US Department of the Interior
National Park Service
National Center for
Preservation Technology and Training
Publication No. 1998-08

Development of a Prototypical Historic Fire Risk Index to Evaluate Fire Safety in Historic Buildings

Final Report

prepared with the support of the

National Center for Preservation Technology and Training
National Park Service
United States Department of the Interior

February 1998

principal investigators:

John M. Watts, Jr., Ph.D.
Fire Safety Institute
P.O. Box 674
Middlebury, VT 05753

Marilyn E. Kaplan
Preservation Architecture
51 Round Lake Road
Valatie, NY 12184

Funding for this report was provided by the National Park Service's National Center for Preservation Technology and Training, Natchitoches, Louisiana. NCPTT promotes and enhances the preservation of prehistoric and historic resources in the United States for present and future generations through the advancement and dissemination of preservation technology and training.

NCPTT's Preservation Technology and Training Grants program develops partners in non-profit organizations, universities and government agencies throughout the United States to complete critical preservation work and lends significant support to developments in the conservation and preservation community.

Development of a Prototypical Historic Fire Risk Index to Evaluate Fire Safety in Historic Buildings

CONTENTS

Development of a Prototypical Historic Fire Risk Index to Evaluate Fire Safety in Historic Buildings

prepared for the
National Center for Preservation Technology and Training
by the
Fire Safety Institute
Middlebury, Vermont

Executive Summary

The difficulty of imposing building and fire codes on historic buildings has been a subject of wide spread concern in recent decades. Most such codes are prescriptive, specification-based criteria that rigidly dictate how a building should be constructed or rehabilitated. They are oriented to new buildings, anticipating modem construction materials and assemblies. When applied to historic buildings such code requirements are often impractical or damaging to architectural and historic character.

Fire risk indexing is a more flexible and inclusive technique for evaluating alternative fire safety configurations in buildings. A fire risk index is a tabular tool for analyzing and scoring hazards and other risk parameters that describe various building features or systems related to fire safety. Numerical values assigned to these parameters are arithmetically manipulated to create a single mathematical expression for the overall level of fire safety provided by the building. Like the codes, existing fire risk index systems focus on modern construction techniques. While these indexing systems can be useful tools for rehabilitation projects, they do not include the range of alternatives that are appropriate for buildings of historic significance.

This project, funded by NCPTT, has produced a prototype fire risk index specifically for historic house museums. An historic house museum is defined as a structure with recognized historic designation, or apparent historic significance, that is open to the public to display the building and its contents. Most often, the historic house museum was originally designed as a single family home. It is typically managed by professional or qualified staff or volunteers with specific expertise in museum management or historic preservation. To a significant extent, the fire risk is dictated by its relatively small size and characteristic function.

The Historic Fire Risk Index (HFRI) is based on two existing risk indexes that have established empirical validity. From these systems, a combined set of fire safety parameters was mathematically normalized and ranked according to their intrinsic level of significance. The parameter list was then adapted for application to historic house museums. This process had four stages: (1) some parameters were identified as not applicable to historic house museums and were deleted from the list, (2) some parameters were combined to better represent their effectiveness, (3) some parameters were expanded to amplify their importance, and (4) new parameters were added to cover the range of fire risk in historic house museums. This latter is the most significant as it introduces fire prevention, emergency response, and historic significance, areas not explicitly addressed by building codes.

The resulting list of eleven fire risk parameters is the essence of the HFRI. Associated with each parameter is a weight or measure of importance derived from the existing fire risk index systems. Onsite survey of an individual historic house museum determines the presence of physical factors that influence effectiveness of the parameters. From this information, a numerical grade for each parameter is calculated by reference to prescribed algorithms created in this research or adapted from existing fire risk index systems. A total fire safety score is computed as the weighted sum of the parameter weights and grades. This score may be compared with an alternative configuration of parameters within a specific historic house museum or to different facility. The result is a relative comparison of fire risk that allows more flexibility than existing building and fire codes. Preliminary field testing has established the HFRI as a workable prototype and identified areas for future improvement.

Overview

This project has produced a workable prototype of a fire risk indexing system for historic house museums. Referred to as the Historic Fire Risk Index (HFRI), it is partially based on analysis of existing risk index systems that have established empirical validity Comprehensive description of the research and development of the prototype HFRI is contained in two major articles that have been submitted to peer reviewed journals:

“One Approach to Creating a Performance Code for Historic Buildings The Historic Fire Risk Index”, submitted to *APT Bulletin.*

“Fire Risk Index for Heritage Buildings”, submitted to *Fire Technology.*

These articles are the primary substance of this report as together they constitute a detailed account of the project including references for the technical literature reviewed.

The HFRI Prototype

The prototype Historic Fire Risk Index consists of five parts: (1) an introduction and General Instructions for use of the system, (2)a Building Data Sheet to be used in collecting appropriate information about a specific historic house museum, (3) a Grading Sheet used to compute the total fire safety score for a particular building, (4) Parameter Grading Schemes that detail how a numerical grade for each parameter is generated from survey data, and (5)a Glossary of terms used in the fire risk indexing process. This package of materials comprises the prototype HFRI and a copy is included in this report.

Dissemination of Information

The work on this project has been widely publicized. In addition to the articles mentioned above, numerous presentations at professional meetings were made by members of the research team and several papers have been published in the proceedings of these meetings. Additional in-house reports provide background for future work. These papers and appearances are listed below:

"Performance-Based Approaches to Protecting our Heritage", *Proceedings of the International Conference on Performance-Based Codes and Fire Safety Design Methods.* Ottawa, Canada, 24-26 September, 1996, Society of Fire Protection Engineers, Boston, 1997.

"Fire Risk Assessment for Historic Buildings," presented to SFPE New Zealand Chapter Christchurch, NZ, 12 March 1997.

"Fire Risk Index for Historic Buildings", presented to NFPA Technical Committee on Protection of Cultural Resources, Oyster Bay, NY, 1 May 1997.

"Development of an Historic Fire Risk Index," presented at the National Fire Protection Research Foundation, Fire Risk and Hazard Assessment Symposium, San Francisco, CA. June 1997.

"Analysis of the NFPA Fire Safety Evaluation System for Business Occupancies," *Fire Technology,* Vol. 33, No. 3, August 1997.

"Fire Risk Evaluation in the Codes: A Comparative Analysis," presented at the 2nd International Conference on Fire Research and Engineering, Gaithersburg, MD, August 1997.

"Fire Risk Analysis", presented at Vermont Museum and Gallery Alliance Workshop, 19 February 1998.

"Analysis of Wisconsin Building Evaluation Method", Unpublished Research

"An Analysis of BOCA Section 3408 for Business Occupancies", Unpublished Research

"Building Significance Rating Systems", Unpublished Research

Directions for Future Work

The prototype HFRI is the first published draft of a risk index system dedicated to historic buildings. Additional research is needed to develop this prototype into a working model that would be suitable for adoption by a code organization or governmental body for application to historic buildings. Future research efforts should include:

- Expanded definitions for parameters and subparameters requiring less subjective responses in data collection, e.g. Housekeeping or Management/Fire Safety Plan.
- Format redesign to create a more user-friendly document.
- Improved tutorial material and refinement of instructional procedures for implementation.
- Validation with additional field testing.
- Development of guidelines for calibration of minimum safety scores.
- Evaluation of redundancy features that may correspond to the codes' reliance on inherent redundancies.
- Address parameter interactions and interdependencies.
- Sensitivity and uncertainty analysis of the linear additive model, especially to relaxation of parameter independence assumption.
- Coordination and integration with NPS facility evaluation questionnaire
- Review and analysis of insurance rating schedules to assess parameter importance in property protection.
- Better integration of computer fire models.
- Improved definition of role in performance-based fire safety evaluation.
- Expansion to other occupancies in historic buildings and non-historic, existing buildings.

DEVELOPMENT OF A PROTOTYPICAL HISTORIC FIRE RISK INDEX TO EVALUATE FIRE SAFETY IN HISTORIC BUILDINGS

Marilyn E. Kaplan, Architect
Preservation Architecture
51 Round Lake Road
Valatie, New York 12184

and

John M. Watts, Jr., Ph D., Director
Fire Safety Institute
P.O. Box 674
Middlebury, VT 05753

Submitted to *APT Bulletin*, November 1997

prepared with the support of
National Center for Preservation Technology and Training
United States Department of the Interior/National Park Service
Northwestern State University
P.O. Box 5682
Natchitoches, LA 71497

Submitted to *APT Bulletin,* November 1997

DEVELOPMENT OF A PROTOTYPICAL HISTORIC FIRE RISK INDEX TO EVALUATE FIRE SAFETY IN HISTORIC BUILDINGS

Marilyn E. Kaplan, Preservation Architecture, Valatie, New York
John M. Watts, Jr., Fire Safety Institute, Middlebury, Vermont

In the context of fire protection, historic buildings have long been under served by the architectural and engineering professions. They have suffered from inadequate attention, and subsequently inadequate protection, given the difficulties and costs involved in retrofitting them to meet current standards. Aesthetic impacts are paramount, access to concealed spaces is limited; and many curators fear that insensitive installations will destroy a building's historic character, or that water discharge from a suppression system will destroy collections. Moreover, historic buildings do not conform to the generic construction model on which modem codes and fire protection systems are based.[1] While codes for new construction focus on life safety, historic buildings present an additional challenge---that of protection of the property itself.

Until the 1970s, many historic buildings were used or rehabilitated under the guise of "don't see, don't tell." Code enforcement officers lacked technical expertise for historic buildings and little guidance was available since preservation represented such an infinitesimal portion of the construction market. The term "historic building" was often assumed synonymous with museum, and, given the perceived low fire risk, variances and exceptions from code requirements were often granted by the code enforcement officer.

