Statistical Data for Fires in Hong Kong and Preliminary Views on Building Fire Risk Analysis

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Abstract

Various standards and regulations are used in building fire safety design and management for life safety and property protection. These regulations, standards are stated in the code of practice, building codes, guideline enforced by various professional bodies and government authorities.

Most of these regulations and standards on fire safety were derived from past experiences on building design and fire fighting, some kinds of scientific analysis, engineering judgment and in some cases, input from manufacturers of building materials, components and even testing authorities. Though such regulations can provide a certain guideline for fire safety design and fire safety management in traditional buildings, but might not be applicable to new architectural features. These regulations might even provide wrong information to the occupants inside the protected building. Therefore, fire engineering approach is proposed for future fire safety design. There, building fire risk analysis becomes an important tool in providing fire safety. Moreover, it can also provide information of the potential risk to the occupants.

There are two objectives in this paper. The first is to review the available statistical data related to fire in Hong Kong. The data for fire accidents and number of false alarms recorded in the past few years are analyzed. The second objective is to express the preliminary views on building fire risk analysis for Hong Kong, in views of the statistical analysis. This came from a brief review exercise on the different risk analysis techniques available in the literature.

Introduction

Building fire risk analysis can be considered as a procedure to identify potential fire hazard in building and quantify the magnitude of possible loss due to building fire. The use of fire risk analysis to assess fire safety building design and management is particularly important in a highly populated city, such as Hong Kong. Hong Kong is situated at the north-west coast of South China Sea. Of its slightly more than 1000 square kilometer area, most of the territory is covered by hills making its 6.7 million population crowded in a small fraction of plain coastal urban areas. Fire hazards is the most common natural disaster and most of the accidents are due to negligence, ignorance or other willful reasons. Since most of the people live in high rise buildings. Once a fire occurred in these buildings, the losses created whatever in property destruction and human life would be very large.

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Fire Statistics in Hong Kong

The data released from Hong Kong annual report and review of Hong Kong Fire Service Department ranging from 1967 to 1995 [1-3] shows that the number of fire calls in the period of 1967 to 1995 follows an increasing trend from 3831 in 1969 to 31014 in 1995. The trend is shown in Figure 1.

Figure 2 shows the fatalities range from 20 to a maximum of about 50 each year and the modal range fell in the range of 30 to 50 per year which means that there was about 1 to 4 deaths in fire incident average in each month during this period.

Figure 3 shows that there was about 400 to 800 injuries during 1967 to 1995, the minimum value is 271, the maximum value is 853, and the modal frequency fell in region 600 to 700.

Causes of Fire

The classification of different fire causes is shown in figure 4. Three major causes of fire incident are careless handling or disposal of cigarette ends, matches, candles, etc.,electric fault general and overcooking of food stuff. Another interest thing is that there is a considerable number of fire calls are false alarms and unwanted alarms constitutes about 40% to 53% from 1986 to 1992.

Figure 5 shows the classification of fire occurred by floor level over the years from 1985 to 1992. The figure shows that most of the fire incidents happened at the 1st to 5th floor and least happened at levels above 25th floors.

A more detailed study of major fire incidents is chosen between the period 1981 to upper half year of 1997 in Hong Kong. A total of 47 major incidents reported during this period, accounting for 118 fatalities and 345 injuries. Of which, 50 fatalities were occurred as a result of arson attack, the most serious fire took away 40 lives in a commercial building.

Worst cases

The worst five fatal incidents in recent years are briefly described below, in which causes, outcome and damage is illustrated in chronological order.

1. Residential estate , 7 fatalities (1997); caused by a careless smoker disposed cigarette end in an illegal store room changed its usage from residential apartment, fire door kept open and smoke spread to other floors throughout stairwell. 7 dead and 38 injured.

2. Karaoke box, 15 fatalities (1997); the karaoke box was divided into many rooms (61 partitions); the suspects threw molotov cocktail, thinner and flammable liquid at the ground floor staircase. Fire rapidly travelled to second and third floor through vent ducts. Victims drank too much before the blast decreased their alertness. 15 dead and 15 injured.

