

Fire Performance and Buildings

1.1 The Dynamics of Building Fire Performance

A building fire is dynamic because hostile fire characteristics change minute by minute. The dynamic fire produces products of combustion that affect the building and its fire defenses. The continually changing building environment influences time relationships for risk characterizations involving occupants and building functions. These actions occur in a variety of sequences and ways for different buildings.

During a fire, some components complete their roles and become inactive before other components become operational. Additionally, actions of some parts of the system depend on the status and sequential phasing of other components. Performance evaluations analyze interactions that combine time-dependent changes in the fire, building fire defenses, and people.

The goal of this book is to organize the complicated process into an analytical framework with which an engineer can evaluate fire performance. A performance evaluation enables one to understand specific component behavior as a part of holistic building performance.

Time is the common factor that links all of the important events.

1.2 The Anatomy of Building Fire Safety

Figure 1.1 shows the major parts of the complete system of fire performance for buildings. Initially, the system is organized into three major groups:

- 1) The *composite fire* combines a diagnostic fire and the active extinguishment actions provided by local fire department manual extinguishment and automatic sprinkler suppression, if present.
- 2) The *building response* is based on the flame-heat and smoke-gas products of combustion produced by the composite fire and their movement through the building. The process continues from ignition to extinguishment.
- 3) The *risk characterizations* for exposed people, property, and functions are based on the building's response.

Figure 1.1 is a static representation of the major parts. At each minute into the fire, the status of each part changes.

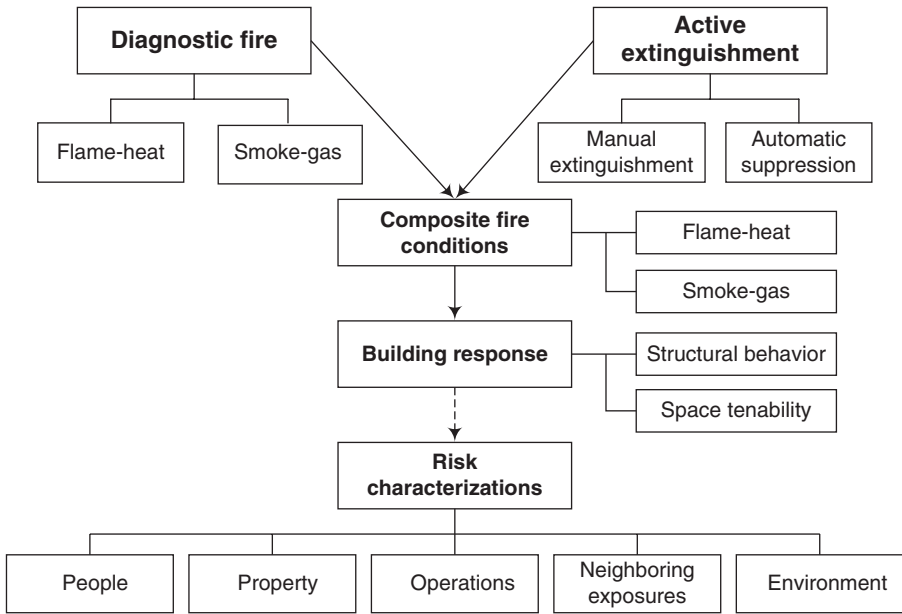


Figure 1.1 System components.

The analytical framework decomposes each part into components that can be evaluated separately. The components are recombined to incorporate the influences of time, fire conditions, and other components within the system. This allows each component to be evaluated as an independent unit and the effects combined to describe holistic performance.

1.3 Analysis and Design

Analysis and design are two sides of the same coin. In its most basic form, all design involves trial and error. For example, a design process starts by gathering information about a building's function, the design objectives, hazards to which the building will be subjected, the dimensional, material, economic and site constraints, and regulatory expectations. An initial trial design is formulated and then analyzed to evaluate the extent to which function, economics, and safety are acceptable. The design is then updated by changing parts of the trial design that did not perform in an acceptable manner. The iterative process of design–analyze–redesign continues until an updated design produces acceptable conditions for function, safety, and economy.

This book does not address building design, nor does it use any specific code or design standard. Rather, it describes how to analyze a building for a hostile fire. The results of the fire analysis provide a basis to characterize risk for people, property, and function. The goal is to describe a way to understand fire performance and risk characterizations for any existing building or proposed new building design. Although the book does not describe conventional procedures to accomplish design objectives, a performance analysis will give an insight into effective ways to achieve stated objectives.

1.4 Performance Analysis

A performance analysis creates an understanding of what to expect during a building fire. After evaluating the building's performance, one can identify associated risk characterizations to people, property, operational continuity, neighbors, and the environment.

