From:	Kimball, Amanda
To:	Hamins, Anthony; Bruce Johnson; Carl Wren; Greg Miller; Hall, John; Harold Hansen; Jeff Tubbs; Jon Nisja; Kelly Nicolello; Dohne, A Kirk; Larry McKenna; Phan, Long Dr.; McNabb, Nancy; Bryner, Nelson P.; Ralph Gerdes; Fahy, Rita; Scott Adams; Shawn Kelley; Solomon, Robert
Subject:	RE: NCST Recommendation Impact Pilot Study
Date:	Wednesday, April 23, 2014 3:43:49 PM
Attachments:	NCST The Station Pilot - Draft Interim Report April 2014 (2).docx The Station Pilot Study - 25 April 2014 Meeting Agenda (1).pdf

All,

Attached is a draft interim report for review. During the call on Friday, I will present the methodology used for Task 3 (changes to model codes) and Task 4 (research literature review). There will be a period after the call for written comments related to these tasks. In addition, I will also ask for any final questions/feedback on Task 2. The full agenda for the call is attached.

Thanks,
Amanda

From: Kimball, Amanda
Sent: Friday, April 11, 2014 4:40 PM
To: Anthony Hamins; Bruce Johnson; Carl Wren; Greg Miller; Hall, John; Harold Hansen; Jeff Tubbs; Jon Nisja; Kelly Nicolello; Kirk Dohne; Larry McKenna; Long Phan; Nancy McNabb; Nelson Bryner; Ralph Gerdes; Rita Fahy; Scott Adams; Shawn Kelley; Solomon, Robert
Subject: RE: NCST Recommendation Impact Pilot Study

All,

I am still working on pulling together the draft final report, but I am sending the revised Task 2 report out to you so I can collect the final comments related to this report ahead of the call. John has made revisions based on the comments received on the first draft. Please provide your final comments on the attached Task 2 report by Friday, April 18th. We can then discuss them on the conference call on the 25th. I will send along the whole draft report soon.

Thanks,
Amanda

From: Kimball, Amanda
Sent: Tuesday, April 01, 2014 3:31 PM
To: Anthony Hamins; Bruce Johnson; Carl Wren; Greg Miller; Hall, John; Harold Hansen; Jeff Tubbs; Jon Nisja; Kelly Nicolello; Kirk Dohne; Larry McKenna; Long Phan; Nancy McNabb; Nelson Bryner; Ralph Gerdes; Rita Fahy; Scott Adams; Shawn Kelley; Solomon, Robert
Subject: NCST Recommendation Impact Pilot Study

Panel Members,

I would like to set up a Panel teleconference to review the draft report in mid-April (ahead of John's retirement at the end of April). The draft report will include a revised Task 2 report (based on comments received from the Panel) and draft Task 3 and 4 reports. The draft report will be circulated next week. Please fill in your availability in the following scheduling poll by Friday, April 4th: https://researchfoundation.doodle.com/yibhg7fty7bfqzhz.

Thank you,
Amanda

Amanda Kimball, P.E.
Research Project Manager

Fire Protection Research Foundation
1 Batterymarch Park, Quincy, MA USA 02169-7471
617.984.7295
akimball@nfpa.org
www.nfpa.org/Foundation

THE FIRE PROTECTION RESEARCH FOUNDATION

Pilot Demonstration of an Impact Evaluation Protocol: NIST NCST Recommendations of the Station Nightclub Fire

Agenda
Project Technical Panel (PTP) Meeting
Conference Call
Friday, 25 April 2014

1. Call to Order and Attendees
2. Final Questions/Comments on Task 2
3. Methodology of Task 3 (changes to model codes) and 4 (research literature review)
4. Panel Feedback
5. Next Steps and Timetable
6. Next Meeting

Pilot Demonstration of an Impact Evaluation Protocol: NIST NCST Recommendations Arising from The Station Nightclub Fire

Draft Interim Report

Prepared by:

John R. Hall, Jr., PhD
Michael Karter
National Fire Protection Association
Quincy, MA

Amanda Kimball, P.E.
Minchao Yin
Fire Protection Research Foundation
Quincy, MA

THE FIRE PROTECTION RESEARCH FOUNDATION

FIRE RESEARCH

THE FIRE PROTECTION RESEARCH FOUNDATION
ONE BATTERYMARCH PARK
QUINCY, MASSACHUSETTS, U.S.A. 02169-7471
E-MAIL: Foundation@NFPA.org
WEB: www.nfpa.org/Foundation

FOREWORD

Under the authority of the National Construction Safety Team (NCST) Act, the National Institute of Standards and Technology (NIST) establishes a National Construction Safety Team to determine the likely technical cause(s) of building failures. These reports include recommendations, but there has been no systematic method available to evaluate the impact of these recommendations. In a time of tight budgets, decisions about the size and even the continuation of the NCST program require information about impact.

