.2.2 Environmental Impact

The potential environmental impact of a fire is a complex issue which cannot be covered as part of this project. The effects of toxic smoke on the immediate environment and the environment on a global scale is very difficult to quantify. Also the toxic runoff from water being applied to a fire into nearby streams, waterways or into the soil also has some impact which is also difficult to deal with. In future the threat to the environment as the result of a fire in a building should be studied and eventually incorporated in a risk assessment model.

10.2.3 Social Impact

The social impact of a fire in a building is also a complex issue and can vary greatly depending on a local society. The loss of a major building in a small community may have a greater impact on society than a similar building in a large city. This type of impact from a fire is difficult to quantify. Future research could involve looking at what features in and around a building reduce and enhance the fire risk when viewed in terms of social impact.

10.2.4 Other Areas

There are many other aspects of this model that could be further studied and their results incorporated into this risk assessment model in the future. These include the detailed effects of sleeping people on life safety versus those awake, the possibility of protection features failing, the effect of disabled and aged people on life safety and many more aspects. These future studies all have the potential to extend into sizeable projects and will all lead to the greater understanding of the risks faced when dealing with the effects of fire.

10.3 Verification of Scores

In future the variables assigned to the risk assessment model can be continuously revised and improved. This can be achieved using a panel of experts as previously mentioned, and using probabilistic methods. As more data becomes available in the future it will be possible to improve the accuracy of risk assessment even more.

10.3.1 Delphi Panel

One effective way of verifying the scores used in this model would be to use a Delphi panel. This would consist of a panel of people who are experts in fire safety and fire engineering. The panel of people would work through the model and the values assigned to the features of buildings. Firstly the individual members of the panel try to verify the scores using their reasoning and judgement along with the information given in this report. They then try and verify the scores used. The results of each individual are compared and discussion raised.

The panel then continues to verify the scores until a consensus is reached. The panel of experts try and agree on suitable numbers to be used in the model. This method is still a subjective judgement method but usually more accurate than the opinions and reasoning of just one person. The various members of the panel would all have different views on the issues incorporated in the model. These can be shared with the other members to try and cover all the issues relevant in verifying the numbers.

10.3.2 Fire Statistics

The subjectivity of the values used in this model could be further improved using fire statistics. There is a relatively small amount of data recorded on fire statistics in New Zealand compared with other countries. As more New Zealand data becomes available it can be incorporated into this model using probabilistic methods.

New Zealand and Australia are quite similar in the nature of their buildings. A possibility would be to use statistical fire data recorded in Australia to increase the database with which to work with to enhance the accuracy of the results obtained using this model.

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Appendix 1

Australian Risk Model Checksheets

New Risk Assessment Model Checksheet

Example

Australian Checksheet 1

CATEGORY 1 HAZARD LOGSHEET

STN NO:

NAME OF PROPERTY:

OCCUPANCY DETAILS:

STREET:

TOWN:

AUTO SUPPRESSION SYSTEM:
- MONITORED BY BRIGADE YES / NO

AUTO DETECTION SYSTEM
- MONITORED BY BRIGADE YES / NO

CONSTRUCTION:
FLOORS - TIMBER / MASONRY
WALLS - TIMBER / MASONRY

NO. OF ABOVE-GROUND LEVELS:

DIMENSIONS: metres X metres

FLOOR AREA:

AGE OF STRUCTURE:

