1 UNDERSTANDING, DECIDING, COMMUNICATING

1.1 The destination

The goal of this book is to organize the system of fire and buildings in a way that explains fire performance. The understanding that evolves during a performance evaluation will help professionals who work in the building industry make better decisions and communicate more effectively with others.

The procedures described in this book can be used for any existing or proposed new building involving any code, standard, or regulatory requirements. In addition to being applicable to any building size or use, the framework for analysis and evaluation procedures may also be adapted to ships, tunnels, and mass transport systems.

Before describing fire performance evaluations, we shall briefly discuss practices relating to building fire safety today. These practices are a basis for the way decisions are made. They affect ways of thinking about design, regulatory compliance, performance expectations, and fire risk management. If performance analysis requires a different way of thinking, a brief review of the current way of thinking enables the distinctions to be put into context.

1.2 Codes and standards

Fire safety decisions today are dominated by building codes, associated standards of practice, and insurance considerations. This is natural because they have been a part of the building process for nearly a century and have demonstrated success in reducing fire losses. The thought process for fire-related decisions is heavily influenced by experiences and interpretations of codes and standards.

Modern building code and standards development can be associated with the first few decades of the twentieth century. At the turn of the century, the second industrial revolution and the population growth in cities was well established. Fire was clearly recognized as a major threat to business, commerce, and society. For example, on March 21 and 22, 1916 three cities in the states of Georgia, Tennessee, and Texas had conflagrations that destroyed over 2700 buildings during that single period. The economic and social impact was devastating. A long-standing recognition of the fire threat, combined with regular and severe fire disasters provided a clear realization that something had to be done.

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Under the leadership of the insurance industry, it was decided that the most effective way of dealing with this major problem was through the building code system. Although building codes did exist at that time, they were not effective in dealing with the fire problem. A restructuring of the codes to deal with fire safety became a major focus of attention. Fire issues during the period around World War I evoked active debate and major decisions culminating with the publication in 1927 of the first edition of the Uniform Building Code (UBC) of the International Conference of Building Officials. This code established a framework from which the organization and practices of succeeding codes have been derived.

Structural, mechanical, and electrical parts of a modern building code are generally performance oriented. However, fire regulations are prescriptive for a number of reasons. The fire safety system is far more complex than other building design disciplines, and a century ago the knowledge base of fire technology was very rudimentary. Individuals with a professional focus on fire protection were not a part of the design team because fire was an "abnormal" rather than a "normal" design function. Existing practices in the building industry combined with historical precedents in the wording of building codes provided a way to structure and enforce fire safety requirements. This environment and a recognized urgency to solve the fire problem became driving forces toward the expediency of developing prescriptive rather than performance codes for fire.

One may look back with admiration at the prescriptive code system that was implemented eight decades ago. The influence of that code and standard system can clearly be identified with major improvements in fire safety and the preservation of economic values. Efforts by enforcement officials in code administration were a major factor in this success. During this time period, advances in fire equipment and knowledge, code improvements, better code administration, the fire service, and insurance protection have greatly diminished the fear of fire among citizens and reduced the concern of fire losses in the business community.

Nevertheless, the existing prescriptive code and standards system is not without its shortcomings. Prescriptive fire regulations developed by consensus committees may be described as a compilation of good practices that have a weak technical basis. They are "easy" to administer, yet difficult to control. Modern regulatory requirements are overwhelming, and the designer is often placed in an adversarial position with conflicts between regulatory conformance and building functionality needs. Questions often arise regarding the justification of certain requirements for a site-specific building condition. Cost and effectiveness are viewed differently by code officials and designers. Differences of opinion are rarely resolved by rational, analytical procedures to predict performance, because an analytical framework has not been established by the fire community.

It is important to recognize that a prescriptive code assumes the responsibility for fire safety rather than a design professional. The code official is a "policeman" obliged to administer the law. Consequently, in a prescriptive code environment, a building is required to "meet the code" rather than to be a fire-safe building. Insofar as the code specifies safety features, the building is presumed to provide a level of safety consistent with those requirements. When codes change, that base level of safety changes. Preexisting buildings are rarely required to be upgraded to the latest requirements. Over a period of time, any city will contain buildings that have been designed in conformance with widely varying sets of requirements. Which are correct? When should a building be upgraded to more modern requirements? How much is enough? How do we know?