A general protocol for conducting such evaluations cannot be created from scratch and still be detailed enough and validated enough to be useful for NIST's purposes. Therefore, the Fire Protection Research Foundation and the National Fire Protection Association (NFPA) is conducting an evaluation of the impact of recommendations from the NCST report on a single incident, to be documented and conducted in such a way that the specific evaluation will also form the basis for defining a general protocol.

The content, opinions and conclusions contained in this report are solely those of the authors.

About the Fire Protection Research Foundation

The Fire Protection Research Foundation plans, manages, and communicates research on a broad range of fire safety issues in collaboration with scientists and laboratories around the world. The Foundation is an affiliate of NFPA.

About the National Fire Protection Association (NFPA)

NFPA is a worldwide leader in fire, electrical, building, and life safety. The mission of the international nonprofit organization founded in 1896 is to reduce the worldwide burden of fire and other hazards on the quality of life by providing and advocating consensus codes and standards, research, training, and education. NFPA develops more than 300 codes and standards to minimize the possibility and effects of fire and other hazards. All NFPA codes and standards can be viewed at no cost at www.nfpa.org/freeaccess.

Keywords: [Insert keywords]

Contents

Background

The Station Nightclub Fire occurred on the night of 20 February 2003 in West Warwick, Rhode Island, and resulted in 100 fatalities. A NIST NCST report was issued in June 2005 and included 10 recommendations. These 10 recommendations are the focus of this pilot study[1]:

Recommendation 1. Model Code Adoption and Enforcement: NIST recommends that all state and local jurisdictions:

a) adopt a building and fire code covering nightclubs based on one of the national model codes (as a minimum requirement) and update local codes as the model codes are revised;

b) implement aggressive and effective fire inspection and enforcement programs that address: (i) all aspects of those codes; (ii) documentation of building permits and alterations; (iii) means of egress inspection and record keeping; (iv) frequency and rigor of fire inspections, including follow-up and auditing procedures; and (v) guidelines on recourse available to the inspector for identified deviations from code provisions; and

c) ensure that enough fire inspectors and building plan examiners are on staff to do the job and that they are professionally qualified to a national standard such as NFPA 1031 (Professional Qualifications for Fire Inspector and Plan Examiner).

Recommendation 2. Sprinklers: NIST recommends that model codes require sprinkler systems according to NFPA 13 (Standard for the Installation of Sprinkler Systems), and that state and local authorities adopt and aggressively enforce this provision:

a) for all new nightclubs regardless of size, and

b) for existing nightclubs with an occupancy limit greater than 100 people.

Recommendation 3. Finish Materials and Building Contents: NIST recommends that:

a) state and local authorities adopt and aggressively enforce the existing provisions of the model codes;

b) non-fire retarded flexible polyurethane foam, and other materials that ignite as easily and propagate flames as rapidly as non-fire retarded flexible polyurethane foam: (i) be clearly identifiable to building owners, operators, contractors and authorities having

[1] Grosshandler, et. al., Report of the Technical Investigation of The Station Nightclub Fire, National Institute of Standards and Technology, NIST NCSTAR2, June 2005.

jurisdiction (regulatory agencies); and (ii) be specifically forbidden, with no exceptions, as finish materials from all new and existing nightclubs;

c) NFPA 286 (Standard Methods of Fire Tests for Evaluating Contribution of Wall and Ceiling Interior Finish to Room Fire Growth) be modified to provide more explicit guidance for when large-scale tests are required to demonstrate that materials (other than those already forbidden in b above) do not pose an undue hazard for the use intended; and

d) ASTM E-84 (Standard Test Method for Surface Burning Characteristics of Building Materials), NFPA 255 (Standard Method of Test of Surface Burning Characteristics of Building Materials), and NFPA 286 be modified to ensure that product classification and the pass/fail criteria for flame spread tests and large-scale tests are established using the best measurement and prediction practices available.

