72 Introduction to Fire Risk Analysis

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Introduction

The risk assessment chapters in this section describe concepts and methods to be used in answering the three questions: What could happen? How bad would it be? How likely is it? This chapter in particular is intended to provide an overview of fire risk analysis as a whole, indicating how the subsequent chapters fit together and how a completed fire risk analysis connects to other evaluative and management activities. The purpose of this introductory chapter is threefold:

1. Introduce some generic terminology and fundamental concepts (building on the three questions raised above)
2. Provide an overview of the other chapters in this section
3. List some broad resources for conducting fire risk analysis (FRA)

What Is Risk?

Risk has always been a part of human endeavor, and for much of human history, the notion that risk could be actively controlled or prevented would have been considered mad or even blasphemous. Even today, when we increasingly expect protection against risk and use codes, regulations, insurance provisions, built-in and planned response mechanisms, and incentives, all to control or reduce risk, very few of our risk reduction and risk management actions proceed from a formal or quantitative risk analysis.

This aspect, too, is changing. Governments around the world are mandating risk analyses in areas of health and safety. Computations of the odds of harm are becoming a powerful force in decisions about activities involving risk.

Every decision related to fire safety is a fire risk decision, whether it is treated as such or not. And so, as our scientific understanding and our suite of quantitative engineering tools have rapidly expanded, we have discovered that we cannot make our fire safety decision-making process more scientific and quantitative unless we first place our new engineering tools into an appropriate fire risk analysis context. To do otherwise is to make many implicit assumptions about patterns of danger and preferences for certainty and for safety versus other human wants and needs.

Basing decisions on fire risk not only requires the challenging technical steps of fire risk estimation but also requires the identification of an acceptable level of risk, which is more a philosophical task than a technical one. Consider, for example, the recent fire loss experience of any country. Does this experience represent a level of fire risk acceptable to the citizens of that country? If the answer is no, then why is there so little attention paid to the problem? If the answer is

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yes, meaning we accept certain losses, then why is there a great clamor for change following every serious fire?

Accepting a level of risk requires a value judgment, and people have different value judgments. Consider four perspectives on the value of residential sprinklers: technical, societal, enforcer, and managerial.

Technical value judgments are made by experts based on the available technical information and their acquired expertise. Experts pretty much agree that residential sprinklers can significantly reduce the calculated fire risk. The experts most aware of the risk reduction potential of sprinklers are also most likely to evaluate the attractiveness of sprinklers based on that potential, more than on other bases. They may embrace residential sprinklers with great enthusiasm on that basis.

Societal value judgments are the judgments of ordinary people balancing benefits, costs, and risks of the full range of activities and events that affect their daily lives. Their estimation of the benefits and the negative side effects of sprinklers may be based on folklore more than the best thinking of the experts, and they are likely to attach more importance to costs and to other hazards and needs than the experts—having a specific focus—do. Currently, it appears that the reduced fire risk produced by a residential sprinkler system is not valued as highly by the average citizen as is the increased benefit of a new car.

Enforcer value judgments are the judgments of a few professionals who are asked by society to protect their interests in a specific area. Enforcers are a special group within the larger group of individuals who provide *fire risk management*. An engineer performing a fire risk analysis will usually be working on behalf of a client with fire risk management responsibility, but the engineer cannot base his or her analysis on the values of the client alone. Instead, the fire risk analysis will need to address the client's values and also societal values. Enforcers are often seen as the interpreters and guardians of societal values, but at the same time, their technical expertise and focused mission of providing fire safety give them a distinctive set of values. Their estimation of benefits and side effects are likely closer to those of the experts, but their evaluation of those benefits and side effects are likely closer to those of the general public, embodied in societal value judgments. And because they directly incur neither the costs nor the benefits of their decisions, they must factor in some other considerations having to do with when it is acceptable to dictate safety choices to people. Is it equitable to require automatic sprinklers in *all* residences? How can cost be fairly distributed? Who is responsible for system reliability? Should production, installation, and maintenance of sprinklers be regulated?

