Fire Risk Analysis: Its Validity and Potential for Application in Fire Safety

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ABSTRACT

Approaches of risk analysis and risk assessment as well as risk concept have been extensively applied to fire research and engineering for solutions of real problems in the past few decades. Further, it is worthy to note that the concept of risk analysis is applied in the methodology of estimation of fire safety level required by the performance-based codes in many countries. In this paper, the author discusses what is usually called "Fire Risk Analysis" and then introduces why and how the analysis of fire statistics is so significant within the context of fire risk analysis. Although statistical analysis using fire data differs in a precise sense from the scenario-based fire risk analysis, it is still the useful method to derive directly the profiles of what consequence a fire will generate to a number of buildings/designs which share some attributes such as property use, size or height, type of construction, type of occupants, etc. and forms a part of fire risk analysis.

KEYWORDS: fire risk analysis, risk assessment, fire statistics, human factors, performance-based design, fire fatality, residential fire

INTRODUCTION

Risk analysis and risk assessment approaches, as well as risk concepts, have been extensively applied to fire research and fire engineering for solution of real problems in the past few decades, even if their application to important questions of fire safety has been limited. Many examples of such studies have been published in the proceedings of past IAFSS Symposia and in major journals on fire safety and fire engineering, such as *Fire Safety Journal* and *Fire Technology* [for example, 1-6].

Risk concepts have been particularly important in setting acceptable fire safety levels for use in performance-based codes, including those in the U.K., Australia, and Sweden, and the performance-based options in the ICC Building Code and NFPA Building Code in the U.S. The ICC Building Code explicitly uses a risk matrix approach, while the NFPA Building Code uses scenario-based fire safety validation in which the scenario selections involve risk considerations [7-10].

In the context of performance-based design, thresholds of acceptability for life safety from fire are usually expressed such that no occupants shall suffer unacceptable fire effects before they can reach a safe area. Such a formulation requires estimation of not only physical impacts to a building from heat and smoke but also human factors which dictate occupant ability and speed to move to a safe area. Human behavior is essential to fire risk assessment. As a provocative suggestion that this linkage is not limited to fire risk assessment, I quote from Hall's invited lecture in the sixth IAFSS Symposium [11],

FIRE SAFETY SCIENCE–PROCEEDINGS OF THE EIGHTH INTERNATIONAL SYMPOSIUM, pp. 85-100

"*Fire safety science means a scientific study on not only the phenomena of fire but also the interaction between people and fire, which is how the threat is manifested.*"

Besides the application to specification and verification of acceptable fire safety levels in performance-based design, risk concepts have been of increasing interest for extreme events like terror attacks and serious arson fires. Especially for insurance companies and other private or public entities with responsibilities for security and a need to be credible, it is no longer possible to plan as if extreme events cannot happen. At the same time, no affordable building design can assure protection from every hazard that could occur. The explicit consideration of probability through risk assessment is the answer. More and more building owners are also concluding that they need information and advice regarding potential risk to fire and/or earthquake motion from a proposed building design.

The question here is whether or not the present stage of developed methodologies for fire risk analysis can measure up to the growing needs mentioned above. There are of course detailed commentaries on terminology, conceptual frameworks, and even instruction manuals for fire risk analysis and fire risk assessment [12-17]. However, there still seems to be space for development and refinement of scientific and engineering tools for application to real fire problems.

As background to my remarks, I assume the adequacy of existing standardization in risk assessment, including the roles of reliability, uncertainty, and sensitivity analysis in the interpretation of outcomes of risk estimation. In this regard, I greatly appreciate the efforts of ISO TC92/SC4 WG10, who are preparing the documents for international standardization of terminology, concepts, and frameworks of fire risk assessment, which we look forward to seeing soon [18].

SCOPE AND DIVERSITY OF FIRE RISK ANALYSIS

In a 2004 overview paper, Meacham [19] described a broad diversity of perceptions of what "risk" is. Given that diversity, it is far from easy to state a definition that everyone would accept as a starting point. In an attempt to be general without being vague, I propose that fire risk is an undesirable consequence potentially induced by a fire. The "potential" is what we try to measure with concepts such as probability, frequency, and likelihood. Direct measures of the frequency of undesirable fire-related events are also provided by statistical analysis of fire incident data. Figure 1 shows the link between direct statistical measure of fire experience and more sophisticated notions of "Fire Risk Analysis."