The level of safety provided in a building code is indeterminate. Although a perception exists that a code-complying building is a safe building, that is not necessarily the case. Regulatory practices provide no way to measure the level of fire safety for a prescriptive code complying building. We do recognize that it is possible to configure architecture and to satisfy modern code requirements in a way that a building will perform poorly in a fire and pose a great risk to its occupants and mission. It is also possible to have a building of the same occupancy and size constructed in the same city under the same code to perform very well and have a minimal risk to its occupants and functions. The difference has more to do with designing fire defenses using understanding and sensitivity than in spending more money for fire-related features.

With all of the strengths and defects in building codes, accepted standards, and their administration, it is important to recognize that today's codes and the fire service provide whatever public fire safety is available to the citizen. And the code is the law.

1.3 Routine practices

In the design and approval of buildings for fire, routine practices are rarely routine. In building design and construction, compliance with the local building code is the usual focus. A thoughtful harmonizing of fire defenses by a trained and skilled fire safety professional to provide identified performance objectives and goals is rarely done. Both extremes can obtain necessary construction permits and certificates of occupancy. One is not necessarily more expensive than the other. Sometimes greater design investment can be offset by lower construction costs.

Regulatory approval practices and inspections by authorities having jurisdiction (AHJs) also can exhibit a wide range of attention. Some AHJs may require only two statements from the designer. One is that the building design complies with all applicable codes and standards, and the second is that construction followed the plans and specifications. Building permits and certificates of occupancy may be given upon receipt of these letters with little or no design review and construction inspection. At the other extreme, a code authority may meticulously review plans, approve equipment designs, conduct acceptance testing, and provide regular field inspections. The quality and extent of the services provided by AHJs depends on the workload of individuals, their qualifications and experience, and community management attitudes. A wide range of enforcement experiences can exist among jurisdictions.

Questions that arise during regulatory approvals can be complex and difficult. For example, how does an AHJ decide if a proposed design alternative is equivalent to a regulatory requirement? These are often known as trade-offs and they may have a substantial impact on building fire performance. Costs are important. How much is enough and what is excessive? Decisions of this type can have a major impact on building functionality, costs, and performance.

Practices of building and fire departments are nonuniform. In some jurisdictions the fire department may never be consulted or involved in the process. In other locations the entire approval process is administered within the fire department. Sometimes the fire department is consulted for advisory opinion only. In other cases the fire department may have approval authority only for certain requirements. A wide range of procedures exist, although a trend of greater fire department participation is emerging.

Differences of opinion about certain code interpretations, uneven enforcement, variability of participation by local fire departments, and the inadequacies of many architectural and engineering design teams in understanding fire and fire defense behavior (as opposed to understanding code requirements) can lead to very different performance among buildings. The vast inventory of existing buildings that have been constructed under different codes and conditions enables one to recognize the fire performance variability that can exist within any community.

The theme of this discussion is that the building code and its administration may produce a legal building, but that credential does not assure safety from fire. The emergence of the modern building code and its enforcement have contributed to an enormous improvement of fire safety. However, it is not difficult to identify legal buildings in which a fire caused extensive destruction or loss of life. All buildings and building operations have risk. Some buildings have much greater risk than others. Building code compliance as evidenced by a certificate of occupancy indicates that the building provides some level of safety, although that level is neither defined nor measured.

1.4 A way of thinking

Building performance evaluations require a different way of thinking from traditional practices. Because the emphasis is on understanding and describing performance, regulations and standards of practice offer little help. Instead, one needs an integrated framework to structure the process and behavior estimates to calibrate performance. Dynamic value estimates are based on available information and knowledge for the specific building being evaluated.

THE FOCUS IS ANALYSIS

Fire safety professionals are usually absorbed with demands of design. Design often involves obtaining information about code requirements, applicable standards, and AHJ expectations for obtaining necessary building permits and certificates of occupancy. Inherent to the process is the way in which fire defenses work and cost comparisons of alternate proposals. Design makes decisions about the best actions to take within existing constraints.