Managerial value judgments are the judgments of all the other professionals with special responsibilities relevant to fire risk management, which for residential fire sprinklers would include such groups as architects, builders, managers of hardware retail chains, and so forth. Their estimation of the benefits and side effects of sprinklers may be similar to the general public's, their estimation of the costs is probably more accurate than that of any other group, and, most important, they themselves are likely to be directly affected by those costs more than by the benefits or side effects. Different information and different goals and values are likely to lead to a different assessment—though still risk based like all the others—of the attractiveness of residential sprinklers.

The chapters of this section are designed to provide the practicing engineer with the contextual tools and supplementary information that will permit him or her to use the knowledge and tools embedded in all the earlier sections and to produce a sound evaluation of alternative choices.

Fire risk estimation is the scientific process of answering three questions: (1) What could happen? (2) How bad would it be if it did happen? (3) How likely is it to happen? Or, to put it another way, risk has two essential components: exposure and undesired consequences. Exposure is a potential risk that becomes real with uncertainty, and so exposure refers to the likelihood or probability of experiencing a destructive event, for example, fire. Undesirable consequences, ranging from deaths or dollars of property damage, to significant intangible losses such as business interruption, mission failure, environmental degradation, and destruction of cultural artifacts, are also potential risks. They become real if exposure occurs. Thus when we speak of fire risk, we are referring to the uncertainty of loss.

Let's return to the three questions that opened this chapter.

What could happen? can refer to a sequence of events ending in a fire loss, the sequence as a whole being called a *scenario,* or to an object or other entity having the potential for a sequence of events ending in a fire loss. A *hazard* is such an object, and *hazard* itself is the potential for loss. *Fire hazard analysis* is a term often used to refer to analyses of what could happen and how bad it would be, without analysis of likelihood.

How bad would it be if it did happen? is often called *consequence* and sometimes called *hazard,* in the sense of a specific measure of potential for loss. The measure of consequence can be direct (e.g., property is damaged) or indirect (e.g., the company is out of business for several days). It can be objective (e.g., replacement cost in monetary units) or subjective (e.g., pain and suffering effects of injury, utility measures of damage).

How likely is it to happen? is usually called *probability*. Probability can be relative (e.g., likelihood of this loss is how much greater or smaller than likelihood of that loss) or absolute (e.g., how many times a year, given a population of people or property). Probability can be regarded as objective and measured objectively (e.g., how many occurrences per year in a recent period of time). It can be regarded as objective but measured subjectively (e.g., how many occurrences do we estimate will occur next year, given data on the number of occurrences last year and impressions on what has changed since last year). It can be regarded as and measured subjectively.

Both consequence and probability can be either explicit in a formal fire risk analysis or implicit and unquantified in a more simplified fire risk analysis (e.g., *fire risk index*).

For purposes of use by fire protection engineers, we assume that fire risk analysis is a scientific process, closely linked to calculations based on proven relationships and the collection and analysis of valid and appropriate data, to describe the form, dimension, and characteristics of the fire risk. Fire risk analysis can take different approaches depending on the purpose and scope of the analysis or assessment. Some assessments look back to try to infer probabilities and other risk-related measures based on practices and fire loss experience after an event such as the introduction of home smoke alarms. Other assessments look ahead and try to predict what the practices and fire loss experience would be after an event such as legislating residential sprinklers in homes.

The approach taken to fire risk analysis can also differ based on the availability—quantity, quality, and detail—of data for the purpose. Assessing the fire risk for U.S. residences, for example, one is able to draw on a very large number of documented fire events but with limited detail. Assessing the fire risk for U.S. nuclear power plants, by contrast, has far fewer fire events to draw upon but much more detail on each such event. And assessing the fire risk in any specific existing building will involve very few events in that building and questions of relevance for data from any other building or group of buildings.