Some fifteen years ago, Hall and I co-authored a general conceptual framework for fire risk analysis [20] which included familiar key elements such as probability, hazard, severity and outcome but devoted considerable attention to scenarios and scenario structure. The term "(fire) scenario" is defined as a set of "specifications of the characteristics of fires and the environments in which they occur." A fire scenario would be a single element of all possible "fire situations," each of which then is defined by "a complete physical description of a fire" including the environment in which it began, developed, and ended as well as its consequences. A fire risk analysis thus defined, or a "scenario-based fire risk analysis" as noted in Fig. 1, generally deals with a specific environment (i.e., an existing building or a design to be embodied in the future) whose fire-induced consequences are the final output of the analysis in terms of severity/outcome measure.

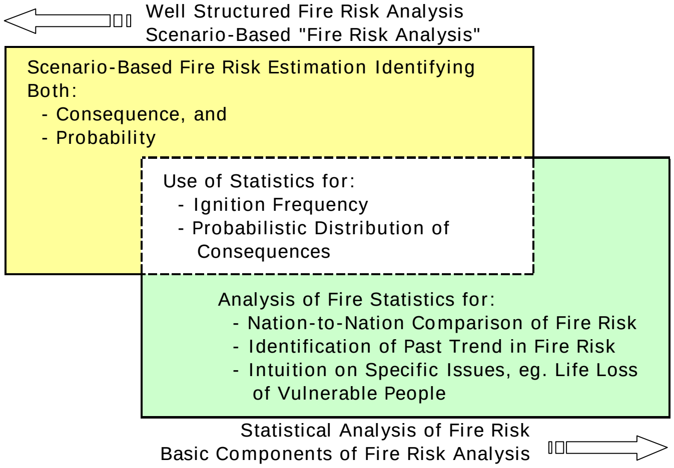


Fig. 1. Taxonomic view on arena of "Fire Risk Analysis."

A conventional statistical analysis [for example, 21,22] using fire incident records differs from a scenario-based fire risk analysis in a number of ways:

- it does not necessarily identify nor describe all the physical aspects of a fire completely but is limited to the few summary details available in the data;
- analysis of past events cannot, by definition, deal with anything new, such as an innovative fire suppression system never before seen in the real world; and
- its subject is not a specific building/design but rather a group of buildings/designs that share some attributes, such as property use, size or height, type of construction, or type of occupants.

Throughout this paper, I will return to the differences between fire risk analysis and statistical analysis and the relationship between them. First, analysis of statistics provides a crucial source for estimation of parameters used in scenario-based risk analyses. Second, analysis of statistics can be used to address many of the same policy questions that would otherwise require more elaborate risk analysis – risk measures without risk analysis, if you will. The work of Keski-Rahkonen and his colleagues at VTT Building and Transport provide a particularly good example of this second point [23,24,25].

In the next sections, I will briefly review the literature focusing on scenario-based risk analysis, analysis of fire statistics, and use of statistics for fire risk analysis. Using this structure, I will then reflect upon my own work in the past.

Scenario-based Fire Risk Analysis

While a fire situation begins with an ignition, a fire scenario begins before ignition, with the pre-ignition status of relevant particulars to a fire such as people and/or property. In Table 1, the four columns represent the time-based parts of a scenario – before ignition, ignition, during fire, after fire – while the five rows reflect the relevant particulars in a fire – two for people (occupants and fire service), two for property (active vs. passive fire protection, where the latter includes potential fuels) – and the physicochemical phenomena (i.e., smoke, toxicity, and odor) that are the effects of fire that people and property react to and are affected by.

Note that the complete four-by-five matrix will not be relevant to all applications of fire risk analysis. Rather, the focus will shift depending on the objective of the analysis. If you are simply looking at the risk in terms of property loss, the focus will be placed on the "property" side, and how occupants will evacuate may not be a critical element. On the other hand, you may not be interested in what happens to the structural elements subjected to a post-flashover fire when you are estimating the effectiveness of fire service in reducing the number of casualties among occupants, etc.

As an illustration, consider the work at Victoria University of Technology, Australia, and the National Research Council of Canada (NRCC) [1,2]. I consider the first software package from this collaboration, FiRECAM™, a good example of the fullest-scope fire risk analysis methodologies. It is extensively documented in the proceedings of IAFSS Symposia, as are other worthy models from one or both of these institutions, including CESARE and FIERAsystem. Other tools similar in scope and structure include FRAMEworks [3,4] in the US, CRISP II [5] in the UK, and a "Fire Phase"-based method in Japan [6]. For a more detailed overview, I recommend the references found in [20,26,27].