This book does not address building design. It does not recommend appropriate ways of designing, suitable values for design, or what to do to produce a better design. The design will have been completed as a prerequisite to evaluating how that design will perform.

The focus of this book is the analysis (evaluation) of building fire performance and the associated risk characterizations to people, property, operational continuity, neighbors, and the environment. An analysis starts with conditions that exist or have been selected for a proposed design. An analysis is structured around understanding what is rather than what should be.

ANALYTICAL FRAMEWORK

Performance evaluations are structured by an analytical framework that examines the functional performance of fire defenses and building features. The systems framework integrates the micro behavior of individual components with the macro building performance.

The framework organizes the complete building/fire system into discrete components that are based on functional performance. These components incorporate traditional active and passive fire defenses, such as sprinkler suppression, manual fire fighting, detection and alarm, compartmentation, and structural frame behavior. Life safety analysis is an integral part of the risk characterizations and is based on the performance expectations for the specific building being evaluated.

Performance evaluations enable one to compare alternatives in a disciplined manner. Thus, one can compare on a consistent, rational basis the impact of specific building features such as sprinklers, early detection and alarm, and smoke management systems on performance that affects risks to life safety, property damage, or operational continuity.

The framework is based on a thought process that tracks functional component performance. Because the thought process and component behavior are so intertwined, each chapter on component evaluation includes a description of the functional operation of the component. This description establishes a logic for the analytical structure.

PERFORMANCE MEASURES

The integration of performance measures into the analytical framework provides the basis for understanding building behavior. The function of this book is to organize a way of thinking that enables one to incorporate building observations with state-of-the-art fire science and engineering, traditional practices, standards, experience, and judgment.

There has been an explosion in knowledge about fire and fire defense behavior in recent years. In particular, the *SFPE Handbook of Fire Protection Engineering* [1], the *NFPA Fire Protection Handbook* [2], published standards of practice [3], computer programs [4] and a variety of books provide a wealth of information that may be incorporated into performance evaluations. This book describes how to organize that knowledge into measures of performance.

Fire performance is dynamic. For one period of time, one may be certain that a component will not act. During another time period one may be confident that it will act. Between these positions, a window of uncertainty exists. Performance within this window of uncertainty is estimated and expressed in descriptive terms or as a subjective probability. Performance is based on information and time available for the evaluation. The framework organizes the analytical needs to enable appropriate information to be selected for event evaluations. The way of thinking can remain constant while confidence in performance estimates grows as knowledge increases.

We work in a very imperfect world. Dynamic behavioral estimates almost always involve poorly understood and uncertain situations. Sometimes the insufficient knowledge is due to our own inadequacies. Sometimes it is because the state-of-the-art fire science and engineering are inadequate. Sometimes it is because important information is not available. Often, sufficient time and resources are not available to acquire the necessary information. Normally it is a combination of all these factors.

Even with all the difficulties encountered in performance evaluations, it is possible to make credible estimates with confidence. The process requires an organized, disciplined framework for thinking as well as a willingness to incorporate whatever knowledge is available to make the best estimates possible under the circumstances that exist at the time of evaluation. Judgment is an integral part of the process. Judgment is the glue that helps to blend available information and encode expected behavior into performance estimates that can be documented if necessary.

TRANSPARENT LOGIC

The understanding that evolves from performance evaluations enhances communication with others. Decisions affecting building fire performance often are made by individuals who have relatively little knowledge of buildings and fire or fire defense behavior. It is important to be able to describe clearly and easily the significance of site-specific building features on building fire performance. Documenting the logic for building performance becomes easier with the understanding that evolves from a complete systems evaluation.

1.5 Evaluation levels

In the world of fire resource and risk management applications, decisions for routine day-to-day decisions involve uncertainty. Koen [5] defines an engineering method as the strategy for causing the best change in a poorly understood or uncertain situation within the available resources. This concept is useful for fire performance evaluations and risk management applications that routinely involve uncertainty, a need or desire for additional information, and limited available time. Although much information and knowledge exists in fire safety, technical knowledge and standardized design guidelines have yet to reach the level of other mature technical disciplines. Consequently, an important aspect of applications is to make appropriate and efficient use of the available resources of time, money, knowledge, information, available procedures, equipment, and confidence.