Recommendation 4. Indoor Use of Pyrotechnics: NIST recommends that NFPA 1126 (Use of Pyrotechnics before a Proximate Audience) be strengthened as described below, and that state and local authorities adopt and aggressively enforce the revised standard.

a) Pyrotechnic devices should be banned from indoor use in new and existing nightclubs not equipped with an NFPA 13 compliant automatic sprinkler system.

b) NFPA 1126 should be modified to include a minimum occupancy and/or area for a nightclub below which pyrotechnic devices should be banned from indoor use, irrespective of the installation of an automatic sprinkler system.

c) Plans for the use of indoor pyrotechnics in new and existing nightclubs should be posted on site; and in addition to the items listed in paragraph 4.3.2 of NFPA 1126, should describe the measures that have been established to provide crowd management, security, fire protection, and other emergency services.

d) Section 6.6.2 of NFPA 1126 should be modified to require the minimum clearance between (i) the nearest fixed or moveable contents, and (ii) any part or product (igniter, spark, projectile, or debris) of a pyrotechnic device permitted for indoor use in new and existing places of assembly, to be twice the designed projection of the device, until such time that studies show that a smaller minimum clearance can guarantee safe operation in spite of the possibility that building decorations or temporary features that greatly exceed flame spread or fire load provisions of the fire code may occur.

Recommendation 5. Occupancy Limits and Emergency Egress: NIST recommends that the factor of safety for determining occupancy limits of all new and existing nightclubs be increased in the model codes in the following manner, and that state and local authorities adopt and aggressively enforce the following provisions:

a) Within the model codes, establish the threshold building area and occupant limits for egress provisions using best practices for estimating tenability and evacuation time; and, unless further studies indicate another value is more appropriate, use 1-1/2 minutes as the maximum permitted evacuation time for nightclubs similar to or smaller than The Station.

b) Compute the number of required exits and the permitted occupant loads assuming at least one exit (including the main entrance) will be inaccessible in an emergency evacuation.

c) For nightclubs with one clearly identifiable main entrance, increase the minimum capacity of the main entrance to accommodate two-thirds of the maximum permitted occupant level (based upon standing space or festival seating, if applicable) during an emergency.

d) Eliminate trade-offs between sprinkler installation and factors that impact the time to evacuate buildings.

e) Require staff training and evacuation plans for nightclubs that cannot be evacuated in less than 1-1/2 minutes.

f) Provide improved means for occupants to locate emergency routes—such as explicit evacuation directions prior to the start of any public event, exit signs near the floor, and floor lighting—for when standard exit signs become obscured by smoke.

Recommendation 6. Portable Fire Extinguishers: NIST recommends that a study be performed to determine the minimum number and appropriate placement (based upon the time required for access and application in a fully occupied building) of portable fire extinguishers for use in new and existing nightclubs, and the level of staff training required to ensure their proper use.

Recommendation 7. Emergency Response: To ensure an effective response to a rapidly developing mass casualty event, NIST recommends that state and local authorities adopt and adhere to existing model standards on communications, mutual aid, command structure and staffing, such as:

a) NFPA 1221, Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems

b) NFPA 1561, Standard on Emergency Services Incident Management Systems

c) NFPA 1710, Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments

d) NFPA 1720, Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Volunteer Fire Departments

Recommendation 8. Research on Human Behavior: NIST recommends that research be conducted to better understand human behavior in emergency situations, and to predict the impact of building design on safe egress in fires and other emergencies (real or perceived), including the following:

a) the impact of fire products (gases, heat, and obscuration) on occupant decisions and egress speeds;

b) exit number, placement, size and signage;

c) conditions leading to and mitigating crowd crush;

d) the role of crowd managers and group interactions;

e) theoretical models of group behavior suitable for coupling to fire and smoke movement simulations; and

f) the level of safety that model codes afford occupants of buildings.

Recommendation 9. Research on Fire Spread and Suppression: NIST recommends that research be conducted to understand fire spread and suppression better in order to provide the tools needed by the design profession to address recommendations 2, 3 and 5, above. The following specific capabilities require research:

a) prediction of flame spread over actual wall, ceiling and floor lining materials, and room furnishings;

b) quantification of smoke and toxic gas production in realistic room fires; and

c) development of generalized models for fire suppression with fixed sprinklers and for firefighter hose streams.

Recommendation 10. Research on Computer-aided Decision Tools: NIST recommends that research be conducted to:

a) refine computer-aided decision tools for determining the costs and benefits of alternative code changes and fire safety technologies; and

b) develop computer models to assist communities in allocating resources (money and staff) to ensure that their response to an emergency with a large number of casualties is effective.

For purposes of generating a protocol, the 10 recommendations can be assigned to two groups:

A. Legislation/Adoption/Enforcement (includes Report Recommendations 1-5 & 7): recommendations for changes in the rules and practices that define local environments and fire department effectiveness; and

B. Research (includes Report Recommendations 6 & 8-10): recommendations for research on fire-related phenomena and mitigation methods that will lead to recommendations for changes in rules.

Evaluation of Group A recommendations requires examination of local rules and practices. NFPA will provide analysis of local data on local rules and practices as well as analysis of the related changes made to model codes and standards.