In fire safety engineering, risk analysis is most generally used to evaluate fire protection strategies for a particular application or for a class of facility or operation. In other words, there are a sizeable number of buildings and some considerable relevant fire loss history to draw upon.

Terminology and Concepts

The terminology of fire risk analysis is not consistent. For example, a committee of the Society for Risk Analysis identified 17 different definitions of *risk* [1]. If one considers risk to be the full probability distribution of hazardous events and loss consequences associated with a building, product, or other entity to be studied, then all 17 definitions can be seen as alternative summary measures taken from that common distribution. The important point, however, is that for many people, a summary measure is not just a summary measure related to risk, useful for analysis; it *is* the risk. As another example, the terms *analysis* and *assessment* are often used interchangeably, yet some sources make sharp distinctions. We will provide distinct definitions.

The rest of the chapters in this section also show some inconsistencies in definitions and concepts. These are largely a function of differences in the authors' backgrounds, topics, resources, and intents. In general, the definitions and concepts used are similar, even when they are not identical.

An overview of terms is best presented in the form of a glossary, but the list below is presented in what is meant to be a logical sequence, rather than alphabetically. More extensive glossaries can be found in Grose [2] and Rowe [3].

Hazard A hazard is a chemical or physical condition that has the potential for causing damage to people, property, or the environment [4]. Hazard is any situation that has the potential for causing injury to life or damage to property and the environment [5].

Risk Risk is the potential for realization of unwanted, adverse consequences to human life, health, property, or the environment. Estimation of risk (for an event) is usually based on the expected value of the conditional probability of the event occurring times the consequence of the event given that it has occurred [6]. It follows that risk for a building, a product, or some other entity would be the probability distribution of events and associated consequences relevant to that building, product, or entity.

Probability According to the frequency interpretation, probability is the proportion of the time an event will occur in the long run. According to the subjective interpretation of probability, it is a measure of the strength of a person's belief concerning the occurrence or nonoccurrence of an event [7]. Probabilistic analysis is not well established in fire protection engineering, where empiricism, heuristics, and, more recently, physics-based modeling are principally used to make decisions. Probabilistic analysis is more established in fields such as decision analysis, management science, operations research, industrial and systems engineering, and systems safety. The mathematics of probability allow us to formulate engineering models which recognize uncertainty and deal with it quantitatively and consistently. Probability and statistics are covered in Chap. 73.

Consequence Consequence is a measure of the expected effects of an incident outcome case [4].

Perceived Risk Any measure of risk preferences in which the scale is not fully explainable by some objective measure of loss, direct or indirect, may be a measure of perceived risk. Studies of risk perception have identified a number of factors that consistently cause objectively equal risks to be perceived differently, including preferences for more certainty over less certainty (i.e., *risk aversion*), familiar over unfamiliar risks, voluntary over involuntary risks, readily detectable risks over undetectable or hidden risks, and common or ordinary risks over dramatic or memorable risks. The field of *risk communication* is devoted, in part, to finding ways for individuals and groups with differing ways of perceiving risks to communicate effectively, understand one another, and collaborate on mutually acceptable analyses and decisions.

Risk Analysis Risk analysis is the detailed examination, including risk assessment, risk evaluation, and risk management alternatives, performed to understand the nature of unwanted, negative consequences to human life, health, property, or the environment. Risk analysis is an analytical process to provide information regarding undesirable events, and it is the process of quantification of the probabilities and expected consequences for identified risks [6].

Risk Assessment Risk assessment is the process of establishing information regarding acceptable levels of a risk and/or levels of risk for an individual, group, society, or the environment [6].

Risk Estimation Risk estimation is the scientific determination of the characteristics of risks, usually in as quantitative a way as possible. These characteristics include the magnitude, spatial scale, duration, and intensity of adverse consequences and their associated probabilities as well as a description of the cause and effect links [6]. One complication is that a totally objective or scientific way to measure fire risk does not exist. Problem identification, data collection and reduction, and integration of information are all replete with subjective evaluations.