The advent of the American historic preservation movement in the 1960s and 1970s brought historic designation to thousands of buildings and the rehabilitation of many of these for residential, commercial and institutional use. These substantial rehabilitation projects were required to comply with the same building codes that were written for new construction, as well as local, state, and federal reviews that insured the retention of historic character. An inherent conflict gained widespread recognition---the difficulty of maintaining the character of historic materials and spaces while achieving the level of safety expected of new construction, the latter of which is likely to require physical interventions that can destroy significant materials or spaces.

Since the late 1970s, to accommodate rehabilitation projects, special codes that recognize the differences between rehabilitation and new construction have been published by model code organizations and government entities. [2] However, negating these codes' efforts to provide flexibility for rehabilitation projects has been an evolving increase in the complexity of all building codes. This trend reflects society's expectations of increased safety, the application of research and technology, the litigious nature of the building industry, administrative efforts to maximize standardization and predictability and to minimize the discretion of the code official, and, not inconsequentially, the codes' availability as receptors for legislative reactions to catastrophic events.

However for the historic building, a host of additional problems persist At the core of these are the difficulty of integrating the technical language of the codes with the philosophical language of the *Venice Charter* or the *Secretary of the Interior's Standards for the Treatment of Historic Properties,* and the difficulty in standardizing buildings that are unique in construction, condition, integrity and current or proposed use.

Parallel to the desire for increased flexibility in the codes has been the reemergence of performance-based codes, documents that differ from their specification-based counterparts, which rigidly specify requirements, by establishing design goals that identify the level of safety to be met. In performance-based codes, it is the role of the design professional, rather than the codes, to specify construction materials and techniques that will achieve that level of safety. One of the principle shortcomings hampering full adoption of performance-based codes is the lack of commonly available methods to evaluate equivalently safe alternatives, a topic currently being addressed by the code community.

Fire Risk Index Systems

The prototype Historic Fire Risk Index (HFRI) described in this paper was created to address some of the above described problems It is a mathematically expressed, performance-based tool that allows a variety of building features to be considered when evaluating the level of safety provided by a specific building. The HFRI provides a focus on protection of property and collections, and gives credit for good fire safety practices. While not inconsistent with prevailing codes, the HFRI is not code dependent and can be used independently.

The HFRI is a descendant of other fire risk index systems that analyze and score fire hazards and other risk parameters.[3] The numerical values assigned to these parameters and their subparameters are arithmetically manipulated to create a single mathematical expression for the overall safety level of the building. The parameters and subparameters represent various building aspects or systems related to fire safety, such as egress, detection and alarm systems, and smoke control systems.

The two risk index systems most commonly used for fire safety applications are the "Fire Safety Evaluation System" (FSES) included in the National Fire Protection Association's *Guide on Alternative Approaches to Life* Safety[5], and "Chapter 34, Existing Buildings" of the *BOCA National Building Code.*[6] The State of Wisconsin's risk index system[7], developed for historic buildings in 1996, is largely based on the BOCA model. While some variations exist among these systems, they share a focus on life safety rather than on property protection.

These risk index systems can be useful tools for rehabilitation projects, although they do not expressly consider the significance of the historic site or give credit for fire prevention, a significant and readily achievable fire safety feature in well managed historic buildings operated as museums and historic houses.

The Historic Fire Risk Index

For the creation of the prototype HFRI, an uncomplicated, but culturally significant, building type, the historic house museum, was selected. Historic house museums are usually pristine buildings with valuable collections whose architectural character can be adversely effected by rigid application of building and fire codes, and it is reasonable to assume that they will not include high risk occupancies, such as those involving hazardous processes or sleeping accommodations. Further, they have the capability of having an extensive, site based fire prevention program that includes features such as staff training and a managerial commitment to fire safety planning. For this project, the historic house museum is defined as:

> A structure, originally designed as a single family residence, of less than 12,000 square feet with recognized or apparent historic significance that is open to the public in order to display the building and its contents. Collections are exhibited in their original context rather than in displays segregated by type or material. The building retains its historic form and details, and has not undergone extensive modifications or modernizations.
>
> Management is by professional or qualified staff or volunteers with specific expertise in museum administration or historic preservation. There are no residential or lodging uses, or conservation processes using laboratory-type facilities, within the building. Accessory functions are limited to museum offices and storage. For building code and NFPA *Life Safety Code* applicability, no room exceeds the capacity of forty nine persons and the structure is classified as a business occupancy.

In the development of the HFRI, the BOCA, Wisconsin and FSES risk index systems were evaluated for their applicability to historic house museums. The distinguishing characteristics of these systems is summarized as follows:

	BOCA	**WISCONSIN**	**FSES**
OBJECTIVES	safety to life and property	safety to life and property	protection of occupants not involved with ignition
NEW vs. EXISTING	existing buildings only	historic buildings only	both new and existing buildings
LEVEL OF SAFETY FOR EXISTING BUILDINGS	greater than for new buildings	greater than for new buildings	less than for new buildings
OCCUPANCIES	all	all	Selected
OCCUPANCY TREATMENT	same set of parameters with different values	same set of parameters with different values	different set of parameters for each occupancy
SCORING	zero-based	zero-based	table of mandatory scores
AREA	entire building	entire building	zones within building

A comparison of the three systems was achieved by a process of mathematically normalizing the parameters included in each. Normalizing required a determination of the spread between the minimum and maximum values of each parameter. The spread was considered to indicate the potential magnitude of that parameter's effect on the General Fire Safety Score and thus a relative measure of the importance of the parameter to life safety. The greater the spread, the greater the impact of the parameter on the fire safety score, and thus the greater the imputed importance.

The spread of each safety parameter was determined from the formulas included in the FSES and BOCA systems. Where computations were required, an imaginary five story building with a maximum ground area of 30,000 square feet and unprotected, combustible construction was used this building description encompasses most historic house museums, and represents the lower limits of building height and area included in BOCA and the FSES.

Once normalized, the BOCA and FSES parameters were ranked according to the intrinsic significance given that parameter by the index system, as shown in *Table 1.* Wisconsin's index system was not included in this exercise given its similarity to the BOCA model, although continued to be used as a reference.

The ranked values for the two systems were then averaged to provide a single working list representing the relative weight of each parameter. (See *Table 2).* The BOCA/FSES list was reconfigured reflecting the authors' judgement of the significance of the various parameters, the grouping of subparameters into overall parameter categories (e.g. the inclusion of the hazard segregation, fire resistance of interior walls, and attic compartmentation subparameters in a parameter entitled Compartmentation parameter); the exclusion of parameters determined to be inapplicable to the historic house museum or adequately addressed in other parameters/subparameters; and the inclusion of new parameters and subparameters relevant to the historic house museum (See *Table 3).*

The final working list of the HFRI includes eleven fire safety parameters, most of which are defined by two or more subparameters, as illustrated below:

Parameter	*Subparameters*
Fire Prevention	Exposure, Security, Staff Training, Management/Fire Safety Plan, Housekeeping
Egress	Adequacy, Utilization, Protection, Availability
Significance	Building, Contents
Vertical Openings	Floors Penetrated, Protection, Firestopping
Automatic Suppression	Coverage, Response Time
Building Height and Construction	Height, Construction
Compartmentation	Hazard Segregation, Interior Walls, Attic Compartmentation
Fuel	Fire Growth Rate
Detection and Alarm	Detection, Alarm
Emergency Response	Capability, Site Water Supply, Response Time, Accessibility
Smoke Control	---

The Historic Fire Risk Index Prototype

The HFRI prototype consists of four sections Part 1, *General Instructions,* Part 2, *Building Data Sheet,* Part 3, *Grading Sheet,* and Part *4, Parameter Grading Schemes.* These parts describe a process to evaluate a building's fire safety characteristics, defined as parameters and subparameters, and to enable a quantitative analysis of a building's level of safety to be performed. It is intended that the HFRI will be conducted by a professional familiar with architectural and fire safety features.

Most of the HFRI's parameters and subparameter grades are determined by information readily available through onsite inspection of the building. Information is gathered and organized according to the questions included in the *Building Data Sheet.* Subparameter grades are determined by reference to the *HFRJ Parameter Grading Schemes.* To illustrate, the following Grading Schemes are provided for two of the HFRI's eleven parameters, Historic Significance and Vertical Openings.

3. HISTORIC SIGNIFICANCE

***DEFINITION* :** Characteristics of a buildings and its contents that are architecturally or historically distinct.

SUB-PARAMETERS:

3.1 ***Building -*** Historic and architecturally characteristics of the building that enhance the need for fire protection and for which the impact or intrusion of installed fire protection features is a major concern. Determined from classified significance and overall quality of the building.

	SCOPE OF HISTORIC SIGNIFICANCE		
QUALITY	National Historic Landmark	National/State Significance*	Local Significance
Excellent	5	4	3
Good	5	4	2
Typical	5	3	1

*Listed on, or eligible for, national or state register

3. 2 ***Contents*** - Artifacts and archives of significance that may be particularly susceptible to effects of heat, nonthermal fire products, and water damage.

HISTORIC GRADING	
Irreplacable	4
Replaceable	3
Expendable	2
Reproducible	1

PARAMETER GRADE: **(BUILDING + CONTENTS - 2)/1.8**

4. VERTICAL OPENINGS

DEFINITION: potential paths of fire spread between floors.

SUB-PARAMETERS:

4. 1 ***Floors penetrated*** - percent of total number of floors that are penetrated = floors penetrated/total number of floors

KEY	%
0	1 story bldg
A	< 50
B	50 to < 100
C	100

4.2 ***Protection of floor penetrations*** - minutes of fire endurance

KEY	MINUTES
A	> 30
B	20 to 30
C	< 20

4. 3 ***Fire stopping*** - add one point to grade

PARAMETER GRADE:

SURVEY ITEM										
Floors penetrated	0	A	A	A	B	B	B	C	C	C
Protection	-	A	B	C	A	B	C	A	B	C
GRADE	4	4	3	1	3	3	1	3	2	0

The total Fire Safety Score of a building is calculated on the *HFRI Grading Sheet* by summing the fire safety score for each parameter, determined by multiplying the parameter grade 'A' by its weight factor 'B' *See Table 4.*

This prototype does not establish minimum safety scores and is not coordinated with specific code requirements. Calibration procedures will be established in the next phase of development following peer review. In the interim, the prototype is a useful, preliminary tool for comparing a group of buildings or separate spaces within a single building in order to determine where additional fire protection measures are most warranted.