3. Galey building, 40 fatalities (1996); the fire was believed to have been started by welding work while building's lift being replaced; quickly filled with smoke and flame soon engulfed the top three floors. 40 dead and 81 injured.

4. Hongkong Bank, 13 fatalities (1991); the offender lit up thinner splashed on floor and bank staff trapped and killed in choking inferno; the staff wrongly assess the threat and unreasonably hide under the office area. Ventilation had no auto-shut down function, no detector, no emergency lighting, no sprinkler system in the bank. Electricity had been cut off so that electric locked doors could not be opened.

5. Bed space apartment, 7 fatalities (1990). Staircases on both ends of the floor were closed; the roof exit door was locked so the hot air and dense smoke could not dissipate. The fire intensified because of combustible bedding, wooden partition between cubicles. Hot smoke further ignited discarded items, flame spread to adjoining bed-space apartment. Firemen's snorkel cage toppled in carrying double load recommended by regulation. 7 dead and 49 injured.

Besides risk to life, financial losses caused by fire cannot be under-estimated, the followings are major events occurred in recent years :

1. Kwai Chung, factory building (1995); a textile factory on sixth floor and 11th floor for storing leather and PVC goods caught fire.

2. Clear Water Bay, film studio (July, 94); props and costumes, and carpentry workshop caught fire. Hugh amount of wooden and Styrofoam fittings, penal and furniture, and polystyrene were kept in it. Tin sheet structure teared and a Chinese style roof collapsed. Losses was estimated at about 10 million dollars.

3. Aberdeen, factory building (Sept., 84); stack full of products, the factory gate was locked because fire occurred before holiday. Damage to 7th, 8th and 9th floor worth 4.8 million dollars, including machinery, finished, unfinished products and furniture.

Fire Risk Assessment

The statistics and the data revealed above from the two sources only serve for a survey on fire occurrence in the past two decades which is not sufficient for a serious analytic study on fire risk. Over the past years various risk assessment methods have been developed.[4]. A brief summary is presented in the flowchart appeared in Figure 6.

It is observed from Figure 6 that there are four main parts in a fire risk analysis procedure :

1. Statistical methods--usually aim at calculating fire cost by regression on past data.

The main purpose of regression is try to find out a linear relationship between input data and output data by estimation of parameters or weighting factors associated with input data. The main disadvantage is that data is not usually available or suitable for analysis. Regression methods only give a functional relation between input and output variables but cannot explain their causal relation.

2. Tradition methods-- these methods include the following activities:

- *hazard identification:* identifying risk agent and the condition under which they potentially produce adverse consequences to life and environment.
- *identifying accident sequence*: describing and quantifying risk.
- *risk evaluation:* comparing and judging the significance of risks.

3. Fire risk ranking -- by assigning cardinal values to different items on a checklist according to the severity or seriousness of the potential hazards of a plant or a factory, then make a decision to alleviate the potential hazards after manipulation of these cardinal values.

There are so many variations in different ranking systems, typical examples are as follows:

- Gretener method
- Dow's Fire and Explosion Index

4. Simulation--to be discussed in the next section.

Simulation :

In order to carry out a meaningful analysis on this topic, it is convenient to develop a mathematical model. Put in a simple way, mathematical model is a representation or an imitation of the real world objects. The logical inter-relationships and phenomena happen in the real world can be deduced. In scientific research, models are classified into experimental and theoretical models. Wind tunnel for obtaining aerodynamic properties of an aircraft under test is one example of experimental model. A theoretical model is a notion or mathematical formulation of the physical objects which can be classified as analytical model or numerical model. Analytical model seeks to find an exact solution to a particular problem while a numerical model aims at finding a reasonable solution confined to an acceptable tolerance in terms of computing time and accuracy of the result. In fire risk analysis, there are lots of combinations of different factors occur in one scenario such as fire location, fire regime, characteristics and number of occupants, and so forth, so we can only tackle this kind of problems by simulation. Simulation is a practice following a technique or a set of techniques for examining the dynamic behaviour of models. [5,9] In the field of fire engineering, BFIRES is a typical simulation model.