Evaluation procedures integrate two distinct parts:

- 1) An analytical framework to provide systematic, methodical procedures to structure individual component behavior and integrate all parts into a holistic entity.
- 2) Quantification to provide numerical measures of performance.

The primary goal of this book is to identify a framework for analyzing fire performance in buildings. However, a framework is sterile without ways to quantify the critical events. One cannot exist without the other.

Fire safety is an emerging engineering discipline. Consequently, all numerical measures for component quantification do not have the same level of development. Some components, such as structural fire analysis and detector actuation, are relatively well developed and one can have confidence in calculations. Room fire models can provide accurate representations of behavior within their limits of theory and input knowledge. On the other hand, certain aspects of manual fire extinguishment, automatic fire suppression, and barrier effectiveness are inadequate for comprehensive numerical analyses. Nevertheless, the framework uses existing knowledge for quantification and developing a performance understanding.

Quantification uses any information or calculation tool that is relevant and seems appropriate to obtain the necessary numerical measures. Sources such as computer programs, experimental data, calculated values, observed information, and failure analyses become resources for quantification. Quantification procedures may be viewed as a set of tools. An engineer selects appropriate and available tools for each need. The framework organizes the analysis to incorporate quantitative measures of performance.

1.5 Quantification

The goal of a performance analysis is to understand expected building behavior and the associated risk characterizations during a fire. Building evaluations use specific fire scenarios to acquire this understanding.

A scenario evaluation uses three types of analysis. A *quantitative analysis* calculates outcomes using available information. Fire safety has not yet evolved to provide reliable, unique source quantification for the range of conditions routinely encountered in buildings. Therefore, the quantitative analysis is augmented by a *qualitative analysis* to provide a sense of proportion for expected behavior. A qualitative analysis incorporates many features that affect outcomes for interpreting numerical calculations.

Quantitative analyses and qualitative analyses are used together in an evaluation. Often, a quantitative analysis is a primary source for performance measures. The qualitative analysis helps to ensure that an outcome incorporates all of the important features and provides reasonable values. At other times, a qualitative analysis is the dominant

evaluative tool and quantitative information is used to augment or give confidence to the estimates. Qualitative analyses are often used to select initial scenarios that become the basis for a performance analysis.

Both quantitative and qualitative analyses are sensitive to changes in condition. For example, the status of a door being open or closed may significantly affect performance. Fuel packages may use differing construction materials that can have significantly different burning characteristics. This produces different time-related outcomes that, in turn, may affect the performance of other components.

Often, “what if” questions become evident during the decision-making function of scenario identification and one may wish to examine performance differences that could occur. A *variability analysis* provides a basis for ascertaining if possible changes will significantly affect performance outcomes or will have only a relatively benign influence. A variability analysis examines important questions that could affect quantitative or qualitative outcomes. Variability analyses establish “windows of behavior” to better understand building features that affect fire safety.

1.6 The Organization

This book organizes the complex system of fire in buildings in a way that enables one to understand both an individual component’s behavior and its effect on holistic building performance. This involves:

- 1) Identification of a comprehensive analytical framework. This framework is logically structured and consistent to be adaptable for any building and geographical location.
- 2) Use of deterministic component evaluations that combine state-of-the-art fire science with engineering knowledge and information.
- 3) Use of organizational charts to record key information and to visualize time-related complexity in a way that performance expectations may be explained to other professions.

The analytical framework is the primary focus of attention, and different aspects of the framework and its quantification are presented in each of the four units of this book:

Unit One: The Foundation. This unit describes the structure of the organizational framework. The framework adapts established techniques of other disciplines for fire safety evaluations. The Interactive Performance Information (IPI) chart becomes the central tool to relate time sequencing with critical events for performance evaluations.

Unit Two: The Parts. The functional behavior and operation of the major components are described in the context of the analytical framework. Functional and quantitative relationships provide guidelines for evaluation.

Unit Three: The Analysis. The descriptive base for the components of Unit Two is organized into networks that structure performance analysis. The networks, in combination with the IPI chart, enable variability analyses to be integrated efficiently into performance understanding.

Unit Four: Managing Uncertainty. Uncertainty and variability are unavoidable in building analysis. This unit introduces different ways to manage uncertainty and to communicate results to non-fire safety professionals.

Collectively, the four units address different aspects of fire safety analysis to provide a comprehensive treatment of a way to consistently evaluate the performance of any building.

In general, the chapters are “stand-alone” units that allow a reader to select topics that satisfy specific needs. Although there is a thematic structure, one need not move sequentially through intervening chapters. Rather, specific topics may be selected to augment information for component functions, operations, quantification, and analysis.