Field Testing

Preliminary field testing was conducted at two historic sites, Lorenzo State Historic Site and the Sheldon Museum, in order to determine the usability of the HFRI and to identify potential modifications for future incorporation.

Lorenzo State Historic Site, located in Cazenovia, New York, is a brick mansion built in 1807-1808 as a single family residence. The wood frame, two story structure was designed with certain fire safety details reflecting Lincklaen's experience of losing his previous residence to fire. The building has a wood frame, two story wing at the rear. Lorenzo was acquired by New York State from descendants of the original family in 1968. The Sheldon Museum in Middlebury, Vermont is a two story brick structure constructed in 1829 as a single family residence. Interior framing is wood Alterations to the building include the additions of 1972 and 1990-1991.

Field testing confirmed the need for the next version of the HFRI to consider safety issues typically influenced by site operations but not addressed by building codes. Examples of these are the upkeep of unlocked and unblocked egress routes, and the maintenance of adequate and safe heating and electrical installations. While such items have significant impact on a building's level of safety, they are inconsistently addressed by management policy or by periodic inspections such as those often required by fire safety codes.

One of the field tests was undertaken by a surveyor unfamiliar with the HFRI, but with extensive experience in fire safety and code enforcement. While supportive of the prototype, the surveyor noted the difficulty in using it without additional background information or training on the HFRI.

Since the HFRI will be one of the first performance-based approaches for historic structures to be presented to the code and architectural communities, an educational component will be necessary to communicate its spirit and intent. Explanatory materials should be developed to provide additional definitions and guidance for the subjective decision-making required, and an example of an executed HFRI may be useful. Further refinements of the HFRI should also consider the ease of gathering data, the expertise required of those conducting the survey, and the format and usability of the final product.

Conclusions

The prototype HFRI described in this paper is the first risk index system dedicated to historic buildings that prioritizes the goal of protection of the significant building and its contents, introduces fire protection, focused on management and operational components, and considers emergency response and fire growth rate. The prototype provides a clear framework with carefully considered subparameters and parameters, and a transparent process for mathematically expressing a building's safety. With the framework and arithmetic process now established, further development, in a context of peers, can proceed readily.

To advance the prototype into a working model suitable for adoption by a code organization or governmental body, the prototype HFRI will require review by a peer group, validation by subjection to testing on a greater number of buildings, and calibration. The final HFRI should also include expanded definitions for parameters and subparameters requiring more objective responses in data collection.

While this prototype has been designed for the historic house museum, the process of its development can readily be duplicated to create an HFRI for other historic building types and occupancies. It is assumed that the list of included parameters and subparameters, and the weight and ranking each is given, will be uniquely determined for each specific building type or occupancy.

ACKNOWLEDGMENT

This work was partially supported by a grant from the National Park Service/National Center for Preservation Technology and Training. The contents of this paper are solely the responsibility of the authors and do not represent the official position or policies of any supporting agencies.

Table 1

Comparative Parameter Spreads for BOCA (1996) and FSES (1995) (Business Use Group/Occupancy)

BOCA PARAMETER	S	NS	FSES PARAMETER	S	NS	AVG
1. Building Height	30	1.66	1. Construction	14	1.85	1.75
2.BuildingArea	40	2.21			0.00	1.10
3. Compartmentation	20	1.10			0.00	0.55
4. Unit Separations	8	0.44			0.00	0.22
5. Corridor Walls	10	0.55	11. Corridor/Room Sep	10	1.32	0.94
6. Vertical Openings	72	3.98	3. Vertical Openings	10	1.32	2.65
7. HVAC Systems	20	1.10			0.00	0.55
8. Automatic Fire Detection	12	0.66	6. Smoke Detection	4	0.53	0.60
9. Fire Alarm System	15	0.83	5. Fire Alarm	6	0.79	0.81
10. Smoke Control	4	0.22	8. Smoke Control	4	0.53	0.37
11. Means of Egress	1	0.06	10. Exit System	11	1.45	0.75
12. Dead Ends	4	0.22	9. Exit Access	4	0.53	0.37
13. Max Travel Distance	40	2.21	9. Exit Access	-	0.00	1.10
14. Elevator Control	8	0.44			0.00	0.22
15. Egress Emergency Light	4	0.22			0.00	0.11
16. Mixed Use Groups	10	0.55			0.00	0.28
17. Sprinklers	24	1.33	4. Automatic Sprinklers	12	1.58	1.45
18. Spec. Occ. Area Protect	4	0.22	2. Segregation of Hazards	7	0.92	0.57
		0.00	7. Interior Finish	5	0.66	0.33
		0.00	12. Occ Emergency Prog	4	0.53	0.26
Totals	326	18		91	12	15

Tables 1 compares the BOCA and FSES parameters according to spread **(S)** and normalized spread **(NS).** The greater the spread, the greater the imputed importance of the parameter.

Table 2

Ranked Average Normalized Spread for Combined BOCA and FSES Parameters (Business Use Group/Occupancy) Expressed as Percentage of Their Sum

PARAMETER	%
Vertical Openings /Vertical Openings	18%
Building Height/Construction	12%
Sprinklers/Automatic Sprinklers	10%
Building Area	7%
Maximum Travel Distance/Exit Access	7%
Corridor Walls/Corridor/Room Separation	*6%*
Fire Alarm System/Fire Alarm	5%
Means of Egress/ Exit System	*5%*
Automatic Fire Detection/Smoke Detection	4%
Spec 0cc Area Prot/Segregation of Hazards	4%
Compartmentation	*4%*
HVAC Systems	4%
Smoke Control/Smoke Control	2%
Dead Ends/Exit Access	2%
Interior Finish	2%
Mixed Use Groups	2%
Occupant Emergency Program	2%
Unit Separations	1%
Elevator Control	1%
Egress Emergency Lighting	1%
Total	100%

Analysis of two widely used multiple-attribute fire-safety evaluation systems produced this combined list of 20 fire safety parameters. The importance associated with each of the parameters has empirical validity based on the accepted use of these systems by fire safety professionals and building code officials.

Table 3

Weighted Parameters for Fire Safety Evaluation of Historic House Museums

PARAMETERS	%
Fire Prevention	15%
Egress	13%
Historic Significance	13%
Vertical Openings	12%
Automatic Suppression	8%
Building Height & Construction	8%
Compartmentation	8%
Fuel	8%
Detection & Alarm	5%
Emergency Response	5%
Smoke Control	5%
Total	100%

Table 4

HFRI Grading Sheet (Part 3)

GRADING SHEET				
No.	**PARAMETER**	**PARAMETER GRADE (A)**	**WEIGHT % (B)**	**FIRE SAFETY SCORE (A x B)**
1.0	**FIRE PREVENTION** Exposure Security Staff Management/Fire Safety Plan Housekeeping		15%	
2.0	**EGRESS/EVACUATION** Adequacy (Automatic suppression, travel distance) Utilization (detection and alarm, emergency lighting) Protection (exits, ways out, direct exit) Availability (capacity, dead ends)		13%	
3.0	**SIGNIFICANCE** Building Contents		13%	
4.0	**VERTICAL OPENINGS** Floors Penetrated Protection Fire Stopping		12%	
5.0	**AUTOMATIC SUPPRESSION** Coverage Response Time		8%	
6.0	**BUILDING HEIGHT & CONSTRUCTION** Height and Construction		8%	
7.0	**COMPARTMENTATION** Hazard Segregation Interior Walls Attic Compartmentation		8%	
8.0	**FUEL** Fire Growth Rate		8%	
9.0	**DETECTION AND ALARM** Detection Alarm		5%	
10.0	**EMERGENCY RESPONSE** Fire Service Capability Water Supply Response Time Accessibility		5%	
11.0	**SMOKE CONTROL**		5%	
TOTAL FIRE SAFETY SCORE				

Endnotes

1 . Kaplan, Marilyn E., “The Regulation of Existing and Historic Buildings,” unpublished thesis, 1996.

2 . Kaplan, Marilyn E. and John M. Watts, Jr., “Performance-Based Approaches to Protecting our Heritage,” in Proceedings, 1996 International Conference on Performance-Based Codes and Fire Safety Design Methods, Ottawa, Canada, Boston Society of Fire Protection Engineers.

3 . Watts, John M. Jr., “Fire Risk Evaluation in the Codes: A Comparative Analysis,” presented at the Second International Conference on Fire Research and Engineering, National Institute of Standards and Technology, Gaithersburg, MD, August 1997.

4. Watts, John M. Jr. and Marilyn E. Kaplan, “Fire Risk Index for Heritage Buildings,” submitted to *Fire Technology*.

5. NFPA 101A, *Guide on Alternative Approaches to Life Safety*, National Fire Protection Association, Quincy, MA (Chapter 7) 1995.

6. *The BOCA National Building Code/1996,* Building Officials and Code Administrators International, Country Club Hills, IL 1996.

7. Wisconsin Administrative Code, Chapter ILHR 70, Historic Buildings, Department of Industry, Labor and Human Relations, Madison, WI, June 1995.

