Analysis of the NFPA Fire Safety Evaluation System for Business Occupancies

John M. Watts, Jr.
Fire Safety Institute, Middlebury, Vermont

Abstract

The NFPA Fire Safety Evaluation System (FSES) provides a multiattribute approach to evaluating fire safety performance. Published in NFPA 101A, which addresses business occupancy as one of the four types of building use, the FSES consists of a process whereby fire safety parameters are assigned values, and a resulting score is calculated. The analysis in this paper uses the parametric value spread to rank these fire safety parameters and assess the differences between criteria for new and existing buildings.

Introduction

NFPA 101, *Life Safety Code*®,[1] is one of the most widely used voluntary codes for identifying a minimum level of fire safety. The Fire Safety Evaluation System (FSES) provides a multiattribute approach to determining equivalencies to the *Code*'s requirements for certain occupancies. The technique was developed in the late 1970s at the Center for Fire Research, National Bureau of Standards (presently the Building and Fire Research Laboratory, National Institute of Standards and Technology). It has been adapted to new editions of the *Life Safety Code* and is presently published in NFPA 101A, *Alternate Approaches to Life Safety*.[2]

The original FSES was developed for health-care facilities as a uniform method of evaluating fire safety to help regulators assess compliance with federal requirements.[3,4] FSES users would be able to determine what measures would provide a level of safety equivalent to that required by the *Life Safety Code*. The FSES was also designed to give the user information efficiently and with minimal effort. NFPA 101A now includes an FSES not only for health-care occupancies, but for correctional facilities, board and care homes, and business occupancies, as well.

Fire Safety Evaluation System for Business Occupancies

Chapter 7 of NFPA 101A provides an FSES for business occupancies, classified by NFPA 101 as buildings used for transactions other than mercantile, for account- and record-keeping, or for similar business transactions. Examples are medical, legal, and government offices. Also included are adult instructional facilities and classrooms holding under 50 persons. The specific provisions of the *Life Safety Code* for business occupancies are in Chapter 26, "New Business Occupancies," and Chapter 27, "Existing Business Occupancies."

The FSES for business occupancies is based on the approach developed for health-care occupancies. It was derived from a project undertaken for the National Aeronautics and Space Administration (NASA) to develop a method to evaluate the relative level of life safety from fire in existing NASA office buildings and combination office-laboratories.[5] Though the system can be readily implemented with common spreadsheet software packages, a PC-based computer program was also created.[6] Future versions of this program will incorporate specific fire hazard calculation methods and fire risk elements to permit risk-benefit analysis of existing and planned office or business occupancies.

Fire Safety Parameters

The FSES for business occupancies allows users to compute a relative level of safety provided by safeguards that are arranged differently than they are in NFPA 101. In the FSES, each of 12 fire safety parameters is assigned a set of applicable values that correspond to facility conditions that may be present to different degrees. These conditions and their values appear as Table 7-1 of NFPA 101A.

The analysis in this study involves examining the range, or spread, of each safety parameter. The spread of a safety parameter from minimum to maximum value is assumed to be a measure of its importance. The greater the spread, the more impact the parameter has on the resulting fire safety score; thus, the greater its imputed importance.

Table 1 of this paper lists the 12 fire safety parameters for business occupancies in the left-hand column. The second and third columns of Table 1 specify the minimum and maximum values for each parameter, extracted from Table 7-1 of NFPA 101A. The last column in Table 1 is the spread between the minimum and maximum values.

Originally published in *Fire Technology*, Vol. 33, No. 3, 1997, pp. 276-282

TABLE 1
Parameter Values for Fire Safety Evaluation for Business Occupancies

Parameter		Min	Max	Spread
1.	Construction	–12	2	14
2.	Segregation of Hazards	–7	0	7
3.	Vertical Openings	–10	1	11
4.	Automatic Sprinklers	0	12	12
5.	Fire Alarm	–2	4	6
6.	Smoke Detection	0	4	4
7.	Interior Finish	–3	2	5
8.	Smoke Control	0	4	4
9.	Exit Access	–2	3	5
10.	Exit System	–6	5	11
11.	Corridor/Room Separation	–6	4	10
12.	Occupant Emergency Program	–3	2	5
Total		–51	43	94

TABLE 2
Ranked Fire Safety Parameters for Business Occupancies

Parameter Spread			Percent
1.	Construction	14	15%
4.	Automatic Sprinklers	12	13%
10.	Exit System	11	12%
3.	Vertical Openings	11	12%
11.	Corridor/Room Separation	10	11%
2.	Segregation of Hazards	7	7%
5.	Fire Alarm	6	6%
7.	Interior Finish	5	5%
9.	Exit Access	5	5%
12.	Occupant Emergency Program	5	5%
6.	Smoke Detection	4	4%
8.	Smoke Control	4	4%
Total		94	100%

In the FSES for business occupancies, eight parameters are used to calculate a building's fire control score, and ten parameters are used to calculate its egress score. Values for all 12 parameters are added together to produce a score for general fire safety. Only the general fire safety scores are considered in this analysis.