The idea that one size does not fit all is an accurate concept when reading this book. Practical applications that involve fire performance can have a wide range of decision-making needs and cost limitations. To accommodate this range of needs and costs, three levels of performance evaluation are described:

- level 1: basic understanding;
- level 2: detailed understanding;
- level 3: sensitivity investigation.

A level 1 evaluation develops a basic understanding of the fire performance of a building and its risk characterizations. The goal is to understand the macro performance of a site-specific building. The key word is *understand*. A level 1 evaluation enables an individual to define the problem, identify the important building features that influence its performance, describe the behavior and the basis for those expectations, and characterize the risk. A focus of a level 1 evaluation involves the ability to recognize the ingredients that are important to performance and risk and gain a sense of proportion for relative magnitudes. Another aspect is time. Level 1 evaluations are rapid. The organization of the process, selection of key details, and ways of estimating performance are important.

Because a level 1 evaluation provides the basic understanding of how the building works, it is a part of all evaluations. Future actions are based on this knowledge. Perhaps the information is sufficient to make management decisions and no additional evaluations are necessary. Perhaps a comprehensive risk management program may be needed. Perhaps the results indicate that a level 2 or level 3 evaluation is needed only for one or a few components. A level 1 evaluation gives information about the building to make informed decisions on future courses of action.

The level 1 evaluation provides the basic information for a level 2 evaluation. A level 2 evaluation focuses on details of component quality and building behavior. While the organization, general structure, and thought process are the same as for level 1, details that affect performance receive much greater attention. The level 2 framework organizes the process in greater detail and the evaluation describes their influence more accurately.

Site-specific building features, fire science, engineering, and experiential knowledge are the main sources of information for performance estimates. Because the framework forces evaluations for relatively specific and narrow conditions, judgment can be used with greater confidence to integrate knowledge and information. When important "what if" questions arise about different conditions or materials, a level 3 sensitivity analysis may be appropriate. A level 3 evaluation investigates the significance of variations on performance.

1.6 Applications

Fire safety design decisions are made with specificity. That is, the water density of a sprinkler system is xx gpm/ft^2; type yy photoelectric smoke detectors will be installed in the following locations; fire department connections to the standpipes are located zz feet to the west of the main entrance; or the local fire department will respond with two pumpers, one ladder, a chief, and a staff of twelve. Someone during the design and construction process or in the local community government will have made those decisions. Decisions such as these can have a significant influence on the building's fire performance, or they may be relatively unimportant to the outcome of a fire. An evaluation can assess the significance of any detail with respect to the building's fire performance. It uses the performance knowledge to characterize risks and to document building or building alternative comparisons in a technically credible manner.

The primary objectives of a performance evaluation are

- to *understand* the building fire performance and risk characterizations;
- to *use* that understanding to make day-to-day work decisions easier; and
- to *communicate* more effectively with others.

The organized, structured procedures will enable decision makers to understand the problem, examine details, develop ways of strategic thinking, identify and evaluate alternatives, and recognize implications of decisions. The insight that is gained by a thoughtful performance analysis enables one to discuss and evaluate alternatives and recognize clearly why one course of action may be more desirable than another.

There are two major types of application that benefit from the understanding that follows a disciplined fire performance and risk characterization analysis. One addresses the management question, How can I do better with my available resources? The other considers technical decisions: Are the fire defenses appropriate for my objectives and how can I improve their performance quality?

Some examples of resource management are:

- *Operational planning*: local fire service officers can plan appropriate and safe fire department responses to specific potential fire incidents.
- *Performance expectations*: local fire service officers can communicate the fire suppression and life safety performance expectations more effectively to owners and occupants.
- *Fire risk management*: consultants and corporate managers can formulate fire risk management programs that integrate appropriate fire defense measures, insurance selection, and loss expectations into cost-effective plans that address specific needs.
- *Emergency planning*: consultants and corporate operations personnel can formulate emergency operational procedures that are tailored to the needs and activities of the specific building being studied.
- *Resource allocation*: business managers can make more informed decisions relating to allocations between accepting losses, transferring risks through the purchase of insurance, and reducing the risk by improving the building fire performance.
- *Risk discrimination*: insurance companies can evaluate the risk characterizations for different site-specific buildings more objectively to decide if they will insure and at what price.