Originally, BFIRES[10] is designed to simulate processes as rescuing non-ambulatory persons in health care facilities as well as emergency responses exit seeking, threat evasion, etc. This program can simulate a wide variety of emergency scenarios and behave in an individual momentary response to the state of environment at a discrete time, t in different time frames t_i i=1,2,...n. people have different locations in space, smoke spread to new locations, the simulated occupants after acquiring these information evaluate alternative responses and selects an action as the response for time t_i

BFIRES finds that familiarity is a necessary component of rapid and direct evacuation during simulated fires, shorter and more direct circulation paths reduce ambiguity and increase the likelihood of safe emergency escape, width of channel affect the walking speed of occupant, the wider the channel, the faster the speed the occupant can evacuate.

The goal of the simulation technique is to develop a deeper understanding of human behavior during fire situation and to develop a standardized technique for analyzing alternative building designs from emergence egress view point.

Simulation and the Monte Carlo Method

Simulation deals with both physical and abstract models. Simulations sometimes might involve participation of real people. It may be impossible or extremely expensive, or morally prohibited to carry out a certain testing to obtain data, human behaviour in a fire apartment is just one example, other processes might be the training of a flight pilot or trying to investigate the affection of the economy after tax rate has been raised.

Secondly, an investigating system cannot be sufficiently described by a set of equations for which analytical solutions are obtainable.

Thirdly, even a set of equation can be formulated to a certain system of interest. The data or input information or the dynamic behaviour might exhibit uncertainty conditions to some extend. Present mathematics are simply unable to handle problems of this nature.

Simulation is a kind of sampling experiment on the model of a system. In a narrow sense, it includes sampling stochastic variates from probability distributions. It is because sampling from a probability distribution involves the use of random number, stochastic simulation usually called Monte Carlo simulation. Random number is actually a set of independent random variables uniformly distributed over range [0,1] and is generated with a computer algorithm called random number generator.

Monte Carlo method is not a commonly used tool to study complex problems. So, we may employ this method to study our fire risk assessment model.

Fire Risk Assessment Model :

The two parameters concerned in Fire Risk Assessment are the 'expected risk to life' and the 'fire cost expectation'. As the model is too complex, it has to be separated into aggregate sub-models.

The sub-models that would exist in a fire risk assessment model include [e.g. 7] :

- Design fire model—in which regime when the fire start, is it a smothering fire or flashover fire;

- Fire growth model—the rate of fire growth;
- smoke movement model—as the fire plume develops, a lot of toxic fumes evolved and spread in the fire apartment;
- Smoke hazard model—how many fatalities occurred if the occupant is trapped inside by the smoke ;
- Flashover fire model—the time when there is a full room involvement in fire;
- Boundary element model—the time when fire resistance failure in boundary elements;
- Property loss model—the total property loss;
- Fire detection model—if the apartment equipped with smoke or heat detector, we want to find out the duration that the heat or smoke activate the detectors;
- Occupant warning and response model—once the heat or smoke detector was activated or other cue(s) that alerted the occupants, what is then their behavior;
- Evacuation duration model—the time that the occupant required to find their way to escape [6,7].

A block diagram of the Fire Risk Assessment model is shown in Figure 6 [e.g. 7]. The whole model is an interaction of other sub-models. For example, the fire severity may directly affect the occupant's behaviour inside the apartment.

Conclusions

In this paper, the seriousness of fire incidents in Hong Kong and the number of fire alarms will be reviewed. The merits and demerits of various methods to carry out in fire risk analysis, from traditional ranking methods to complex computer simulation will be studied. Then the effect of false fire alarm to the awareness of the occupants should be focused on. Suggestion is made on developing an algorithm as part of the fire risk analysis model. This will be reported in sequent papers.

A mathematical model to carry out a Fire Risk Analysis by a stochastic approach by combining the heuristic knowledge ever found in fire research can help us to set up a simulation model.