Table 1 indicates that the lowest possible general fire safety score for any business occupancy is –51 points. Similarly, the highest possible score is +43 points. The spread of possible scores is the difference between the highest and lowest possible scores, or 94 points.

Analysis of Parameter Importance

The spread from a parameter's minimum to maximum value indicates the potential magnitude of its effect on the general fire safety score. Thus, the spread of a parameter's values may be taken as a relative measure of the importance of the parameter to life safety. In Table 2, the fire safety parameters are ranked according to the size of

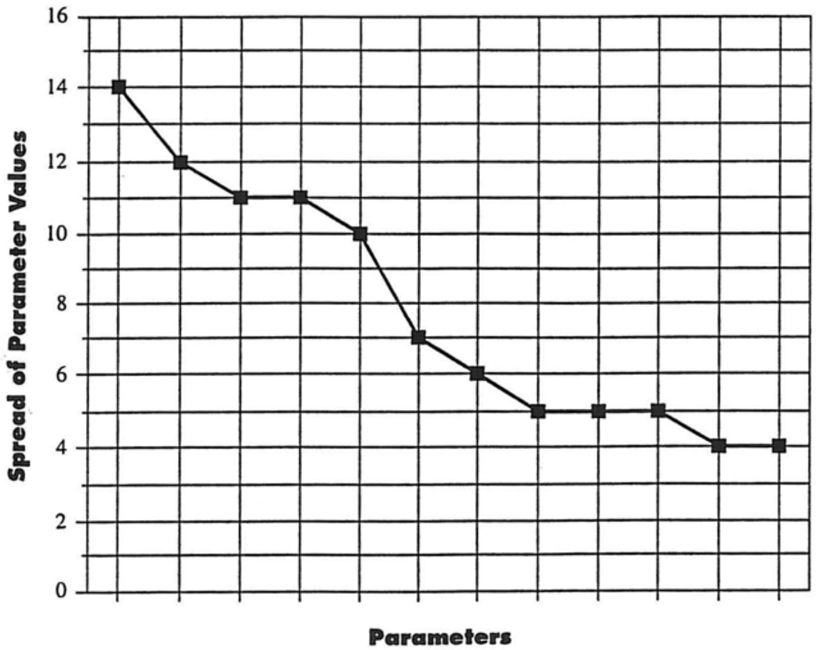

Figure 1. Graphical plot of the ranked fire safety parameters.

the spread from minimum to maximum value, as calculated in Table 1. The first column in Table 2 is the parameter's rank according to its spread, as shown in Column 3. The last column in Table 2 is the percentage of a parameter's spread out of the total spread of points (94) in the general fire safety scoring.

Table 2 shows two distinct sets of fire safety parameters in terms of their value spread. The first five parameters in Table 2 account for 63% of the 94 possible points, while the last seven parameters account for only 37%.

The parameters that we see in these two groups may not be as intuitively important or unimportant to a fire protection engineer as their spread ranking implies. For example, one might intuitively believe that fire detection (parameter 6, rank 9) and interior finish (parameter 7, rank 8) would be more important to life safety in business occupancies than corridor/room separation (parameter 11, rank 4).

Distribution of Parameter Importance

In 1897, Vilfredo Pareto identified a mathematical relationship that describes the distribution of a country's income among a few wealthy and many poorer taxpayers. Pareto's Law has since been applied to other phenomena wherein the greatest usage or impact is distributed among a relatively few items or factors. It is intuitively appealing to postulate that fire safety is a Paretian phenomenon, in that a relatively small number of factors account for most of the problem. This situation is supported by fire incident data that suggest a small number of factors are associated with a large proportion of fire loss.

Figure 1 is a graphical plot of the ranked fire safety parameters shown in Table 2. It portrays the classical shape of a Pareto distribution, in which there are a few major and many minor contributors to fire safety. The tail of the distribution is asymptotic to the abscissa, indicating that countless factors may influence fire safety, but that the magnitude of their influence is quite small.

Mandatory Requirements for Business Occupancies

The FSES for business occupancies lists mandatory requirements for each of six categories of building height (Table 7-3 of NFPA 101A). These mandatory requirements are intended to represent scores that would be achieved by buildings that conform exactly to the details of NFPA 101, Chapters 26 and 27.