Examples of technical decisions may include

- *Equivalency acceptance*: local authorities having jurisdiction (AHJ) can compare building code equivalency proposals on a consistent basis.
- *Code interpretation*: local AHJ examiners can interpret the functional basis for prescriptive regulatory requirements.
- *Performance-based design approval*: local AHJ examiners can have a basis for comparing a performance-based design with the equivalent performance that would be expected from prescriptive code compliance.
- *Impairment planning*: local fire departments can document a rationale for identifying acceptable equivalency alternatives during temporary impairment of fire protection systems for servicing.
- *Cost-effectiveness comparisons*: fire safety engineers can compare cost and effectiveness among fire defense alternatives more rationally.
- *Fire reconstruction*: fire investigators can plan and conduct fire reconstructions to compare the manner in which a building actually performed with the manner in which it had been expected to perform.

- *Design alternative comparisons*: an architectural design team can compare the fire performance and associated costs that could be expected from prescribed building regulations with those which could be expected using a desired alternative design.

1.7 Road map

Some fire professionals are knowledgeable about the complete systems performance of buildings. Others may specialize in certain parts of the complete process and have less detailed knowledge about other parts. Many individuals may understand codes well, but are not as comfortable with details of equipment. The fire service may be very knowledgeable of fire ground operations whereas others who have no experience will feel uncomfortable making the estimates. Some individuals may be starting on the road of fire protection. A variety of reader backgrounds are anticipated. The materials are organized to accommodate those differences.

The destination is a way of thinking about fire and buildings. This requires a general functional understanding of the major components and the critical events that influence their behavior. It also includes an acceptance that perfection is not attainable, but we do the best we can with what we have. The more one knows, the greater the comfort level in making estimates. Often a specialist may be very comfortable with estimating performance within his or her competence, but very uncomfortable when confronted with an area outside that scope of knowledge. We cannot rely on codes and standards to replace our understanding.

The way of thinking moves back and forth between microanalysis of individual components and the macrobehavior of the site-specific building. The intent is to relate the pieces to the whole. To do this, topics are organized into two packages. Chapters 2 through 6 describe basic concepts and tools for analysis. Chapter 4 describes a building that provides a unified thread for performance analysis. If one is interested in background, Appendix A describes the relationship of this framework to traditional risk assessment tools. Appendix B discusses the rationale for using subjective probability as the basis for performance measures, and Appendix C illustrates levels 1, 2, and 3 for a single component example.

Chapters 8 through 16 focus on the individual components. Chapters 18, 19, and 20 look at risk characterizations and risk management. Specialists in component design will be very knowledgeable in individual topics. However, the purpose is to describe the functional operations that form the basis for the thought process described by the framework. A basis for estimating performance is also provided. As with all performance estimates, the more one knows, the more narrow the window of uncertainty. Information for the major factors that influence performance provide a base for evaluations. In-depth references can provide more detailed information, if needed.

The goal of this book is to describe a way of thinking. An integral part of this thinking is decision making involving numbers and a sense of proportion. This gives some difficulty in dealing with measurements and units. SI units are generally used with fire science calculations, and there is no difficulty with direct conversion between English units and SI units. However, sometimes for convenience and often because the author doesn't know appropriate standard dimensions, US fire service or construction practices have been used. Practices in different countries use local standards. For example, the usual hose length in the United States is 50 ft; this is about 16 m. A visibility of 3 m is about 10 ft and a length of 13 ft is about 4 m. When the goal is conceptual association rather than precise correlation, a sloppiness has been used in conversions to convey a sense of proportion. Whether proper or not, this sloppiness is intentional. I hope that readers will forgive these shortcomings. Bon voyage.

References

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