FIRE RISK INDEX FOR HERITAGE BUILDINGS

John M. Watts, Jr., Ph.D.
Director
Fire Safety Institute
P.O. Box 674
Middlebury, VT 05753

and

Marilyn E. Kaplan
Preservation Architecture
51 Round Lake Road
Valatie, NY 12184

Submitted to *Fire Technology*, February 1998

prepared with the support of
National Center for Preservation Technology and Training
United States Department of the Interior/National Park Service
Northwestern State University
P.O. Box 5682
Natchitoches, LA 71497

Submitted to *Fire Technology*, February 1998

Fire Risk Index for Hertiage Buildings

John M. Watts, Jr., Fire Safety Institute, Middlebury, Vermont
Marilyn E. Kaplan, Preservation Architecture, Valatie, New York

Abstract

Fire protection engineers and preservation architects have long recognized the difficulty in applying building and fire codes to historic buildings. Prescriptive codes that dictate how a building should be constructed rely on specification standards derived from technology and research on modem construction materials and assemblies. When applied to historic buildings, these codes can mandate impractical solutions or those that require extensive, unacceptable alterations. Although performance-based fire safety evaluation offers an alternative approach, most performance-based evaluation procedures involve elaborate computer modeling techniques. These methods are cost effective for only 5 to 10 percent of new buildings and for an even smaller percentage of existing buildings.

Small, older buildings of significant historic value need a more efficient approach to performance-based evaluation. One technique that has gained acceptance is fire risk ranking or risk indexing. The Historic Fire Risk Index system developed in this paper uses a linear additive model of multiple attribute evaluation to produce a measure of relative fire risk. Weights are established to indicate the importance or significance of fire risk parameters. Then, for each specific historic structure, parameter grades, i.e., the amount or degree that a parameter is present, are determined from information collected in a detailed site survey. Fire risk is evaluated by the scalar product of the parameter weights and grades, producing a single numerical value representing the level of fire safety provided in the building. This is a more rational and transparent method than the risk indexing systems currently published in model codes and standards.

Introduction

Traditionally, US building codes tend to exempt historic buildings and rely on the code official to determine what is safe, or what is an acceptable equivalency to a specific code requirement.[1] Historic buildings suffer under codes that virtually ignore historic significance or that rigidly impose safety requirements with minimal regard for culturally significant spaces and fabric. In the US, building codes are written to prescribe minimum safety requirements for occupants of new buildings. They do not provide guidance to design professionals or code officials working with historic properties. As a result, the historic character of a building can be desecrated by rigid application of fire safety regulations that do not provide adequate protection of the structure for fixture generations. At the same time, the current international perspective on fire safety objectives specifically includes the protection and preservation of life, property, mission, environment, and cultural heritage.[2]

The heritage building poses unique problems for fire protection. Unlike most public and commercial buildings, an historic structure exists as an artifact or visual record of architectural or historical significance. If the building is destroyed, this function ceases to exist. Creative solutions must be developed that meet fire and life safety objectives without compromising the historic or architectural significance of the heritage building. Yet, no statistics are available to determine the vulnerability of historic buildings to fire.[3] How much of our cultural heritage is lost to fire is unknown. Fire loss data is collected only on factors that relate to fire cause and origin. There is no fire loss data by historic significance or building age. We learn about fire losses of historic buildings by observing those that occur around us or through media attention to those that are most significant and newsworthy.

The vulnerability of historic buildings to loss or damage from fire is reinforced with each major fire that destroys an historic structure and its contents. Historic structures are not buildings that can be replaced, but rather irreplaceable artifacts whose value cannot be recovered by insurance payments. Very few organizations can match the financial resources used to reconstruct Britain's Windsor Castle. Instead, buildings of less significance, albeit with historic designations, often fall prey to the wrecking ball following a major fire.[4]

As rehabilitation and adaptive reuse of existing buildings has increased, some attempts have been made to devise separate code provisions for certain classes of these structures. While some of the resultant approaches are more progressive than others, most are riddled with immeasurable terms such as "minimum", "acceptable", "adequate", and "reasonable". This situation places a tremendous burden on the code official, the design professional, and the property owner who lack the technical and financial means to adequately determine alternatives and equivalencies.

Furthermore, building codes prescribe only minimum criteria for various fire safety features and do not associate benefit to buildings in which these criteria are surpassed. For example, reducing travel distances or increasing the number of exits beyond code requirements is not recognized as improving fire safety. New approaches to fire risk assessment and performance-based design are addressing this issue.

For world heritage class buildings, the evolution of performance-based fire safety evaluation and design is a boon. Computer fire modeling and simulation can identify solutions that meet multiple objectives of life safety and historic preservation. Performance-based codes and fire safety design methods involve comparing predicted outcomes with stated objectives. The performance-based approach is one that establishes fire safety objectives and leaves the means for achieving those objectives to the design professional. Implementation requires the capability to evaluate whether the stated fire safety objectives are met, which in turn mandates the establishment of an acceptable level of performance. An acceptable design is one that satisfies the specified performance evaluation. However, there are significant costs associated with such analysis.

Difficulties with performance-based fire modeling that have yet to be overcome include identification of appropriate safety factors and how to address subjective attributes such as human

behavior and emergency response. Additional problems for historic buildings are the limitation of design options for existing buildings and the high cost of performance-based fire-safety engineering.

Fire Risk Indexing

For many situations where a quantitative fire safety evaluation is desirable, an engineered fire risk assessment may not be cost-effective or appropriate. This could be the case where a large number of properties suggests a simple, standardized procedure or where the size and condition of a building does not warrant a detailed engineering analysis. Risk indexing can provide a cost-effective means of fire safety evaluation that is sufficient in both utility and validity. Other advantages of indexing systems include overcoming evaluation problems of inadequate data, eliminating need for safety factors, ad integration of qualitative attributes.

Fire risk indexing systems, also referred to as risk ranking, rating schedules, point schemes, and numerical grading, are simplified models of fire safety. They constitute various processes of analyzing and scoring hazard and other risk parameters to produce a rapid and simple estimate of relative fire risk. Such quantitative approaches to fire risk assessment has been in use at least since the beginning of the twentieth century.[5] Fire risk indexing has been applied to a variety of hazard and risk assessment projects to reduce costs, to set priorities, and to facilitate the use of technical information. They have typically evolved in an *ad hoc* manner and the most widely-used approaches are reviewed in the literature.[6]

Indexing systems are based on relative or comparative risk rather than absolute risk. The lack of statistical data of fire loss in historic buildings makes determination of absolute risk impossible, thus, relative risk is the only alternative. In a study of comparative risk, there is no need to introduce explicit safety factors as any uncertainties in the calculation procedures will apply to both benchmarks and alternative designs. While typical engineering models of fire risk are awkward in their consideration of subjective fire safety attributes such as human behavior and attitudes, the structure of a risk index system facilitates quantification and inclusion of such factors.

Several risk indexing systems have been applied to historic buildings. The Fire Safety Evaluation System (FSES)[7] is an indexing approach to determining equivalencies to the NFPA *Life Safety Code*[8]. It does not distinguish between new and existing buildings except in the total score. A similar system appears in Chapter 34, "Existing Buildings" of the BOCA *National Building Code*[9]. However, Section 3406 in that chapter specifically exempts historic structures.

Chapter ILHR 70 of the Wisconsin Administrative Code is a building code for historic structures.[10] Subchapter IV is an indexing system called the Building Evaluation Method. This system assesses life safety for a qualified historic building by comparing seventeen building safety parameters with the requirements of the prevailing building code of the State of Wisconsin. Most of these parameters are the same as in the BOCA system and quantitatively the difference in parameter values is negligible.

Like the other indexing systems, the Historic Fire Risk Index (HFRI) described in this paper provides a single numerical value used in fire safety decision making that is produced by analyzing and scoring safety features, hazards, and other risk parameters. Using professional judgement and past experience, fire risk indexing assigns values to selected variables representing both positive and negative fire safety features. The selected variables and assigned values are then operated on by some combination of arithmetic functions to arrive at a single value which is then compared with other similar assessments or to a standard. The HFRI is unique in its focus on historic house museums and its inclusion of attributes for fire prevention, building significance, fire growth rate, and emergency response.

Multi-attribute Evaluation

Multiattribute evaluation is an aggregation of system attributes into a single index to reflect an ordinal evaluation. It is used to develop simplified but robust models of complex systems. Meteorologists, for example, realized that temperature alone does not represent the coldness of a winter day. They created the wind-chill factor from a combination of temperature and wind speed to measure overall cooling effect. Such multiattribute evaluations have been widely used in fire safety.

Multiattribute evaluation is a common and powerful heuristic decision-making technique that is supported by a large body of knowledge described in the literature of decision analysis and management science. It is a formal procedure for structuring and quantifying complex problems with multiple concerns to provide a logical, rigorous, and defensible basis for resulting decisions. Multiattribute evaluation has been used to produce meaningful risk index models of fire safety that rely heavily but not exclusively on demonstrated principles of physical or management science.[11]

Fire safety decisions require more than one attribute to capture all relevant aspects of the consequences. If there are n attributes for a decision problem, x_1 x_2, x_3,…, x_n, then an evaluation function $E(x_1, x_2, x_3,\ldots, x_n)$ needs to be determined over these measures in order to conduct a performance assessment. A linear measure of the overall outcome of a system is given by

$$E(x_1,\ldots,x_i,\ldots,x_n) = \sum w_i,R_i(x_i)$$

where the w_i are weighting constants greater than zero and the $R_i(x_i)$ are normalizing functions of the attributes' grades.

This is referred to as a linear additive model, in which each attribute of fire safety is decomposed into a weight and a grade and their products are summed to give a score. Since not all fire safety attributes are equally important, the role of weight serves to express the importance of each attribute compared with the others. Also, individual buildings will vary in the degree to which each attribute exists or occurs. Attribute grades, also called ratings or values, are measures of the intensity, level, or degree of danger or security afforded by the attributes in a particular application

In a typical compensatory evaluation procedure, good performance of one attribute can at least partially compensate for low performance of another attribute. This is also called tradeoff or equivalency. Accommodating tradeoffs of low versus high performance among attributes generally requires normalization of incommensurate data, i.e., each quantitative attribute typically has a different unit of measurement. Quantitative attribute grades must be normalized to a scale that is common for all attributes. This is accomplished by constructing a normalizing function $R_i(x_i)$ for each attribute *i.* Normalization aims at obtaining comparable scales that allow interattribute comparison, consequently, the normalized grades are dimensionless.