Table 1. Elements related to scenario-based Fire Risk Analysis.

		Pre-Ignition Status	Fire Situation		
			Ignition	Post-Ignition Status	Consequences
Property	Fire-Safety and Protection Systems	Detectors Alarm Smoke Control Automatic Extinguishing System System Maintenance	NA	Activation Success/Failure	Fire/Heat-Induced Building Element Damage Heat/Smoke/Odor-Induced Equipment/Product Damage Water-Induced Damage and Other Property Loss Property-Loss-Induced Service Interruption
	Building Equipment Combustibles and Other Contents	Location/Layout Property Use Size/Height Type of Construction Fire Resistance Barrier Performance Materials and Products	Item/Material First Ignited Equipment Involved Deficiency/Failure	Combustion Heat Transfer Thermal Deformation Loss of Stiffness Collapse	
Fire/Smoke/Toxity/Odor		NA	Heat Source Cause of Ignition Fire Origin	Fire Growth Fire Spread Extinguishment Generation and Movement of Smoke/Toxity/Odor	NA
People	Occupants	Number Distribution Activity Awareness Human Factors	Human Factors Contributing to Ignition	Fire Cue First-Aid Suppression Evacuation	Casualties Casualties-Induced Service Deterioration
	Fire Service	Location Law Enforcement Prevention Initiative	NA	Arrival Time Firefighting Search and Rescue Apparatus/Resources	

FiRECAM™ consists of a number of sub-models that cover most of the elements shown in Table 1 in the four-by-five matrix. For example, in their Design Fire Model, numerous possible fire scenarios for compar™ents within a building are grouped into only six types. ISO TC92 SC4 WG10 calls these groups "scenario clusters" and refers to the design fire scenario used to represent a cluster as a "representative fire scenario." This is the kind of simplification that every fire risk analysis method must perform in order to be both practical and valid. If many scenarios are not represented in the analysis, its validity must be questioned. If many variations of the many defining characteristics for fire scenarios are included, however, the calculation burden for the fire risk analysis grows exponentially. For example, in the case of FiRECAM™, multiplying fire types while also multiplying distinct points of origin (e.g., distinguishing different types of rooms and areas) will have a compounding effect on the number of distinct cases to be analyzed.

It should be pointed out that within the context of scenario-based fire risk analysis above, fire statistics play an important role. Just one example from the FiRECAM™ framework: the probabilities of six design fires are based on the proportions of three types of fire (smoldering, non-flashover fire, and flashover fire) observed in the past in buildings of a specific property use.

Analysis of Fire Statistics

As shown by the FIRECAM™ example, a fire risk analysis typically estimates risk measures using a sequence of modeling components. Except for the conditions of ignition and the conditions at time of ignition, nothing about the fire or its effects is directly measured. In statistical analysis, everything is directly measured, as illustrated in the relevant literature [21,22,28-30].

The primary objective of analysis of statistics is to identify, directly from the data, sources of fire risk and their relative importance, so as to improve fire safety by enhancing awareness, updating codes and standards, deploying fire service more strategically, etc. For this purpose, the style of expression in the most generally used methods is bar charts and /or cross tabulations to present the findings from fire statistics obtained over a specific period of time. Another type of representation widely used is time histories; year-by-year comparison of one or more parameters of interest helps read from statistics whether a trend exists or not, and whether or not the parameter is relatively constant over time.

Correlations among parameters sometimes give you more insight about the reality than bar charts and time histories alone can do. The work of Saerdqvist and Holmstedt [31] of Lund University is one good example in this point. They investigated 307 non-residential fires in the greater London area between 1994 and 1997, to identify the effects of firefighting activities on fire consequences. A fire's consequence was represented by fire area, which was compared with a variety of time intervals defined among such events as pre-heating start, ignition, discovery, fire brigade arrival, fire dead, etc. The uniqueness of their study appears to lie in the availability of such entries in statistics as fire area at the time of detection as well as at arrival of fire brigade. Approximately 75% fires are already self-contained at the time of fire brigade arrival. By excluding the 75%, the study succeeded in identifying a positive correlation between final fire area and time from ignition up to fire brigade arrival.