OCCUPANCY RATING

Low Hazard	160
Mod. Hazard	320
High Hazard	450

SCORE

AGE OF STRUCTURE

<1945	300
1945 to 1974	200
>1975	120

SCORE

GROUND FLOOR AREA

0 to 500m sq	20
501 to 2000	60
> 2000	100

SCORE

NUMBER OF FLOORS

1 to 3	20
4 to 8	120
9 to 15	90
16 to 25	120
26 to 50	150

SCORE

SUB TOTAL

FIRE PROTECTION

Auto Det Sys .75 x SUB TOTAL	
Auto Spr Sys 1.25 x SUB TOTAL	

SCORE

WEIGHTING TOTAL

TOTAL

ADDITIONAL NOTES

THEREFORE THE SITE IS CLASSIFIED AS A CATEGORY HAZARD

Australian Checksheet 2

NO	BUILDING DETAILS		SPECIAL RISK SYMBOL	Stories	FLOORS			FLOOR AREA				SEPARATION BUILDING ON				CONSTRUCTION					OCCUPANCY				POTENTIAL RISK			
	NAME	ADDRESS		ABV / BLW	1-3	4-6	7+	400 3700	3701 9300	9301 18600	18600 +	1	2	3	4	NON COMB	NON OS	TRAD	TIMB	OPEN	TYPE	L	M	H	TOTAL SCORE	A	B	C
1	POST OFFICE	80 EAST ST.,		2	2			2						6				3					3		14		✓	
2	TELECOM EXCHANGE	12 DENHAM ST.,		3	2				5					6		1							3		12		✓	
3	KITTY MAYS	78 EAST ST.,		1	2			Ø						6			2						3		13		✓	
4	COMMONWEALTH BANK	74 EAST ST.,		2	2			2					4				2						3		11		✓	
5	DISTRICT COURTS	72 EAST ST.,		1	2			2					4			1							3		10			✓
	BUILDING SCORES				2	4	6	2	5	7 Discount Lowest Score	9	2	4	6	8	1	2	3	5	5		1	3	5		A	B	C
6	MAGISTRATES COURTS	66-68 EAST ST.,		1	2			2				Ø				1							3		8			✓
7	POLICE OFFICES	161 BOLSOVER ST.,		2	2			2				2					2						3		9			✓
8	QPS CELL BLOCK	159 BOLSOVER ST.,		1	2			2					4			1								5	12		✓	
9	STORE	155 BOLSOVER ST.,		1	2			2					4					3	5			1			10			✓
	BUILDING SCORES				2	4	6	2	5	7 Discount Lowest Score	9	2	4	6	8	1	2	3	5	5		1	3	5		A	B	C
10	PUBLIC TOILET	BOLSOVER ST.,		1	2			Ø						6			2					1			11		✓	
11	STORAGE SHED	BOLSOVER ST.,		1	2			0						6			2					1			11		✓	
12	COMMUNITY CORRECTIONS SERVICE	153 BOLSOVER ST.,		1	2			Ø						0		1							3		6			✓
13	SUPREME COURTS	70 EAST ST.,		2	2			2					4					3					3		12		✓	
14	OLD GOVT BUILDING	149 BOLSOVER ST.,		4		4		2						Ø			2						3		11		✓	
	BUILDING SCORES				2	4	6	2	5	7 Discount Lowest Score	9	2	4	6	8	1	2	3	5	5		1	3	5		A	B	C

Building Fire Risk Assessment Checksheet

Admin Details

Date ______________________________ Risk Score__________

Fire Station ______________________________

Building Name ______________________________

Address ______________________________

Fire Severity, Y

	Growth			
Ignition	Low	Medium	Fast	U. Fast
Low	1	2	3	4
Medium	2	3	4	5
High	3	4	5	6
			Score Used	

Occupants

Number of Occupants

No. Occupants	Category	Score	
0 to 2	Low	4	
3 to 5	Medium	6	
6 to 20	High	8	
over 20	Extreme	10	
	Score Used		a

Aged, Immobile, Children

	Score	
Yes	4	
No	0	
Score Used		b

Sleeping Occupants

	Score	
Yes	4	
No	0	
Score Used		c

Building

No. Stories

No. Stories	Category	Score	
1	Low	0	
2 to 4	Medium	3	
over 5	High	5	
	Score Used		d

Exit Quality

Alternative Egress?

	Score	
Yes	0	
No	2	
Score Used		e

Confusing Exits?

	Score	
Yes	2	
No	0	
Score Used		f

Sufficient Exits?

	Score	
Yes	0	
No	2	
Score Used		g

<u>Fire and Smoke Spread</u>

Concealed Spaces?

	Score	
Yes	2	
No	0	
Score Used		h

Open Shafts?

	Score	
Yes	2	
No	0	
Score Used		i

Holes or Penetrations?

	Score	
Yes	2	
No	0	
Score Used		j

<u>Hazardous Substances</u>

Present?

	Score	
Yes	3	
No	0	
Score Used		k

<u>Management Practices</u>

Obstructions in Exitways?

	Score	
Yes	1	
No	0	
Score Used		l

Wedges Under Doors?

	Score	
Yes	4	
No	0	
Score Used		m

Evacuation Procedure?

	Score	
Yes	-2	
No	0	
Score Used		n

Trial Evacuations?

	Score	
Yes	-1	
No	0	
Score	Used		o

Staff Training?