The summation of the each attribute's weight times its grade is referred to as the scalar product and assumes that the attributes are independent, i.e. there is no accounting for interactions among attributes. Linear additive models are widely used in many areas of decision making and have been found to be quite robust even when the attribute independence assumption is not fully valid[12].

Multiattribute evaluation requires selection of appropriate parameters, the assignment of levels of importance or significance to each parameter, and the identification a metric and corresponding normalizing function for each parameter. There are many different ways to accomplish these tasks and the procedures used for the HFRI represent just one approach.

Attributes

Fire safety is a complex system affected by a large number of factors ranging from ignitability of personal clothing to availability of a heliport for evacuation. However, it is appropriate to use only a relatively small number of these variables given our computational and cognitive limitations and since general fire loss figures indicate that a small number of factors are associated with a large proportion of fire loss. It is thus necessary to identify as attributes some defensible combination of factors that account for an acceptable portion of the fire risk.

Multiattribute evaluation begins with the generation of a list of attributes that provides a means of evaluating goal achievements. Fire safety attributes are components of fire risk that are quantitatively determinable by direct or indirect measurement or estimate. They are intended to represent factors that account for an acceptably large portion of the total fire risk. Usually they are not directly measurable. This is especially true for existing buildings where only limited information is readily available. Attributes may be either quantitative or qualitative and both types of attributes are important.

In the HFRI model, the set of system attributes that are selected as having the greatest impact on fire risk are referred to as the fire safety parameters. These parameters were chosen through examination of other well-established fire risk indexing systems. The initial list of HFRI parameters was derived from the two most widely used risk index systems, FSES and BOCA which have a long history of accepted use for life safety evaluation. Combining the parameters from these systems results in a list of twenty fire safety parameters (Table 1).

Table 1. Combined List of Parameters from NFPA and BOCA Index systems

Compartmentation	Vertical Openings
HVAC Systems	Building Height/Construction
Smoke Control	Automatic Sprinklers
Dead Ends/Exit Access	Building Area
Interior Finish	Maximum Travel Distance/Exit Access
Mixed Use Groups	Corridor Walls/Corridor/Room Separation
Occupant Emergency Program	Fire Alarm System
Unit Separations	Means of Egress/ Exit System
Elevator Control	Automatic Fire/Smoke Detection
Egress Emergency Lighting	Spec Occ Area Prot/Segregation of Hazards

Historic house museums were selected as the occupancy for development of a prototype HFRI. An historic house museum is considered to be a structure with recognized historic designation or apparent historic significance that is open to the public in order to display the building and its contents. Most often, the historic house museum was originally designed as a single family residence. The historic house museum is usually managed by professional or qualified staff or volunteers with specific expertise in museum management or historic preservation.

For the Historic Fire Risk Index, it was assumed that the primary function of the building is as a museum. There is no residential or lodging use of the building, accessory functions that support the museum are limited to offices and storage, and no conservation processes using laboratory-type facilities are undertaken within the building.

Historic house museums are distinct from other museums and galleries as typically, the structure housing the collections has not been fully modernized for use as a museum. Items are exhibited in context as they were seen and used when the houses were occupied by their last owners, and not in cases or behind glass or segregated by type or material.

For historic house museums, the size of the structure and interior spaces are relatively small. It is assumed that there are no rooms in which more than fifty persons assemble. For the purposes of U.S. model building codes and the NFPA *Life Safety Code,* these buildings are classified as business occupancies.

Using this definition and set of characteristics, the combined NFPA and BOCA parameter list was modified. Parameters not applicable to historic house museums were deleted, some parameters were combined to simplify application, several parameters were expanded to include important components, and new parameters deemed necessary to fire risk assessment were added. It was determined that five of the parameters in Table 1 were not applicable to historic house museums, Building Area, Corridor Walls/Corridor/Room Separation, Mixed Use Groups, Occupant Emergency Program, Unit Separations, and Elevator Control. The parameters Maximum Travel Distance/Exit Access, Means of Egress/Exit System, Dead Ends/Exit Access, and Egress Emergency Lighting were combined as a single parameter, Egress. Fire Mann System/Fire Alarm and Automatic Fire Detection/Smoke Detection were combined as Detection and Alarm. The Compartmentation parameter, was expanded to include Spec Occ Area Prot/Segregation of Hazards and HVAC Systems. Fuel is a new parameter that represents an expansion of Interior Finish to include other combustibles in the facility and entirely new parameters were introduced to cover areas of Fire Prevention, Historic Significance, and Emergency Response. The resulting list of eleven parameters of the HFRI is shown as table 2.

Table 2. Parameters for Fire Safety Evaluation of Historic House Museums

Fire Prevention	Compartmentation
Egress	Fuel
Historic Significance	Detection & Alarm
Vertical Openings	Emergency Response
Automatic Suppression	Smoke Control
Building Height & Construction	

Parameter Weights

Not all fire safety attributes have equal importance. Parameter weights serve to express the importance of each attribute compared with the others. Hence the assignment of weights is a key component of multiattribute evaluation. Implied weights from the NFPA and BOCA fire risk index systems were used to develop a set of parameter weights for the HFRI.

In the NFPA and BOCA systems each parameter is evaluated by only a single measure, thus weights and grades are not distinguished. Using a form of reverse engineering, implicit weights were extracted from these systems [13, 14] The weight of a parameter is a measure indicating its influence or significance to fire risk. The spread or range of possible values of each parameter was assumed as a measure of this importance. To make meaningful comparisons between the two systems, the individual parameter spreads were normalized. This was accomplished by adjusting.

for variations between systems in terms of overall spread in total scoring and the difference in the number of parameters used in each system. This process resulted in a combined list of twenty weighted parameters (table 3).

Table 3. Ranked Average Normalized Spread for Combined BOCA and FSES Parameters (Business Use Group/Occupancy) Expressed as Percentage of Their Sum

PARAMETER	PERCENT
Vertical Openings /Vertical Openings	18%
Building Height/Construction	12%
Sprinklers/Automatic Sprinklers	10%
Building Area	7%
Maximum Travel Distance/Exit Access	7%
Corridor Walls/Corridor/Room Separation	6%
Fire Alarm System/Fire Alan	5%
Means of Egress/ Exit System	5%
Automatic Fire Detection/Smoke Detection	4%
Spec Occ Area Prot/Segregation of Hazards	4%
Compartmentation	4%
HVAC Systems	4%
Smoke Control/Smoke Control	2%
Dead Ends/Exit Access	2%
Interior Finish	2%
Mixed Use Groups	2%
Occupant Emergency Program	2%
Unit Separations	1%
Elevator Control	1%
Egress Emergency Lighting	1%
Total	100%

The aforementioned deletions, combinations, expansions, and additions to the parameter list were then quantitatively and qualitatively evaluated in regard to these weights The resulting HFRI parameters and their weights are shown in table 4

Table 4. Weighted Parameters for Fire Safety Evaluation of Historic House Museums

PARAMETERS	%
Fire Prevention	15%
Egress	13%
Historic Significance	13%
Vertical Openings	12%
Automatic Suppression	8%
Building Height & Construction	8%
Compartmentation	8%
Fuel	8%
Detection & Alarm	5%
Emergency Response	5%
Smoke Control	5%
Total	100%

Parameter Grades

Parameter grades are measures of the intensity, level, or degree of danger or security afforded by the selected attributes. Individual buildings will vary in the degree to which each parameter exists or occurs. In the HFRI the parameters are comprised of both quantitative and qualitative attributes, and methods to make them commensurable are necessary.

Scaling techniques are used to capture the essential meaning of qualitative parameters and to develop scales upon which surrogate measures or grades are based. Quantitative parameters are readily measured but require scaling to convert to a compensatory measure. In the HFRI, Likert scaling is used to grade parameters as 0,1,2,3,4, or 5, reading from unfavorable to favorable.

Most of the parameter ranges are similar to their counterparts in the NFPA and BOCA systems. New grading schemes are developed for the additional parameters and those that have been significantly altered.

Example: Fire Prevention

As an example of subjective parameter grading, consider fire prevention, which was added as an important parameter of fire risk in historic house museums. Five sub-parameters of fire prevention were identified as significant measurable components of the parameter, exposure, security, staff training, management, and housekeeping.

Exposure is intended to assess the likelihood of fire spread to a historic house museum from another building and is measured by the separation distance from other buildings. This distance is then converted to a Likert scale according to typical insurance rating criteria and as shown in figure 1.

Physical security of the building is used as a measure of arson prevention. The level of security is based on facility staffing during visiting hours, electronic monitoring, and 24 hour guard service. These items make up the set of conditions in a decision table.[15] The conclusions of the table are the possible sub-parameter grades.

Staff training is expected to include fire safety orientation, evacuation procedures, and hands-on fire extinguisher use. To facilitate measurement, parameter grading is based on records of training frequency.

Management attitude is considered a critical component of fire prevention. Because it is so difficult to measure directly, a surrogate is the subjective evaluation of a regularly updated fire safety plan that includes inspection and maintenance of fire safety systems. Similarly, the sub-parameter housekeeping is assessed subjectively in terms of the cleanliness of storage and utility areas.

Grading schemes for each of the remaining ten parameters were developed in a comparable fashion, using Likert scaling and decision tables where appropriate. The sub-parameters for each parameter are listed on the HFRI Scoring Sheet shown in figure 2. The final fire safety score of a facility is given by the scalar product of the parameter weights and grades as shown in figure 2. This score enables one building to be compared to another or to a standard established by management or society.

1. FIRE PREVENTION

DEFINITION - physical and managerial mitigation of fire hazards.