Finally, I would like to make a few remarks on the recent activities by Tillander and Keski-Rahkonen at VTT in Finland. By using fire- and building-stock-related statistics from high-quality, very complete databases, their approach has identified in detail the dependence of ignition frequency on the floor area of specific types of building. Thus, by establishing the availability and suitability of floor area as a measure of exposure, they have provided an objective base to be used in converting fire experience measures into rates suitable for use as estimated probabilities of ignition/fire in the context of scenario-based fire risk analysis [24,25].

Over the past few decades, I have dedicated much of my effort to the analysis of fire statistics and other data related to residential fire risk, especially fatal fire risk, and assessment of potential countermeasures. As I have seen in countries such as the U.K., the U.S., Australia, Finland, and Korea, as well as Japan, there is increasing recognition worldwide, even in developing countries, of the value of a strong fire statistics system in making appropriate policy decisions on fire safety strategies based on the facts from real fire experience.

Hereafter, it is not my intent to comment on basic features or principles of fire risk analysis. Such information has been published extensively and readers who need such guidance should consult the listed references. In the following sections, I introduce some of my own work to provide additional examples of the significance of analysis of fire incident data and statistics to fire safety research and engineering.

HUMAN FACTORS IN FIRE RISK AND FIRE SAFETY MEASURES

Disasters or accidents are generally related to human error. People use fire but not always carefully. People conduct activities with fire potential that they do not recognize or do not control for. People react to fire in ways that make the fire worse or the danger to themselves greater. People design products that create or permit greater fire danger to the people who use those products. Fire is a disaster significantly involving human factors in various aspects, although human factors in fire are most often discussed and analyzed in the narrow context of escape activities. Here, I would like to discuss the importance of human factors when we consider fire risk and fire safety measures.

In Japan, there is a traditional event called "Yama-Yaki" in Japanese, which is burning off dried grass in a mountain and longing for spring. Sometimes, it looks like the entire mountain is on fire. But, it is well known to people living near the area as an event in February, and of course it is not counted as a fire incident. To someone unfamiliar with this festival tradition, it looks like a major wildfire, but to the people of the area, it is perceived as a well-controlled activity and not a hostile fire. Imagine what this might mean for the reaction time of spectators if in fact the fire was no longer under control.

I adduce this example because humans have used fire since the onset of civilization. Fire is still used in a number of ways in factories, industries, internal combustion engines, cookeries, etc. Fire itself is universal and not necessarily dangerous on its own. What makes a fire into a hostile fire is the absence of appropriate control, and control is a human factor. And what is considered appropriate control can vary considerably from one culture to another, which introduces social aspects. Therefore, fire disasters naturally have social aspects and human factors.

Fire Disaster Has a Social Dimension by Definition

A definition of fire is provided in the "Fire Report Instruction Manual" published by the Fire and Disaster Management Agency, Ministry of Internal Affairs and Communications, which collects fire and fire death reports in Japan. There are many types of fire, ranging down to an infinitely small accident. Therefore, it is necessary to determine the levels of fire for collection in fire reports. The manual defines a fire as "*a phenomenon of combustion that is generated or spread against human intention or generated by arson and that requires extinction or use of fire protection equipment and/or something with similar effects or is a phenomenon of spread explosion.*" Explosion has been recognized as combustion and expressly included as fire in fire reports since 1984, even if its combustion is not externally visible.

The characteristic of this definition is first of all that a reportable fire is generated or spread against human intention or involves arson. A fire started for one’s use is not a fire disaster and a fire left unattended is not a disaster, at least until it grows beyond what was intended. Also, the definition of “a phenomenon of combustion that requires extinction or use of fire control equipment or something with similar effects” has been understood to imply a minimum severity or size. For example, a fire that can be smothered by a dishrag or the lid of a cooking pan would not require a report to the fire department. Fire entails a certain degree of firefighting action as a fire disaster, such as serious use of a fire extinguisher or a water bucket. Fire itself is a simple phenomenon of combustion or explosion in a physiochemical sense, but fire disasters have social aspects, which are the social view of what constitutes a level of damage worthy of notice.

Impacts of Human Factors to Risk of Fire Deaths

Human activity influences whether there will be a fire or not, whether it will grow or not, and whether it will cause serious harm or not. Here, I would like to examine the human aspects of fire as discussed in some of my past papers on fire statistics.