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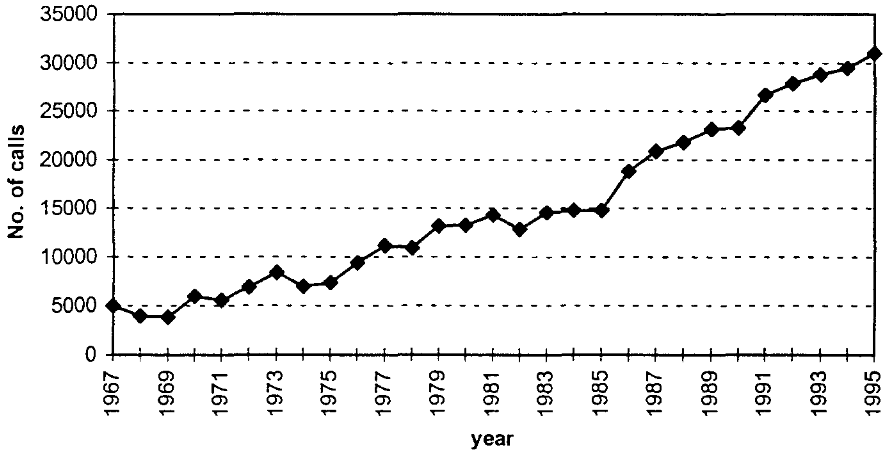

Figure 1 No. of fire calls from 1967-1995 in Hong Kong.

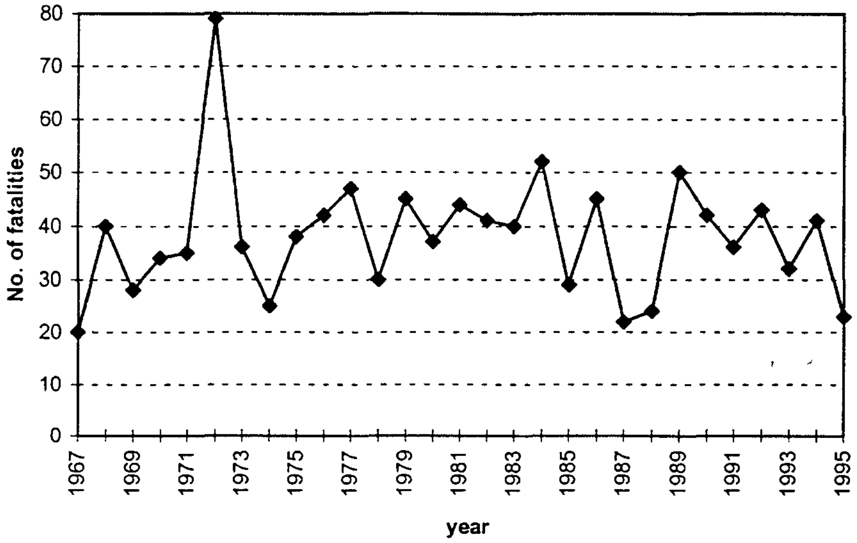

Figure 2 No. of fatalities in each year from 1967 -1995 in Hong Kong.

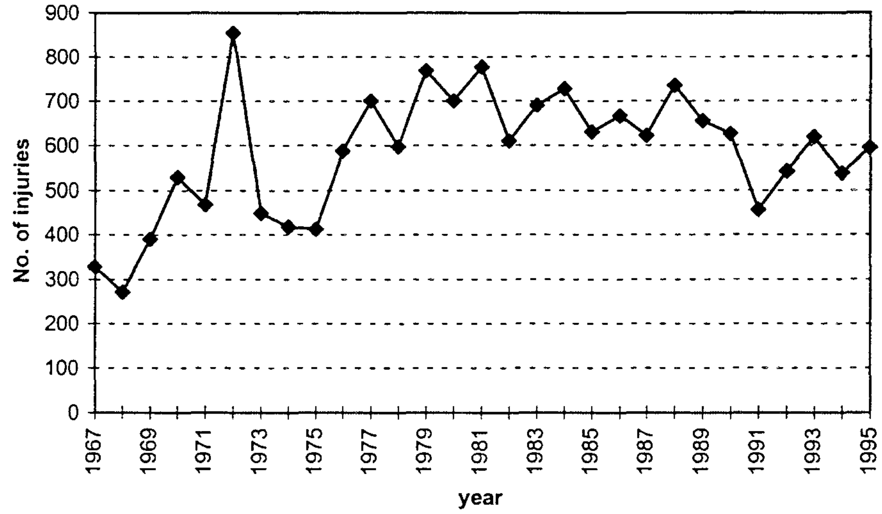

Figure 3. No. of injuries from 1967-1995 in Hong Kong.