Risk Evaluation Risk evaluation is a component of risk assessment in which judgments are made about the significance and acceptability of risk [6].

Risk Identification Recognizing that a hazard exists and trying to define its characteristics is called risk identification. Often risks exist and are even measured for some time before their adverse consequences are recognized. In other cases, risk identification is a deliberate procedure to review, and, it is hoped, to anticipate possible hazards [6].

Acceptable Risk A value judgment applied to a particular scale for the measurement of risk yields a definition of acceptable risk. It therefore requires a prior decision on the scale and method used to estimate or measure risk and a second decision on the person or group whose views on acceptability are to be used. For a practicing engineer, acceptable risk is likely to be risk acceptable to the client. For an authority having jurisdiction (AHJ) or anyone answerable to an AHJ, acceptable risk is meant to be acceptable to society in general or to a particular community.

It is an axiom of fire risk analysis that zero risk is not an achievable goal. There are no risk-free alternatives available to individuals or organizations. No technology is 100 % reliable or totally immune to misuse, and even if technological risk could be eliminated, natural catastrophes such as lightning strikes, wildland fires, earthquakes, and wind storms include the potential for fire loss. An important corollary is that reducing fire risk may increase other forms of risk. An obvious case is the potential damage to the ozone layer from use of halon.

The goal that comes closest to being practical and yet striving for zero risk is to require that risk be as low as is technically possible. For fire protection engineering, this goal may take the form of accepting the residual risk after all identified risk reduction strategies and choices have been adopted. Or, for individuals with special preferences for particular fire protection strategies (e.g., active systems over product or material requirements, or vice versa, and either over education and training), acceptable risk may be the residual risk after favored choices are in place. One complication is that the residual risk in these cases may be perceived as zero, implying no prior acceptance of the nonzero risk that actually remains.

A Universally Acceptable Level of Fire Risk Does Not Exist No matter how one defines the term *acceptable level of fire risk,* it will be dependent on the problem context and on the individual judging acceptability, that is, on the alternatives and objectives. Individuals and organizations are inconsistent in their risk aversion. Surveys show wide variations with respect to factors such as voluntary versus involuntary risk and perceived versus calculated risk.

One contention is that the present public fire risk situation must be acceptable since otherwise there would be greater concern and call for action. This view is not a fully reliable generalization. People may have "accepted" the current risk because they believed it to be lower than it really is, believed no technically feasible alternative existed (which can change because technology changes or because perceptions of technology change), or saw no politically effective way to make their lack of acceptance known. Moreover, the current situation is a compromise among the greatly differing preferences of many individuals and groups, whose relative influence on the process of choice may also change. More elaborate discussion of the issues associated with acceptable risk can be found in Lowrance [8] and Fischoff et al. [9].

Vulnerability The susceptibility of life, property, and the environment to injury or damage if a hazard manifests its potential is vulnerability [5].

Methods of Fire Risk Analysis

Fire risk analysis is basically a structured approach to decision making under uncertainty. Within this general structure, there are many techniques or approaches to both qualitative and quantitative fire risk analysis. For each application, consider the level of mathematical sophistication appropriate to meet objectives.

A generalized concept of fire risk analysis has these steps:

1. Identify fire hazards.
2. Quantify the consequences and probabilities of the fire hazards.
3. Identify hazard control options.
4. Quantify the effects of the options on the risks of the hazards.
5. Select the appropriate protection.

At each of the two stages of quantification, there is a wide range of possibilities of depth and detail, and the actual quantification can take place anywhere on a spectrum from a principal basis in hard data and established science to a principal basis in expert judgment.

Fire risk analysis begins—and for some applications may end—with the identification of fire hazards. A preliminary assessment of areas of potential concern in facility design and operational concepts may be organized by location (e.g., area of a plant) or by activity (e.g., manufacturing versus office functions, wherever they occur). This identification provides a structure for subsequent estimates of the probability of occurrence of the events in each possible accident sequence and thereby of each possible deleterious consequence.