Every year in Japan, over 900 people lose their lives in residential fires, accounting for approximately 90% of all fatalities in structure fires. In addition, as in the U.S. and the U.K. [21], fire death rates are very high for the elderly population in Japan (per 100,000 population), especially for those over 75 years old, as seen in Fig. 2 [32]. Also, Japan is a highly aged society with the elderly over 65 years old accounting for 19% of the total population in 2003, compared to 16% in the U.K., 12% in the U.S., and a 7% average worldwide [33].

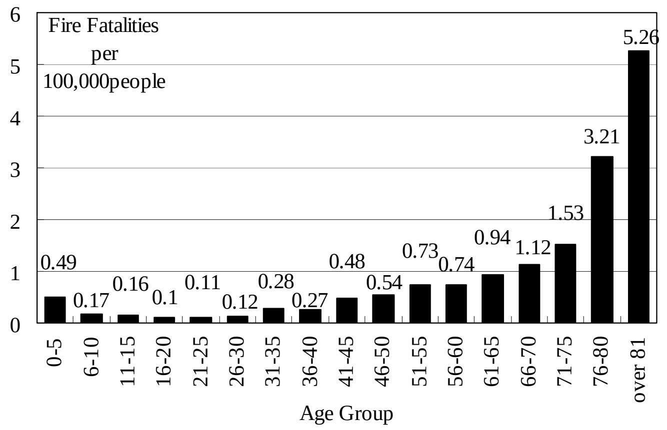


Fig. 2. Residential fire fatalities per 100,000 people by age group in Japan.

Regarding the home fire problem, there have been several studies that examined factors associated with high risk of fatality and injury, based on home fire data. Thomas pointed out the relationship between occupants’ attributes and the type of room where fires that harm them begin, using U.S. apartment fire data [34]. Thomas found, for example, that elderly females are highly represented among injurious and fatal fires beginning in kitchens, while children under five are highly represented among fatal fires beginning in bedrooms and in living rooms, family rooms and dens. Using fire death data for the City and County of Nottinghamshire, Taylor found heightened risk for such characteristics as (1) elderly male smoker, also likely to consume alcohol, (2) living in a semi-detached house, and (3) spending a great deal of time, particularly in the winter, in a cluttered living room [35].

On the other hand, some papers have looked at factors beyond these socioeconomic and demographic factors. Brennan pointed out the value of distinguishing between occupants who initiate an uncontrolled fire and occupants who face a fire not of their own making [36]. She said effective and cost-effective prevention strategies targeted on occupants who initiated fires while engaging in customary behavior would have to address the needs of those people that led them to behaviors that ended in fire. Loveridge argued that strategies should not be limited to smoke alarms and education but should incorporate design and construction factors in an integrated approach for greatest effectiveness [37]. Also, I pointed out that the popularization of safer heating appliances and fire-resistive houses must provide us a good prospect for reducing fire fatalities in the future as a potential alternative approach to active fire protection systems [22].

Impact of Human Factors on Escape Activity

Since joining the National Research Institute of Fire and Disaster, I have had opportunities to study many past fire cases. I have seen that many fatalities occur when there is a failure to promptly evacuate from the area of the fire, even upon hearing a fire alarm. Why? Failing to evacuate upon hearing an early fire alarm is a serious problem requiring improvement.

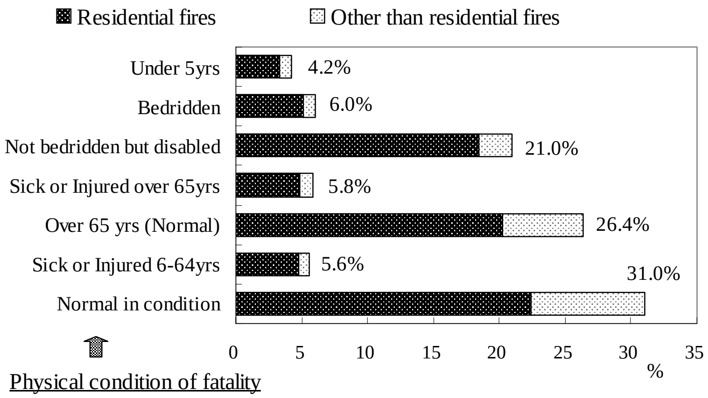
Past studies of evacuation from fire have found that the time to start evacuation is overwhelmingly long, compared to the time required to evacuate from a typical building. That makes this “pre-movement” or “pre-evacuation” time the critical factor in evacuation success. Through the analysis of 112 fire cases documented by the Tokyo Fire Depar™ent, Murosaki obtained mean times for evacuation. While the time from the start of the fire to the start of evacuation was 6 to 8 minutes on average, the time to actually evacuate was 2 to 3 minutes on average, indicating that the former requires proportionately much more time [38]. Mito pointed out that people first perceive abnormalities, often auditory, such as noises of people, sounds of crackling fire with peculiar smells, the sound of a smoke alarm, etc., which are audible from a distance [39]. However, this perception is followed not by immediate evacuation but by action to confirm the information, because people tend to want to visually confirm the fact of a fire before deciding to evacuate. Perhaps evidence of the eyes is less ambiguous than evidence of the ears; there is nothing else it could be but a fire. Whatever the reasons, the time from perceiving the fire to deciding to evacuate must be shortened; otherwise, even early perception of the first cues of fire will not allow sufficient time for people to evacuate.