	Score	
Yes	-1	
No	0	
Score	Used		p

Protection

Sprinklers?

	Score	
Yes	-6	
No	0	
Score	Used		q

Smoke Alarms?

	Score	
Yes	-4	
No	0	
Score	Used		r

Heat Detectors?

	Score	
Yes	-2	
No	0	
Score	Used		s

Manual Call Points?

	Score	
Yes	-2	
No	0	
Score	Used		t

Brigade Connection?

	Score	
Yes	-2	
No	0	
Score	Used		u

Probable Fire Severity, **Y** = ______

Total Consequence Score, **Z** = a + b + c + d + e + f + g + h + i + j + k + l + m + n + o + p + q + r + s + t + u = ______

Risk, X = Y x Z = x =

Example

An example of the application of the model is presented here to illustrate its use. Consider a building which is a 3 storey office block.

There are heaters and computers in the offices and loose papers, foam stuffed furniture, curtains etc also.

The building contains 40 people, none of which sleep in the offices.

There are no aged or disabled occupants and no children.

The exits are of good quality however there are boxes and other office equipment stacked in some of the exitways.

There are no concealed spaces, holes or penetrations or shafts which smoke would be likely to travel through.

There are no hazardous substances stored.

There is an evacuation plan in place but almost all of the staff have no idea it exists, nor have they had any training in evacuation of that building.

The protection system consists of sprinklers, manual call points and a brigade connection.

There are no wedges under the smoke stop doors.

The checksheet and risk for this example building is shown as follows.

Building Fire Risk Assessment Checksheet - Example

Admin Details

Date 25/2/97 Risk Score 16

Fire Station Sockburn

Building Name Bareback & Co Ltd

Address Christchurch, NZ

Fire Severity, Y

	Growth			
Ignition	Low	Medium	Fast	U. Fast
Low	1	2	3	4
Medium	2	3	4	5
High	3	4	5	6
			Score Used	4

medium ignition, fast growth

Occupants

Number of Occupants

No. Occupants	**Category**	**Score**		
0 to 2	Low	4		
3 to 5	Medium	6		
6 to 20	High	8		
over 20	Extreme	10		
	Score Used		10	a

Aged, Immobile, Children

	Score		
Yes	4		
No	0		
Score Used		0	b

Sleeping Occupants

	Score		
Yes	4		
No	0		
Score Used		0	c

Building

No. Stories

No. Stories	**Category**	**Score**		
1	Low	0		
2 to 4	Medium	3		
over 5	High	5		
	Score Used		3	d

Exit Quality

Alternative Egress?

	Score		
Yes	0		
No	2		
Score Used		0	e

Confusing Exits?

	Score		
Yes	2		
No	0		
Score	Used	0	f

Sufficient Exits?

	Score		
Yes	0		
No	2		
Score	Used	0	g

Fire and Smoke Spread

Concealed Spaces?

	Score		
Yes	2		
No	0		
Score	Used	0	h

Open Shafts?

	Score		
Yes	2		
No	0		
Score	Used	0	i

Holes or Penetrations?

	Score		
Yes	2		
No	0		
Score	Used	0	j

Hazardous Substances

Present?

	Score		
Yes	3		
No	0		
Score	Used	0	k

Management Practices

Obstructions in Exitways?

	Score		
Yes	1		
No	0		
Score	Used	1	l

Wedges Under Doors?

	Score		
Yes	4		
No	0		
Score	Used	0	m

Evacuation Procedure?

	Score		
Yes	-2		
No	0		
Score	Used	0	n

Trial Evacuations?

	Score		
Yes	-1		
No	0		
Score	Used	0	o

Staff Training?

	Score		
Yes	-1		
No	0		
Score	Used	0	p

Protection

Sprinklers?

	Score		
Yes	-6		
No	0		
Score	Used	-6	q

Smoke Alarms?

	Score		
Yes	-4		
No	0		
Score	Used	0	r

Heat Detectors?

	Score		
Yes	-2		
No	0		
Score	Used	0	s

Manual Call Points?

	Score		
Yes	-2		
No	0		
Score	Used	-2	t

Brigade Connection?

	Score		
Yes	-2		
No	0		
Score	Used	-2	u

Probable Fire Severity, **Y** = 4

Total Consequence Score, **Z** = a + b + c + d + e + f + g + h + i + j + k + l + m + n + o + p + q + r + s + t + u = 4

Risk, X = Y x Z = 4 x 4 = 16

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