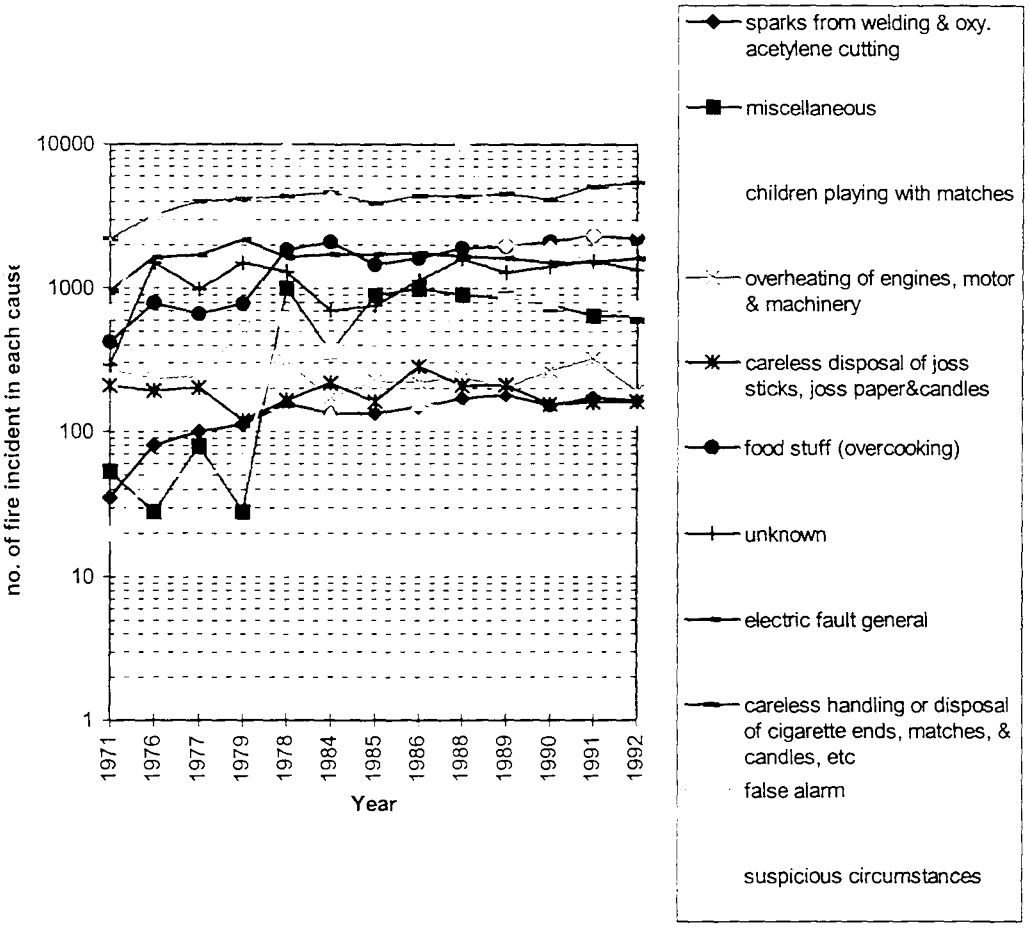

Figure 4. Classification of fire incident by cause from 1971 to 1992 in Hong Kong.