Furthermore, there are three factors delaying evacuation [40]. The first factor is a mental process called “*Normalcy Bias,*” which is a tendency to resist concluding that one is in a serious situation; in other words, it is a tendency to maintain psychological peace. The second factor is underestimation of the speed or severity of a looming threat due to a lack of proper knowledge of fire, which is the most critical. And the third factor is the desire to confirm each piece of information on fire or smoke visually. Improving these three points may shorten the evacuation time.

Which Populations are Most Vulnerable to Fire?

When we refer to vulnerable populations to fires, we typically imagine wheelchair users in public buildings, such as assemblies, office buildings, and so on. And, in most cases, special care is given to the specification of design guides and requirements relating to the evacuation safety of public buildings by vulnerable people. However, this is not enough for the fire safety of vulnerable populations. Although some vulnerable people may spend time in such buildings, most vulnerable people spend most of their time in their own homes.

Figure 3 shows percentages of fire fatalities by physical condition of victims in Japan [41]. From this figure, we can see that 69% of fatal victims have some vulnerability characteristic of health condition or age. It can also be seen that most fire fatalities occur in residential fires, which include fires in dwellings, apartments and dormitories but do not include hotels and motels.



*Source of Data: Fire Fatality Data of the Fire and Disaster Management Agency in Japan for 1995 - 2001.

Fig. 3. Physical characteristics of fatalities at a fire by type of occupancy.

Also, there is considerable variety in vulnerabilities, from physical to mental, from age-related to not age-related. Physical vulnerabilities alone can involve physical handicap, sight impairment, hearing impairment, pregnancy, infancy, and the frailty of age. Temporary vulnerabilities include being injured, sick or drunk. And, some vulnerabilities involve not the individual but his or her context, such as the language barrier in different countries and the problems of reacting to fire in an unfamiliar building. Figure 3 does not show all these types of vulnerabilities, but the ones it does show affect more than two-thirds of all victims. And, fire safety measures and devices to help vulnerable people must be tailored to the type of vulnerability.

Everybody may be vulnerable to fire depending on the time, place, and circumstances. The risk of fire death depends not only on the severity of fire, but also on characteristics of occupants and of environments around occupants, including the type of facility where fire occurs. Therefore, in order to select best strategies for fire-death-reduction programs, it is very important, in research and development as well as policies of fire safety, to take account of high risk groups and vulnerable populations, as well as the types of buildings and facilities where they may become involved in a fire. For example, vulnerable people need special provisions for emergency assistance in evacuation, which need to consider the availability and appropriateness of family members, neighbors, and professionals to provide that assistance. In addition to tailoring fire safety measures to existing vulnerabilities, we should seek to help vulnerable people become less vulnerable. Their living conditions and other circumstances, including daily care, must be improved in order to mitigate fire deaths and related fire risk.

FIRE RISK ANALYSIS FOR REDUCING RESIDENTIAL FIRE FATALITIES

The reduction of residential fire deaths is attained not only by popularization of fire protection equipment, such as smoke alarms and residential sprinklers, but also by many other efforts, such as improvement in fire safety of appliances and furniture, popularization of fire-resistive construction in homes, and fire safety education of the public and of care personnel for vulnerable people. I believe that preventing fire ignitions and mitigating fire damage through passive features are both effective and fundamental approaches to reduce future fire deaths, in addition to fire protection systems.

Here, I would like to introduce one of the examples of our fire risk analyses, where we analyze quantitatively how much risk the vulnerable people such as the elderly have in residential fires [42]. We are working toward examining the availability of various measures that would reduce residential fire fatalities in high-risk groups. For this purpose, two main kinds of data sources were used in the analysis. One is the national database of fire incident and fire fatality reports collected by the Fire and Disaster Management Agency. The other source is the housing survey [43], with data such as population by age group, households by number of family members, dwellings by type of structure, and so forth.