Formal fire risk assessment evolved with the insurance industry in the nineteenth century. Methods of fire risk analysis may be classified into four categories: (1) checklists, (2) narratives, (3) indexing, and (4) probabilistic methods [10]. Checklists and narratives are nonquantitative approaches that may address steps 1, 3, and 5 above while bypassing steps 2 and 4. Indexing is a thorough quantification method that is heuristic rather than fundamentally based. Probabilistic methods have grown in use over the last third of a century but remain rare even today.

Checklists are a common accessory of fire safety consisting of a listing of hazards, usually with recommended practices. A checklist is usually less generic than a model code or standard. It may even be so specific that it is intended to apply to a single class of buildings under management of a single owner, reflecting the special concerns of that owner.

A checklist is a practical tool to support analysis of a building relative to a code or standard that forms the basis for the checklist. It is very seldom that all criteria in a code or standard apply to a single building. The fire protection engineer must focus on only those requirements that are applicable to a specific project. A checklist can aid in this process. It also makes requirements easier to read, understand, and track to compliance.

Checklists face a trade-off between practicality and ease of interpretation. A long checklist might list 50 fire safety factors, with each item described in a manner that is readily visible or measurable, but those 50 items are not all likely to be comparably important. A short checklist, on the other hand, is usually composed of conceptual features of fire safety, which may all be very important but may all require interpretation to be made measurable.

Moreover, checklists do not capture the interaction of fire risk factors, including the manner in which the importance of one fire risk factor will change as a function of performance on another factor. For example, the relative value of hydrants, sprinklers, and extinguishers is not constant but a function of other features of a structure’s form and utility.

Narratives consist of a series of recommendations—things to do and not do—related to fire risk and safety. They are probably the earliest approach to fire risk assessment, stemming from the observation that fire is capable of destroying certain materials, such as wood, fur, and flesh. This realization would have led to a communication from parent to child on the avoidance of these fire dangers. In this earliest form, narratives were much simpler and less finished than checklists. They were not comprehensive with regard to hazards, and so they did not support a thorough review.

As the piecemeal parent's advice format evolved over the years, the narrative approach developed into the present multivolume set of the NFPA *National Fire Codes®* 2000 edition [11]. These contain the bulk of our present-day wisdom on fire safety. The information is presented in the form of descriptions of various hazardous conditions and ways to reduce or eliminate them. In this modern form, narratives are often more finished than checklists, which may be developed as simplified, practical tools to serve the more basic narratives.

Like checklists, narratives do not attempt to evaluate the fire risk quantitatively. A risk is judged acceptable if it is addressed in accordance with published recommendations. The criterion is one of pass or fail, and the residual risk remaining if you pass is never quantified or evaluated. Also like checklists, narratives cannot hope to cover the myriad conditions of human activity. While there is much common ground among different fire hazard situations, there is considerable variation in detail.

Indexing is representative of the quantitative fire risk assessment that originated with the insurance rating schedule. The approach has broadened to include a wide variety of applications. In general, fire risk indexing assigns values to selected variables based on professional judgment and past experience. The selected variables represent both positive and negative fire safety features and the assigned values are then operated on by some combination of arithmetic functions to arrive at a single value. This single value can be compared to other similar assessments or to a standard to rank the fire risk. Chapter 82 covers this subject.

Some measures used in fire risk analysis, such as *probable maximum loss* (PML), sound more fundamentally grounded than fire risk indexes but may actually be less so. There is no established consensus on how improbable a loss must be to be ineligible as the probable maximum loss, and the designation is sometimes given without benefit of any explicit or formal analysis. The resulting subjectivity of such a determination suggests that this value is more of an ordinal label than a quantitative measure of risk (which is not to say that it does not have usefulness).