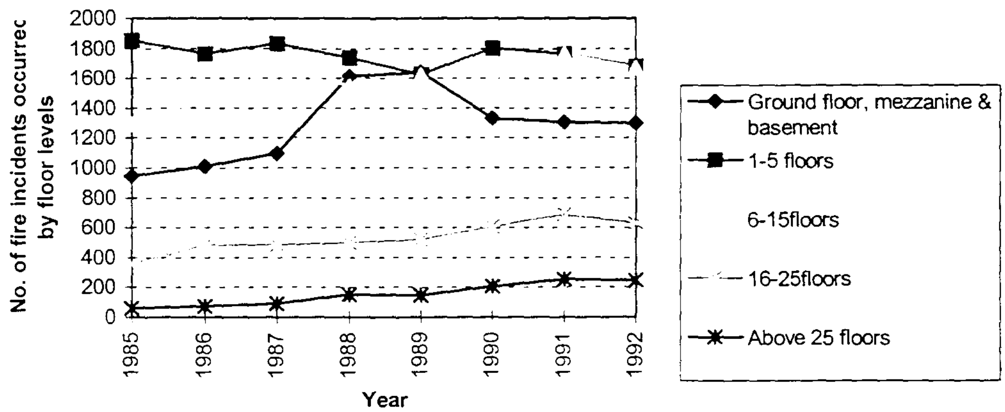

Figure 5. Classification of fire incident by floor level from 1985 to 1992 in Hong Kong.

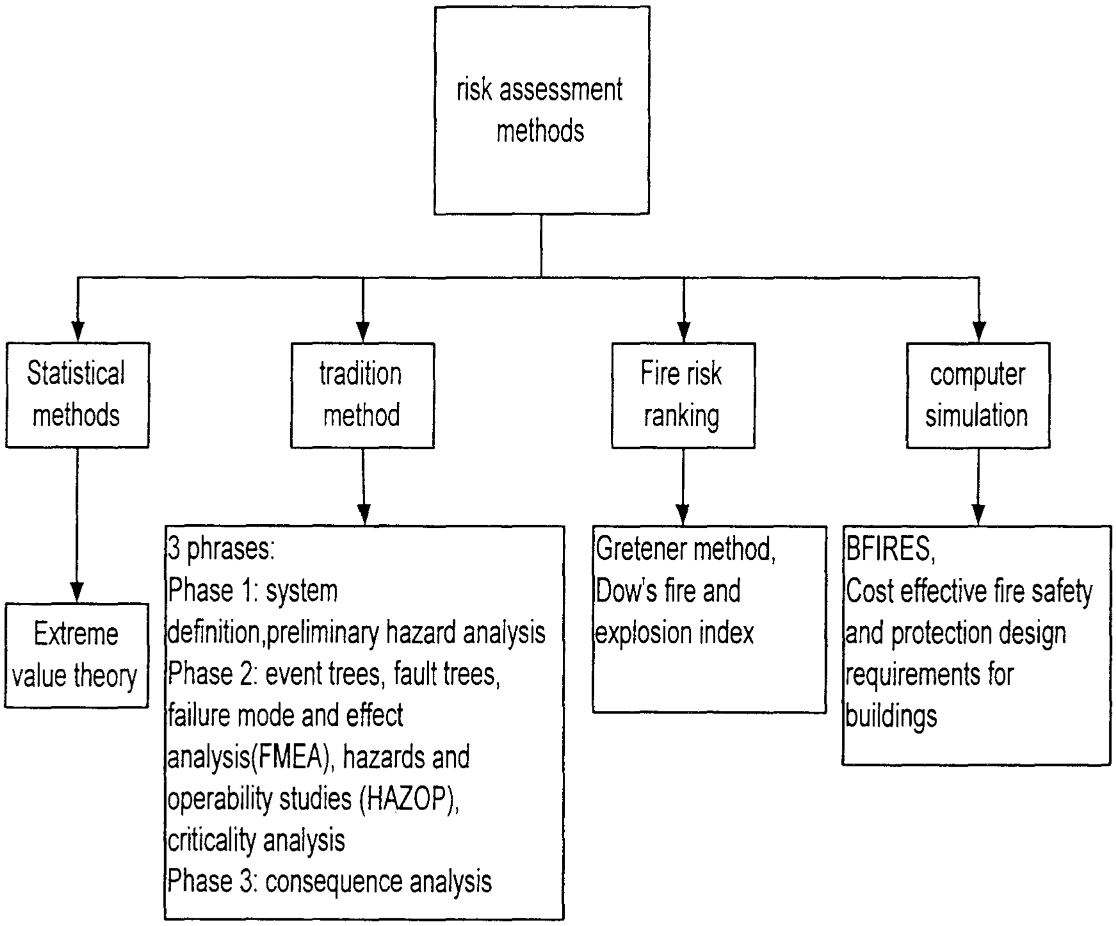

Figure 6. Various Risk Assessment Methods