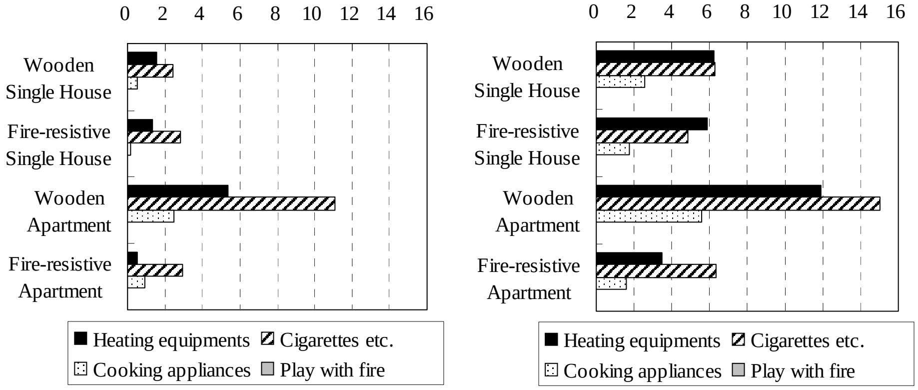
Fire Fatality Rates by Major Fire Cause and by Type of Homes and Age Group

As shown in Fig. 4, major causes of fatal fires differ according to age group. For age groups under 14, playing with fire is the leading cause, and in other age groups, the leading cause is cigarettes. Furthermore, in the over-75 group, heating equipment ranks almost as high as cigarettes except in fire-resistive apartments. Fire fatality rates also differ by age group for the same cause. It is not uncommon to see the risk of fatality being more than five times as much in the over-75 age group as in the under-64 age group. Because those in the age group over 75 have less physical ability compared with younger groups, even if the cause of the fire is the same, it is considered more likely that they will not be able to take the appropriate response, thus leading to a greater risk of death even if the physical hazard is the same.

The fire fatality rate in wooden apartments is higher than that in other types of homes. Figure 4 shows that this fatality rate is higher not just for older age groups but also for the under-64 age group. It is obvious that the influence of type of home is as strong as that of age group. It is important to consider fire safety measures suitable to actual conditions of type of home.

Further, the fire fatality database gives details on many aspects of the fire itself and also physical conditions and situations of fire victims, which can be used to clarify the risk of fatal fires in relation to various factors.

(1) Under 14 (2) 15-64

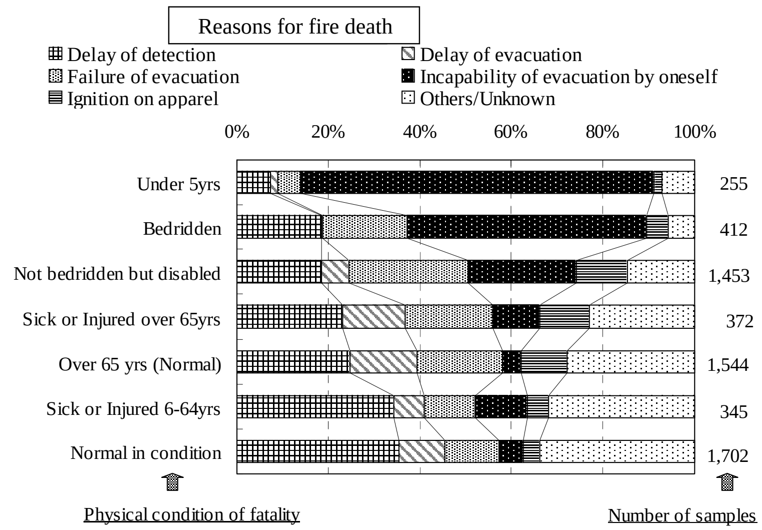


(3) 65-74 (4) Over 75

Fig. 4. Fire fatality rates by major fire cause and by type of homes and age group.