Matrices and *contours* are methods that can fall between indexes and full-fledged probabilistic methods. A risk matrix typically provides a discrete partitioning of relative consequences along one dimension and relative likelihood along the other. The entry in each matrix cell may include a description of hazards known or believed to have that combination of consequence severity and likelihood, and may also be used to record judgments on the acceptability of such risks and/or recommendations on steps to take to reduce such risks. A risk contour is a continuous analogue to a risk matrix. Curves are drawn on a two-dimensional graph with one axis for consequence and one for probability, with a curve representing types of hazards or technically achievable states.

Probabilistic methods are the most informative approaches to fire risk assessment in that they produce quantitative values, typically produced by methods that can be traced back through explicit assumptions, data, and mathematical relationships to the underlying risk distribution that all methods are presumably seeking to address. Most of the chapters in this section of the handbook are devoted to engineering methods of use in executing a formal probabilistic analysis of fire risk. Some common, generic methods of fire risk analysis follow.

Event Tree An event tree is a graphical logic model that identifies and quantifies possible outcomes following an initiating event [4]. The tree structure is organized by temporal sequence. Probabilities can be calculated from the tree, and consequences are typically assigned to the end states but may cumulate along the tree.

Fault Tree A fault tree is a method for representing the logical combinations of various system states that lead to a particular outcome [4]. The tree structure is organized by logical dependency. Probabilities can be calculated from the tree. Consequences are typically defined in an either/or form (success or failure) so that the probabilities suffice to calculate the risk, as defined.

Decision Tree A decision tree is a method for representing the possible outcomes following a succession of events, combining points where the ensuing path is subject to choice and points where it is not. The analysis operates similarly to an event or fault tree, and the simplest decision trees consist of a set of initial choices and an event or fault tree associated with each.

Influence Diagram An influence diagram is a graphical representation of the relationship of the decisions and uncertainties in a decision problem [12, 13]. The diagram is more flexible and less unidirectional than any type of tree diagram. It is designed to focus more on the elements of decision making and less on relevant underlying physical phenomena.

Overview of the Section

This section of the handbook is organized into three broad areas that progress from the general to the specific. There are some basic tools that most approaches to fire risk analysis should consider if not incorporate. There are some examples of generic models applied to fire safety problems, and there are detailed descriptions of fire risk analysis procedures that have been adopted in several areas of application.

The most common use of fire risk analysis is as a basis from which to make choices. The choice may be between two alternative designs for a building or two alternative formulations for a model code or standard. The choice may be whether to tighten requirements on product type A or product type B. Chapter 77 describes *decision analysis,* a generic field on forms of analysis that support this kind of decision making. *Cost-benefit analysis* is a specific type of decision analysis, in which a fire risk analysis provides estimates for some of the benefits, and other analysis quantifies corresponding costs.

Chapter 74 addresses *reliability*. Fire risk analysis depends upon many types of probabilities. One is fire scenario probability, the estimation of likelihood for the initial conditions and ensuring major events in fire development. Another group of probabilities might be transitory conditions related to people, such as the locations and capabilities of occupants when a fire begins. A critically important set of probabilities have to do with status and capabilities of fire protection equipment, features, and arrangements. Is the battery working in the smoke alarm? Is the sprinkler valve open or closed? Is the fire door working or blocked open? These are all questions of reliability addressed in Chap. 74.

Chapter 76 addresses *uncertainty*. Early on, the comment was made that the term *fire risk* refers to the uncertainty of loss. The concept of safety itself is one of uncertainty. There is no such thing as absolute safety; human activity will always and unavoidably involve risks. Chapter 76 addresses a narrower definition of uncertainty—not the uncertainty of the potential victim regarding the fact of fire loss but the uncertainty of the engineer or decision maker regarding estimates of the magnitude of fire risk.