SUB-PARAMETERS:

1 ***Exposure*** - separation distance from other buildings

FEET	0	1-11	11-30	31-60	61-100	> 100
GRADE	0	1	2	3	4	5

1.2 ***Security*** - staffing during visiting hours, electronic monitoring, and 24 hour guard service

SURVEY ITEMS	**DECISION RULES**							
staffing (N,Y)	**N**	**V**	**N**	**V**	**N**	**V**	**N**	**Y**
Electric (N,Y)	**N**	**N**	**Y**	**Y**	**N**	**N**	**Y**	**Y**
24 hour guards (N,Y)	**N**	**N**	**N**	**N**	**Y**	**Y**	**Y**	**Y**
GRADE	**0**	**1**	**2**	**3**	**3**	**4**	**4**	**5**

1.3 ***Staff Training*** - to include fire safety orientation, evacuation procedures, and hands-on fire extinguisher use Parameter grading based on records of training frequency

TRAINING	none	<annual	annual	>annual
GRADE	0	1	3	3

1.4 ***Management*** - regularly updated fire safety plan that includes inspection and maintenance of fire safety systems.

GRADE	None=0	poor=1	OK=3	good=5

1.5 ***Housekeeping*** - cleanliness (storage and utility areas)

1.6

GRADE	Poor=0	OK=3	Good=5

PARAMETER GRADE [Exp+ Sec+ Staff÷(2x Mgmt) + Hskpg]/6

Figure 1. Parameter grading scheme for "Fire Prevention".

PARAMETER	PARAMETER GRADE (A)	WEIGHT % (B)	FIRE SAFETY SCORE (A x B)
FIRE PREVENTION Exposure Security Staff Management/Fire Safety Plan Housekeeping		15%	
EGRESS/EVACUATION Adequacy (Automatic suppression, travel distance) Utilization (detection and alarm, emergency lighting) Protection (exits, ways out, direct exit) Availability (capacity, dead ends)		13%	
SIGNIFICANCE Building Contents		13%	
VERTICAL OPENINGS Floors Penetrated Protection Fire Stopping		12%	
AUTOMATIC SUPPRESSION Coverage Response Time		8%	
BUILDING HEIGHT & CONSTRUCTION Height and Construction		8%	
COMPARTMENTATION Hazard Segregation Interior Walls Attic Compartmentation		8%	
FUEL Fire Growth Rate		8%	
DETECTION AND ALARM Detection Alarm		5%	
EMERGENCY RESPONSE Fire Service Capability Water Supply Response Time Accessibility		5%	
SMOKE CONTROL		5%	
TOTAL FIRE SAFETY SCORE			

Figure 2. HFRI summary score sheet.

Future Work

Preliminary field testing of this prototype fire risk index for historic buildings has been under taken. This experience confirmed a need for an educational component of the index[16]. Additional work also remains to be done on verification and validation of the HFRI.

Acknowledgment

This work was partially supported by a grant from the National Park Service and the National Center for Preservation Technology and Training. The contents of this paper are solely the responsibility of the authors and do not necessarily represent the official position or policies of any supporting agencies.

References

1. Kaplan, Marilyn E., "The Regulation of Existing and Historic Buildings" unpublished thesis, Rensselaer Polytechnic Institute, Troy, NY, 1996.

2. ISO/TC 92/SC 4, "Fire Safety Engineering - The Application of Fire Performance Concepts to Design Objectives", Committee Draft ISO CD 13387, International Organization for Standards, 1997 (p. 5)

3. Watts, John M., Jr., "Fire Risk Assessment in Cultural Resource Facilities", Proceedings Fire Risk and Hazard Assessment Symposium, National Fire Protection Research Foundation, Quincy, MA, 1996.

4. Watts, John M., Jr., and Marilyn E. Kaplan, "Performance-Based Approaches to Protecting our Heritage, *Proceedings of the International Conference on Performance-Based Codes and Fire Safety Design Methods*, Ottawa, Canada, 24-26 September, 1996, Society of Fire Protection Engineers, Boston, 1997.

5. Dean, Albert Flandreau, "Analytic System for the Measurement of Relative Fire Hazard", Western Actuarial Bureau, Chicago, 1902.

6. Watts, John M., Jr. (1995a) "Fire Risk Ranking", section 5, chapter 2, in Philip J. DiNenno, et al., eds., *SFPE Handbook of Fire Protection Engineering*, 2nd ed., National Fire Protection Association, Quincy MA, pp. 5-12 to 5-26.

7. NFPA 101A, *Guide on Alternative Approaches to Life Safety*, National Fire Protection Association, Quincy MA (Chapter 7)1998.

8. NFPA 101, *Life Safety Code*,, National Fire Protection Association, Quincy MA, 1997.

9. *The BOCA National Building Code*/1996, Building Officials and Code Administrators International, Country Club Hills, IL, 1996.

10. Wisconsin Administrative Code, Chapter ILHR 70, Historic Buildings, Department of Industry, Labor, and Human Relations, Madison, WI, June 1995.

11. Wafts, John M., Jr., "Fire Risk Assessment Using Multiattribute Evaluation", *Fire Safety Science, Proceedings of the Fifth International Symposium*, International Association for

Fire Safety Science, 1997.

12. Dawes, Robyn M., “The Robust Beauty of Improper Linear Models in Decision Making”, American Psychologist, Vol. 34, No. 7, July 1979, pp 57 1-582.

13. Wafts, John M., Jr., “Analysis of the NFPA Fire Safety Evaluation System for Business Occupancies,” *Fire Technology,* Vol. 33, No. 3, August 1997.

14. Watts, John M., Jr., “Fire Risk Evaluation in the Codes: A Comparative Analysis,” presented at the 2nd International Conference on Fire Research and Engineering, Gaithersburg, MD, August 1997.

15. Watts, John M., Jr., Edward K. Budnick, and Brian D. Kushler, “Using Decision Tables to Quantify Fire Risk Parameters”, *Proceedings - International Conference on Fire Research and Engineering,* Society of Fire Protection Engineers, Boston, 1995.

16. Kaplan, Marilyn E., and John M. Watts, Jr., “Development of a Prototypical Historic Fire Riskl Index to Evaluate Fire Safety in Historic Buildings”, submitted to *APT Bulletin*, December 1997.

THE HISTORIC FIRE RISK INDEX

prepared with the support of
National Center for Preservation Technology and Training
United States Department of the Interior/National Park Service
Northwestern State University
P.O. Box 5682
Natchitoches, LA 71497

June 1997

principal investigators
John. M Watts, Jr., Ph.D.
Director
Fire Safety Institute
P0 Box 674
Middlebury, VT 05753

Marilyn E Kaplan
Preservation Architecture
51 Round Lake Road
Valatie, NY 12184

HISTORIC FIRE RISK INDEX

PART 1
GENERAL INSTRUCTIONS

Introduction

The Historic Fire Risk Index (HFRI) for historic house museums is a system to achieve a single numerical value for a building's fire safety that can be used in fire safety decision making. The value is determined by analyzing and scoring safety features, hazards, and other risk parameters.

Parameters are components of fire risk determinable by direct or indirect measure or estimate. Parameter grades represent the amount or degree that a parameter is present. They are assigned as an interger from a scale of 0-5, where 0 is the highest risk or worst feasible case and 5 is the theoretical optimum equivalent to zero risk contribution Parameter grades are calculated from survey items or measurable features of the building. In most cases the parameter grade is determined from more than one survey item, either subparameters or intermediate components leading to the parameter assessment.

The historic house museum is defined as:

> A structure, with recognized historic designation or apparent historic significance, that is open to the public in order to display the building and its contents. Most often, the historic house museum was originally designed as a single family residence. The historic house museum is usually managed by professional or qualified staff or volunteers with specific expertise in museum management or historic preservation. The primary function of the building is as a museum,, and that there is is no residential or lodging use of the building. Accessory functions that support the museum are limited to offices and storage, no conservation processes using laboratory-type facilities are undertaken within the building.
>
> Among the characteristics that distinguish historic house museums from other museums and galleries is that the structure has not been modified or modernized for use as a museum. Collections are exhibited in context rather than segregated by type or material, and are usually seen as used when the houses were occupied.
>
> The size of the historic house museum and the spaces within are relatively small. It is assumed that there are no rooms in which more than fifty persons assemble. For purposes of U S model building codes and the NFPA Life Safety Code, these buildings are classified as business occupancies.

General Instructions

1. Complete *Part 2, Building Data Sheet.*
   This form to be completed by a professional familiar with architectural and fire safety features.
   a. The 'Data' column is completed with information gathered through an onsite evaluation and interview with building management. The exceptions are the Historic Significance and Emergency Response parameters for which consultation

with the State Historic Preservation Office and Fire Service may be required.

b. The 'Subparameter Grade' column is completed using *Part 4, Parameter Grading Schemes.*

c. If construction or use inconsistencies exist within the building, the predominant condition reflecting at least 90% of existing conditions should be used. Where greater differences in existing conditions exist, the worst case scenario, e.g. highest fire risk, should be used.

d. In buildings with discrete sections with different construction materials and design, a separate HFFRI evaluation should be conducted for each section of the building.

2. Complete *Part 3, Grading Sheet*

Complete this form using the values for parameter grades ('A') determined in *Part 2*. To determine the Fire Safety Score for each parameter, multiply 'A' by 'B', the parameter weight. The building's Total Fire Safety Score is determined by summing the eleven parameter Fire Safety Scores.