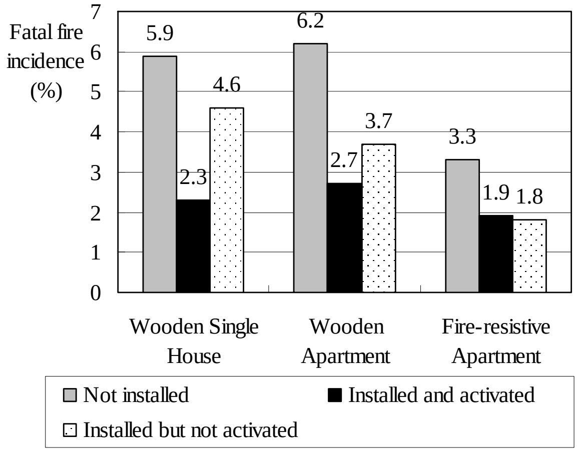
Reasons for Fire Death by Type of Physical Condition at a Time of Fire

Figure 5 classifies types of fatalities into seven categories of physical conditions according to ability to react to fire using recorded attributes in a fatality report. The proportion of estimated citations as a reason for fire death, for each type of physical condition of victim, is shown in this figure, which gives us a very informative picture on how they were involved in fires that resulted in death. Victims who were bedridden, disabled physically, or under 5 years of age, were likely to be killed in home fires mostly due to incapability and/or failure of evacuation related to their reduced ability to evacuate. For victims who were disabled physically but not bedridden or over 65 years of age, a relatively large proportion had as reasons the ignition of wearing apparel and/or delay of evacuation. By contrast, for victims who are normal in physical condition or simply sick or injured and 6-64 years old, the shares for the reasons mentioned above are relatively small, but delay of detection is a major reason and higher than other reasons. In addition, attention should be paid to the fact that the leading fire death reason for younger children, aged under 5, is incapability of self-evacuation when unattended by parents or other family members at a fire caused by playing with fire.



*Source of Data: Fire Fatality Data of the Fire and Disaster Management Agency for 1995 - 2001.

Fig. 5. Reasons for fire death by type of physical condition at a time of fire.



*Source of Data: Fire Incident Data of the Fire and Disaster Management Agency for 1995 - 2001.

Fig. 6. Fatal fire incidence by condition of installation/activation of fire alarm system.

Effect of Smoke Alarms in Reducing Fire Deaths in Homes

The number of fire deaths in the U.S. has been continuously decreasing during the past two decades and was reduced almost by half in this period. Possible reasons often cited for this dramatic decrease in fire deaths include the diffusion of smoke alarms in homes and the introduction of upholstered furniture and mattresses with less flammability in the U.S., as well as decreases in the percentage of the population who smoke. When home smoke alarms were present comparison with when they were absent, there was an estimated 46% reduction in death rate per 100 fires in the U.S. [44], which is quite similar to the 56% reduction when smoke alarms are present and activated, compared to when they are absent or do not activate, in the U.K [45].

In Japan, although there has not been so much diffusion of smoke alarms in homes so far, there are sizable numbers of homes installed with ordinary fire alarm systems, especially among apar™ent houses. Therefore, we tried to validate the evidence of the effect of existing fire alarm systems in Japanese homes on mitigating fire deaths, based on statistical analysis of fire data from the Fire and Disaster Management Agency. Figure 6 [46] shows reduction percentages associated with the presence and activation of fire alarm systems, ranging from 41% for fire-resistant apar™ent buildings to 56% for wooden apar™ent buildings. This range is very close to the estimates in the U.S. and U.K. as cited above. Further, since the Fire Service Law was amended in June 2004 to require the installation of home smoke alarms in all housing units in Japan, we think it very important to conduct a follow-up study regarding the effect of home smoke alarms in reducing the risks of fire deaths and damage in the future.

CONCLUDING REMARKS

In this paper, I first described what is usually called “Fire Risk Analysis” and then discussed why and how the analysis of fire statistics is so significant within the context of fire risk analysis. In the roughly 30 years since I joined the National Research Institute of Fire and Disaster, I have dedicated much of my effort to statistical analysis using the fire incident database and investigations of major fire incidents. Although conventional statistical analysis using fire data differs in details from scenario-based fire risk analysis, it is still a useful method to directly derive profiles of the consequences a fire will generate in buildings/designs that share some attributes, such as property use, size or height, type of construction, type of occupants, etc. This is a part of fire risk analysis.

If we look with wider vision over the methodology and terminology of fire risk analysis, we can see the diverse applications of risk analysis and/or risk concepts to resolve the real problems of fire safety. What is most important is not to distinguish one from another approach but to encourage researchers and engineers to conduct useful studies relating to fire risk analysis in any style or form, which, I believe, will fertilize and advance fire risk analysis for the future.

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