Uncertainty may be caused by imprecision or bias in our techniques of observation or calculation, a lack of clarity in our goals, uncontrollable technological variation, or variations of natural phenomena, to name only the major components. The concept of fire is also uncertain. Unwanted combustion is perhaps the least predictable common physical phenomenon. Uncertainty analysis is the scientific calculation procedure that should underpin choices of *safety factors* and *safety* *margins*. It is central to the valid use of fire risk analysis—or any other form of engineering analysis—for code equivalency, design approval, or any other important decision in the real world.

Chapter 78 addresses *data sources* for engineering analysis, particularly data useful for calculating scenario probabilities, reliability probabilities, or any other probabilities needed for fire risk analysis.

Chapter 79 addresses the *measurement of consequences in economic terms*. This measurement includes indirect losses, economic measures of the value of a lost life or of an injury, and the use of utility measures to capture people's desire to avoid uncertainty about loss, as well as loss itself, the implications for people's risk aversion for the basic mathematics of insurance, and so on. The common theme is treating consequences comprehensively and in a form that captures people's real preferences and can be readily compared to the costs of alternative choices. Chapter 81 addresses *other economic topics* that arise in the practice of engineering analysis, with particular emphasis on monetary valuations over time (e.g., rate of return, interest, discounting).

Chapter 80 describes techniques and available models using *computer simulation,* with special emphasis on those having a fire risk analysis basis, such as state-transition models. Chapter 82 describes less-quantified methods of fire risk analysis, involving *fire risk indexing*. Fire scenarios play an important role in many aspects of fire safety engineering. Significant among these is fire risk analysis, hence Chap. 38 describes methods of scenario development and quantification. This is a task that applies to all applications of fire risk analysis, though it tends to take a different form specific to each application, but is not required in this form or detail in other types of fire protection engineering analysis.

Chapters 75 and 83, respectively, describe general techniques and available methods for fire risk analysis of buildings and processes. Chapter 89 describes the specific methods tailored to application where the use of fire risk analysis is far more common than in others, namely, nuclear power plants. Chapter 90 describes applications for transportation vehicles. Chapter 84 presents the means to use fire risk analysis in the evaluation of the safety of consumer products. Chapter 85 shows applications to *health care facilities*.

Activities and Resources

Every major group involved in guidance related to fire safety now has a committee or a publication devoted to fire risk analysis, and the emphasis on risk-based or risk-informed approaches to decision making is growing rapidly. Thus, in addition to the many sources of specific models and methods mentioned in the subsequent chapters, there are a growing number of sources for generic work and guidance. Among the more important activities are the following:

- SFPE has added the *SFPE Engineering Guide to Fire Risk Assessment* to its growing collection of practice guides. In addition, fire risk analysis is addressed in context in a more limited form in the SFPE publication on an overview of performance-based design, the *SFPE Engineering Guide to Performance-Based Fire Protection.*
- NFPA's Technical Committee on Fire Risk Analysis, whose purpose is to provide assistance and guidance to other committees on methods and concepts in fire risk analysis, published NFPA 551, *Guide for the Evaluation of Fire Risk Assessments,* in 2004. The same committee now maintains NFPA 550, *Guide to the Fire Safety Concepts Tree,* 2002 edition, one of the most widely cited and used fault tree formats in fire risk analysis. Development of fire risk analysis methods for general and specific purposes has been a recurring emphasis of projects organized by NFPA's Fire Protection Research Foundation.
- ASTM maintains Standard E 1776, *Standard Guide for the Development of Fire-Risk-Assessment Standards,* to guide the writing of fire risk assessment standards for burnable products.

- The International Organization for Standardization (ISO) TC 92/SC 4 has published Technical Specification 16732, *Guidance on Fire Risk Assessment*. This international document is compatible with but much less detailed than the SFPE guide, which was published later.
- The Society for Risk Analysis is the principal worldwide professional organization devoted to risk analysis. It devotes comparatively little emphasis to engineering applications and to acute outcomes, instead focusing more on long-term chronic illness consequences.
- The Institute for Operations Research and the Management Sciences (InFORMS) has areas of emphasis in decision analysis and applies and develops risk analysis concepts and methods through that activity.

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