Table 3 shows the general fire safety requirements, or evaluation criteria, for new and existing occupancies. The far right column is the difference between the criteria for new and existing occupancies for each of the specified building-height categories.

In the FSES for business occupancies, building height primarily affects the values of Parameter 1, construction. However, for one-story buildings and buildings over 150 feet, the height also affects minimum values for Parameter

TABLE 3
General Fire Safety Mandatory Requirements

	Mandatory Requirements		
Building Height	**New**	**Existing**	**Difference**
One story	2	-1	3
Two stories	-1	-4	3
Three stories	3	0	3
>Three stories & < 75 ft	6	2	4
> 75 feet & < 150 ft	10	6	4
> 150 ft	13	9	4

TABLE 4
General Fire Safety Scores for Business Occupancies

Building Height	**Min**	**Max**	**Spread**
One story	-28	40	68
Two stories	-38	40	78
Three stories	-49	42	91
>Three stories and < 75 ft	-49	42	91
> 75 feet and < 150 ft	-38	42	80
> 150 ft	-38	42	80

TABLE 5
Adjusted General Fire Safety Mandatory Requirements

		Adjusted Requirements			
Building Height	**Min**	**New**	**Exist.**	**Diff.**	**Percent**
One story	–28	30	27	3	10%
Two stories	–38	37	34	3	8%
Three stories	–49	52	49	3	6%
>Three stories and < 75 ft	–49	55	51	4	7%
> 75 feet and < 150 ft	–38	48	44	4	8%
> 150 ft	–38	51	47	4	8%

3, Vertical Openings, and Parameter 12, Occupant Emergency Program, as indicated by Notes A and N to Table 7-1 in NFPA 101A.

The minimum and maximum possible general fire safety scores for each of the six construction categories was calculated from the values in NFPA Table 7-1, within the range of construction types for which the evaluation system is indicated as being valid. These scores are shown in Table 4.

Analysis of Criteria for New vs. Existing Occupancies

Adjusting the mandatory requirements to a common fixed baseline will allow comparisons between new and existing occupancy evaluation criteria. The mandatory requirements were adjusted by adding the minimum score in each building height category to both new and existing requirements. This creates a uniform interval scale with a zero baseline for all the mandatory requirements. The results are shown in Table 5.

The six building height categories are listed in the first column of Table 5, and the second column lists the minimum possible general fire safety scores for each category, as was shown in Table 4. Columns three and four in

Table 5 are the adjusted mandatory requirements for new and existing business occupancies; that is, the minimum score in column two is added to the mandatory requirements shown in Table 3. The adjustment process is transitive, so the differences between minimum and maximum values shown in column five of Table 5 remain the same as those shown in Table 4. The last column in Table 5 is the difference between mandatory requirements for new and existing buildings expressed as a percentage of the adjusted requirements for new buildings.

Table 5 shows a difference in general fire safety requirements between new and existing occupancies of 6-10%. Broadly interpreted, these results show that in the *Life Safety Code*, the existing business occupancies requirements of Chapter 27 provide a relative level of safety that is 6-10% lower than that provided by the *Code* requirements of Chapter 26 for new business occupancies.

Given the many assumptions and inaccuracies in measuring relative levels of safety, this difference could be considered negligible. However, for any particular building, the reduction in requirements may be significant with respect to cost or preservation of historic integrity.

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 author and do not necessarily represent the official position or policies of any supporting agencies.

References

1. NFPA 101, *Life Safety Code*, Quincy, Mass: National Fire Protection Association, 1994.
2. NFPA 101A, *Guide on Alternative Approaches to Life Safely*, Quincy, Mass: National Fire Protection Association, 1995.
3. Benjamin, I. A., "A Fire safety Evaluation System for Health Care Facilities," *Fire Journal*, Vol. 73 (1979), No. 2.
4. Nelson, H .E., and A. J. Shibe, "A System for Fire Safety Evaluation of Health Care Facilities," NBSIR 78-1555 (1980),Center for Fire Research, National Bureau of Standards, Washington, D.C.
5. Nelson, H. E., "Fire Safety Evaluation System for NASA Office/Laboratory Buildings," NBSIR 86-3404 (1986), National Bureau of Standards, Gaithersburg, MD.
6. Hughes Associates, Inc., "Fire Safety Evaluation System (FSES) for Business Occupancies Software (ver 1.0 for Windows®) Users' Manual," NISI GCR-96-692 (1996), National Institute of Standards and Technology, Gaithersburg, Md.