PART 2
BUILDING DATA SHEET

NO	PARAMETER	DATA	SUBPARAMETER GRADE	PARAMETER GRADE
1.0	FIRE PREVENTION			
1.1	Exposure	*Distance from other buildings* _____'		
1.2	Security	*Quality* ? None ? Electronic *Is trained staff on duty in visitor areas when building is open to the public?* ? Yes ? No		
1.3	Staff Training	*Frequency of staff training* ? None ? < Annual ? Annual ? > Annual		
1.4	Management/ Fire Safety Plan	? No Plan ? Acceptable Plan		
1.5	Housekeeping	*Quality* ? Poor ? Acceptable ? Good		
			1.0 PARAMETER GRADE	

PART 2
BUILDING DATA SHEET

NO	PARAMETER	DATA	SUBPARAMETER GRADE	PARAMETER GRADE
2.0	EGRESS			
2.1	Adequacy	*Is an operable automatic suppression* system installed? ? *Yes* ? No *Maximum travel distance to exit* _____'		
2.2	Utilization	*How is fire alarm activated?* ? Automatically ? Manually ? No Alarm *Is building equipped with emergency lighting?* ? Yes ? No *Is trained staff on duly in visitor areas* when *the building is open to the* public? ? Yes ? No		
2.3	Protection	*Are there direct exterior exits?* ? Yes ? No *Fire resistance of exit enclosures* ? >1 hour ? 1 hour ? <1 hour ? None		
2.4	Availability	*Is more than one exit an approved* exit? ? Yes ? No *Maximum length of dead end corridors* _____'		
			2.0 PARAMETER GRADE	
3.0	SIGNIFICANCE			
3.1	Building	*Historic designation of building* ? National Historic Landmark ? National or State Register of Historic Places ? Local designation ? Other significance		
3.2	Contents	*Replaceability of contents* a Irreplaceable ? Replaceable ? Reproducible ? Expendable		
			3.0 PARAMETER GRADE	

PART 2
BUILDING DATA SHEET

NO	PARAMETER	DATA	SUBPARAMETER GRADE	PARAMETER GRADE
4.0	VERTICAL OPENINGS			
4.1	Floors Penetrated	*Total number of floors* _____ *Number of floor penetrated* _____		
4.2	Protection	*Minute **of** fire endurance **of** **penetrations*** ? >30 minutes ? 20-30 minutes ? <20 minutes		
4.3	Firestopping	*If yes, add one point to overall parameter grade* ? Yes ? No		
			4.0 PARAMETER GRADE	
5.0	AUTOMATIC SUPPRESSION			
5.1	Coverage	*Coverage of system* ? Complete coverage, NFPA 13 ? Complete coverage. NFPA 13D ? Other partial coverage ? None		
5.2	Response time of sprinklers	*Speed **of** response* ? Fast response sprinklers ? Standard response sprinklers		
			5.0 PARAMETER GRADE	
6.0	BUILDING HEIGHT & CONSTRUCI'ION			
6.1	Height	*Number of stories* _____		
6.2	Construction	*Combustibility and fire endurance **of** load bearing structural assemblies* ? Fire Resistive ? Noncombustible ? Protected combustible ? Heavy timber ? Wood frame		
			6.2 PARAMETER GRADE	

PART 2
BUILDING DATA SHEET

NO	PARAMETER	DATA	SUBPARAMETER GRADE	PARAMETER GRADE
7.0	COMPARTMENTATION			
7.1	Hazard Segregation	*Number of hazards* ____ *Number contained* ____		
7.2	Interior Walls	*Fire endurance of any subdividing fire barrier?* ☐ 0 ☐ < 20 minutes ☐ 20-60 minutes ☐ > 60 minutes		
7.3	Attic Compartmentation	*Square feet of largest compartment* ☐ No attic ☐ <1000 sf ☐ 1000-2000 sf ☐ > 2000 sf		
			7.0 PARAMETER GRADE	
8.0	FUEL			
8.1	Fire Growth Rate	*Building Contents* ☐ None ☐ Sparsely furnished, minimum upholstery and fabrics ☐ Moderately furnished, some upholstery and fabrics ☐ Heavily furnished, extensive upholstery and fabrics ☐ Excessive amount of stored combustible materials		
			8.0 PARAMETER GRADE	
9.0	DETECTION AND ALARM			
9.1	Detection	*Equipment and systems for detecting fires* ☐ None ☐ Heat or smoke (heated areas) ☐ Partial or complete		
9.2	Alarm	*Equipment and systems for transmitting a fire alarm* ☐ Fire alarm sounds within building ☐ Fire alarm automatically notifies fire department		
			9.0 PARAMETER GRADE	

PART 2
BUILDING DATA SHEET

NO	PARAMETER	DATA	SUBPARAMETER GRADE	PARAMETER GRADE
10.0	EMERGENCY RESPONSE			
10.1	Capability	*ISO Public Protection Classification of fire service* ____		
10.2	Water Supply at site	*ISO Rating: Needed Fire Flow (NFF)* ____		
10.3	Response Time	*Response time of fire department* ☐ 0-5 minutes ☐ 5-10 minutes ☐ 10-15 minutes ☐ 15-20 minutes ☐ > 20 minutes		
10.4	Accessibility	*Number of accessible sides of building* ____		
			10.0 PARAMETER GRADE	
11.0	SMOKE CONTROL			
		System for limiting spread of toxic and corrosive fire products ☐ None ☐ Operable windows ☐ Automatic smoke vents ☐ Engineered smoke control system		
			11.0 PARAMETER GRADE	

PART 3
GRADING SHEET

No.	PARAMETER	PARAMETER GRADE (A)	WEIGHT % (B)	FIRE SAFETY SCORE (A x B)
1.0	**FIRE PREVENTION** Exposure Security Staff Management/Fire Safety Plan Housekeeping		15%	
2.0	**EGRESS/EVACUATION** Adequacy (Automatic suppression, travel distance) Utilization (detection and alarm, emergency lighting) Protection (exits, ways out, direct exit) Availability (capacity, dead ends)		13%	
3.0	**SIGNIFICANCE** Building Contents		13%	
4.0	**VERTICAL OPENINGS** Floors Penetrated Protection Fire Stopping		12%	
5.0	**AUTOMATIC SUPPRESSION** Coverage Response Time		8%	
6.0	**BUILDING HEIGHT & CONSTRUCTION** Height and Construction		8%	
7.0	**COMPARTMENTATION** Hazard Segregation Interior Walls Attic Compartmentation		8%	
8.0	**FUEL** Fire Growth Rate		8%	
9.0	**DETECTION MID ALARM** Detection Alarm		5%	
10.0	**EMERGENCY RESPONSE** Fire Service Capability Water Supply Response Time Accessibility		5%	
11.0	**SMOKE CONTROL**		5%	
TOTAL FIRE SAFETY SCORE				

PART 4
PARAMETER GRADING SCHEMES

The Historic Fire Risk Index (HFRI) is a single numerical value used in fire safety decision making that is produced by analyzing and scoring safety features, hazards, and other risk parameters of an historic building. Eleven specific parameters have been identified the HFRI for historic house museums. These parameters are listed below.

Parameters of the Historic Fire Risk Index

1	Fire Prevention
2	Egress
3	Historic Significance
4	Vertical Openings
5	Automatic Suppression
6	Building Height & Construction
7	Compartmentation
8	Fuel
9	Detection & Alarm
10	Emergency Response
11	Smoke Control

Parameters are components of fire risk that are determinable by direct or indirect measure or estimate. Parameter grades represent the amount or degree that a parameter is present in a specific historic house museum. They are assigned as an integer from a scale of 0-5, where 0 is the highest risk or worst feasible case and 5 is a theoretical optimum equivalent to zero risk contribution. Grades are calculated from survey items or measurable features of an historic house museum. In many cases there are also sub-parameters or intermediate components of a parameter with a grade or assessment based on one or more survey items.

The following pages outline procedures for calculating parameter grades for historic house museums to produce the HFRI.

1. FIRE PREVENTION

DEFINITION - physical and managerial mitigation of fire hazards

SUB-PARAMETERS:

1.1 ***Exposure*** - separation distance from other buildings

FEET	0	1-11	11-30	31-60	61-100	>100
GRADE	0	1	2	3	4	5

1. 2 ***Security*** - staffing during visiting hours, electronic monitoring, and 24 hour guard service

SURVEY ITEMS	DECISION RULES							
staffing (N,Y)	**N**	**Y**	**N**	**Y**	**N**	**Y**	**N**	**Y**
electronic (N,Y)	**N**	**N**	**Y**	**Y**	**N**	**N**	**Y**	**Y**
24 hour guards (N,Y)	**N**	**N**	**N**	**N**	**N**	**Y**	**Y**	**Y**
GRADE	**0**	**1**	**2**	**3**	**3**	**4**	**4**	**5**

1.3 ***Staff Training*** - to include fire safety orientation, evacuation procedures, and hands-on fire extinguisher use. Parameter grading based on records of training frequency.

TRAINING	none	< annual	annual	> annual
GRADE	0	1	3	5

1.4 ***Management*** - regularly updated fire safety plan that includes inspection and maintenance of fire safety systems.

GRADE	None = 0	poor = 1	OK = 3	good = 5

1.5 ***Housekeeping*** - cleanliness (.storage and utility areas)

GRADE	poor = 0	OK = 3	good = 5

PARAMETER GRADE:

$$[\text{Exp} + \text{Sec} + \text{Staff} + (2 \times \text{Mgmt}) + \text{Hskpg}] / 6$$

2. EGRESS

DEFINITION: adequacy and reliability of emergency exits.

SUB-PARAMETERS:

2. 1 ***Adequacy*** - fire growth rate as determined by automatic suppression, and time for evacuation as determined by travel distance to exits [S = short (<50 ft), M = moderate (50-99 ft), L = long (100-150 ft), V = very long (>150 ft)].

SURVEY ITEMS	DECISION RULES							
automatic suppression (Y,N)	Y	Y	Y	Y	N	N	N	N
travel distance (S,M,L,V)	S	M	L	V	S	M	L	V
ADEQUACY	5	4	3	2	3	2	1	0

2. 2 ***Utilization*** - alerting the occupants to the need to evacuate (A = automatically, M = manually, N = no alarm), emergency lighting, and identifying exits for those unfamiliar with the premises.

SURVEY ITEMS	DECISION RULES											
alarm activation (A,M,N)	A	A	A	A	M	M	M	M	N	N	N	N
emergency lighting (Y,N)	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N
identifying exits (Y,N)	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N
UTILIZATION	5	4	4	3	3	2	2	2	1	1	1	0

2. EGRESS (cont.)

2.3 ***Protection -*** fire endurance of exits (H= >1 hr, M= 1 hr, L = <1 hr, N = none)

SURVEY ITEMS	DECISION RULES				
direct exits (Y,N)	Y	N	N	N	N
exit enclosures (H,M,L,N)	-	H	M	L	N
PROTECTION	5	4	3	2	0

2.4 ***Availability -*** number of exits and length of dead ends [S = short (<50 ft), L = long (=50 ft)]

SURVEY ITEMS	DECISION RULES			
number of exits (Y,N)	Y	Y	N	N
dead ends	S	L	S	L
AVAILABILITY	5	3	1	0

PARAMETER GRADE: Based on a sub-component weights developed using an analytical hierarchy process (AHP)

(Adq x 0.26) + (Utl x 0.13) + (Prot x 0.07) + (Avl x 0.54)

3. HISTORIC SIGNIFICANCE

DEFINITION: Characteristic of a buildings and its contents that are architecturally or historically distinct

SUB-PARAMETERS:

3.1 ***Building*** - Historic and architecturally characteristics of the building that enhance the need for fire protection and for which the impact or intrusion of installed fire protection features is a major concern. Determined from classified significance and overall quality of the building.

QUALITY	SCOPE OF HISTORIC SIGNIFICANCE		
	National Historic Landmark	National/State Significance*	Local Significance
Excellent	5	4	3
Good	5	4	2
Typical	5	3	1

*Listed on, or eligible for national or state register

2 .2 ***Contents*** - Artifacts and archives of significance that may be particularly susceptible to effects of heat, nonthermal fire products, and water damage.

Historic Grading	
Irreplaceable	**4**
Replaceable	**3**
Reproducible	**2**
Expendable	**1**

PARAMETER GRADE:

(building + contents - 2) / 1.8

4. VERTICAL OPENINGS

DEFINITION : potential paths of fire spread between floors.

SUB-PARAMETERS:

4. 1 ***floors penetrated -*** percent of total number of floors that are penetrated = floors penetrated/total number of floors

KEY	%
0	1 story bldg
A	< 50
B	50 to < 100
C	100

4.2 ***Protection of floor penetrations*** - minutes of fire endurance

KEY	MINUTES
A	> 30
B	20 to 30
C	< 20

4. 3 ***Fire stopping -*** add one point to grade

PARAMETER GRADE:

SURVEY ITEM										
Floors penetrated	0	A	A	A	B	B	B	C	C	C
Protection	-	A	B	C	A	B	C	A	B	C
GRADE	4	4	3	1	3	3	1	3	2	0

5. AUTOMATIC SUPPRESSION

DEFINITION : equipment and systems for automatic application of water to a fire

SUB-PARAMETERS.

5.1 ***Coverage:***

C	Complete coverage with NFPA 13 system
D	Complete coverage with NFPA 130 system
P	Other partial coverage
N	None or system that is not maintained

5.2 ***Response time of sprinklers:***

F	Fast response sprinklers
S	Standard response sprinklers

PARAMETER GRADE:

SURVEY ITEM							
Coverage	N	P	P	D	D	C	C
Response	-	S	F	S	F	S	F
GRADE	0	1	2	3	4	4	5

6. BUILDING HEIGHT & CONSTRUCTION

DEFINITION: number of stories and the combustibility and fire endurance of load bearing structural assemblies

SUBPARAMETERS:

6. 1 ***Height*** number of stories, 1-5

6. 2 ***Construction*** - combustibility and fire endurance of load bearing structural assemblies

Fire Resistive	= 1
Noncombustible	= 2
Protected combustible	= 3
Heavy timber	= 4
wood frame	= 5

PARAMETER GRADE:

(10 - Construction height) / 1.6

7. COMPARTMENTATION

DEFINITION : extent to which floor areas are divided by fire and smoke resistive walls and partitions

SUB-PARAMETERS:

7.1 ***Hazard Segregation***

SURVEY ITEM										
Number of hazards	3	3	3	3	2	2	2	1	1	0
No Contained	0	1	2	3	0	1	2	0	1	-
GRADE	0	1	2	4	1	2	4	2	4	5

7.2 ***Interior Wails*** - fire resistance of sub-dividing fire barrier

MINUTES	0	1-20	21-60	> 60
GRADE	0	1	3	5

7.3 ***Attic Compartmenation*** - square feet

no attic	< 1000	1000-2000	> 2000
5	3	1	0

PARAMETER GRADE:

[(2xHaz) + Walls + Attic] / 4

8. FUEL

DEFINITION: amount and type of ordinary and other combustible contents, including interior finish, that may contribute to the spread and severity of a fire.

The rate at which a fire grows from ignition to fully developed depends largely on the chemistry and physical configuration of the fuel. Typical fire growth rates can be categorized ias follows.

Noncombustible: If no fuels are present, the fire growth rate will be zero. This is an unusual situation and not to be expected in a historic house museum.

Slow burning: The nature of the fuel is such that fire development is prolonged. Burning rate is of an order that takes approximately 10 minutes to reach a heat release of 1.0 MW (one megawatt). One such fuel is upholstered furniture with cotton or treated foam plastic padding, covered with cotton or other fabric that resists melting, and weighing more than 75 pounds. The most common example is a typical administrative office occupancy.

Moderate burning: Fuel is typically of mixed products in significant amounts. Burning rate is of an order that takes approximately 5 minutes to reach a heat release of 1. 0 MW. For example upholstered furniture with cotton or treated foam plastic padding, covered with cotton or other fabric that resists melting, and weighing less than 75 pounds.

Fast burning: Large amounts of readily combustible materials lead quickly to a free burning fire. Burning rate is of an order that takes approximately 2 minutes to reach a heat release of 1. 0 MW. Examples are accumulations of packaging materials, plastic components, or trash. Examples are wooden pallets, full mail bags, and empty cardboard cartons. This situation may represent a special hazard.

Very fast burning: Fuels which burn with great intensity. Burning rate is of an order that takes approximately 1 minute to reach a heat release of 1. 0 MW. Examples include flammable liquids and large quantities of dust or finely ground debris. This situation should be considered a special hazard.

GRADE	FIRE GROWTH RATE
1	Very Fast
2	Fast
3	Moderate
4	Slow
5	Noncombustible

9. DETECTION & ALARM

DEFINITION: equipment and systems for detecting fires and transmitting an alarm of fire

SUB-PARAMETERS:

9. 1 ***Detection*** - type (N = none, H = heat, S = smoke) and coverage (P = partial, C = complete)

SURVEY ITEM					
type(N,H,S)	N	H	H	S	S
coverage (P,C)		P	C	P	C
GRADE	0	1	2	3	5

9.2 ***Alarm*** - transmission of alarm locally or to fire Department

SURVEY ITEM				
local alarm (N,Y)	N	N	Y	Y
fire department (Y, N)	N	Y	N	Y
GRADE	0	1	3	5

PARAMETER GRADE:

$$0.55\,[(\text{alarm}) + 0.8\,(\text{detection})]$$

(Note: ratio of 0. 8 is from ranked averages of BOCA and FSES)

10. EMERGENCY RESPONSE

DEFINITION: preplanned actions by external agencies to mitigate fire loss.

SUB-PARAMETERS:

10. 1 ***Capability*** of responding fire service to control a structural fire Determined by ISO Public Protection Classification of responding fire service.

10.2 ***Water Supply -*** needed fire flow (NFF) is determined from the table below. Divide NFF into amount of water that is available from hydrants within 1000' of the site or that can be otherwise delivered. Multiple by 10 and round to the nearest integer. Cannot exceed 10.

Distance between buildings (ft.)	Needed fire flow (gpm)	
	1-2 stories	3-5 stories
0-10	1500	3000
11-30	1000	2000
31-100	750	1500
over 100	500	1000

10. 3 ***Response time*** of fire service to the site. (May be calculated using the distance (D) from the nearest fire station to the site in the "Rand" formula: T = 0. 65 + 1. 7D.)

RESPONSE TIME (min)	0-5	5-10	10-15	15-20	>20
CLASSIFICATION	4	3	2	1	0

10. 4 ***Accessibility*** of the site to fire service equipment and operations. Determined by the number of sides of the building (0-4) that are accessible.

PARAMETER GRADE:

[(10- CAPABILITY) + (WATER SUPPLY) + (2 x RESPONSE TIME) + (2 x ACCESSIBILITY)] / *7*

11. SMOKE CONTROL

DEFINITION: equipment, systems, and protocols for limiting spread of toxic and corrosive fire products

PARAMETER GRADE:

SMOKE CONTROL	GRADE
None	0
Operable windows	1
Automatic smoke vents	3
Engineered smoke control system	5

(Adapted from TABLE 70. 22. 11 of Wisconsin Historic Building Code. Smoke-proof stair credits considered more applicable to egress parameter.)

PART 5
GLOSSARY

HFRI:

(Historic Fire Risk Index) Single numerical value used in fire safety decision making that is produced by analyzing and scoring safety features, hazards, and other risk parameters of an historic building.

GOALS:

a) Provide acceptable level of risk to life from fire
b) Minimize loss of historically significant building fabric or contents

PARAMETER:

Component of fire risk determinable by direct or indirect measure or estimate.

WEIGHT:

Importance of a parameter indicating influence or significance to fire risk. Assigned as a percentage contribution to relative fire risk.

GRADE:

Amount or degree that a parameter is present in a specific historic house museum. Assigned as an integer from a scale of 0-5, where 0 is the highest risk or worst feasible case and 5 is a theoretical optimum equivalent to zero risk contribution.

FIRE SAFETY EVALUATION:

Scalar product of parameter weights and grades.

FIRE RISK INDEX:

Complement of Fire Safety Evaluation.

SURVEY ITEM:

Measurable feature of an historic house museum that serves as a constituent part of one or more parameters or subparameters.

SUB-PARAMETER:

Intermediate component of a parameter with a grade or assessment based on one or more survey items.