Evaluation of Group B recommendations as those recommendations are stated requires examination of published research results and ongoing or planned research programs. A literature review approach will be completed to assess the impact of these recommendations. The Group B recommendations are intended to lead to research that will in turn lead to new rules and practices. The literature review will pay particular attention to the degree of progress toward this ultimate goal.

In some cases, research may already have developed findings relevant to rules and practices, possibly some of the same rules and practices addressed by Group A recommendations. In a separate research task, the Foundation and NFPA will look at the results of its two primary evaluation tasks synergistically to provide an overall impact evaluation and complete the development and demonstration of a comprehensive general impact evaluation protocol.

Task 2: Analysis of Data Related to Fire Departments/Legislation, Adoption, and Enforcement Recommendations

Task 2 consists of the evaluation of the Group A recommendations (Recommendations 1-5 and 7) defined in the previous section. NFPA had its own interest in these same recommendations, dating back to the NFPA findings in NFPA's own investigation of The Station night club fire and NFPA consideration of proposals for changes in codes and standards arising from those findings. Before the NIST project was authorized and begun, NFPA had developed and conducted a survey of U.S. fire departments protecting populations of at least 50,000, with questions about local practices, local codes and standards, and local enforcement activities related to those local codes and standards, for each of six groups of issues:

- Adoption of current codes and standards and activities related to general enforcement of codes and standards
- Sprinkler requirements for nightclubs

- Interior finish requirements for nightclubs
- Indoor pyrotechnic requirements for nightclubs
- Occupancy limits and egress requirements for nightclubs
- Communications, incident management and deployment requirements for incident response

The goal of an exercise like Task 2 is to provide an evaluation of the degree of implementation of features and practices that were recommended – usually in the form of a new code or standard or changes to an existing code or standard. What is sought is information on:

- *adoption* of requirements (for those features and practices), which connects the gap between impact of recommendations at the national level (on model codes and standards) and impact at the local level (on local requirements and practices);
- *compliance* with requirements (for features of properties but not for fire department practices; if fire departments report adoption of requirements for fire department practices, then there is no point in asking fire departments about inspection and enforcement activities to check compliance); and
- *timing of changes* in requirements, as this is the most accessible information indicating a role on NIST recommendations and other national changes or guidance following a major incident in changing local practices (e.g., some localities may already have local practices that match the recommendations)

An evaluation exercise can be conducted using a number of different types of information:

- The exercise can be conducted using only local *information that is already routinely collected*, recorded and transmitted to a national body. Such an exercise will be very inexpensive, but it is very unlikely that such existing, nationally compiled data sources will be able to provide enough details for any significant evaluation.
- The exercise can be conducted using *site visits and/or special data collection protocols* that are set up to run for at least a year. Such an exercise will likely require a six-figure budget and still provide data on only a dozen or so communities. The detail obtained will be the most possible and will address the recommendations and their impacts in the greatest detail possible, but the lack of breadth of coverage will severely limit any conclusions that can be reached. Previous such studies have rarely incorporated smaller communities. Including these communities will add to the costs of the study, but not including these communities may limit the generalizability of any conclusions.
- The best balance of affordability and useful detail will probably be achieved through a *survey*. However, it is important to check costs, response rates, design bias, and resulting statistical significance of a particular survey proposal, and it is also important to check whether the level and type of detail obtainable from a survey will provide sufficient evaluative depth to be worth the cost. For this prototype application of an evaluation protocol, NFPA was able to use data collected in the earlier, independent NFPA survey

because the issues addressed match well with the NIST recommendations on similar topics. In a normal application of the generic protocol, the people conducting the evaluation would have to review the considerations listed here for and against a survey as a source of evaluative information. They would also have to design a survey if they chose to conduct one. Appendix A contains the survey used by NFPA, which is offered here for its illustrative value to anyone seeking to develop a survey with the same structure for evaluation of any set of recommendations arising from investigation of a major incident.

In this report, comments about the general approach and comments about the nightclub fire example are interwoven. Comments about the example are indented to help the reader.

Although this protocol is limited to evaluation of local adoption of and compliance with particular recommendations, it may be useful to include information on the degree of success in having the recommendations adopted into national model codes or recognized best practices. A lack of success at the national model code stage will likely make the downstream questions moot.

The protocol sometimes uses "the community" and "the building or fire department" interchangeably when talking about adoption and activities to check compliance. The measurement of adoption and compliance proceeds in the same manner regardless of who has what role, authority or responsibility in achieving the desired results, but the application of the findings will depend very much on those roles and should be included in the evaluation.

The description of the protocol is fairly basic and could be refined for more ease of use. For example, there may be value in converting the evaluation scores to letter grades, which may convey the most important summary information more quickly than do the current formats.

Step 1. What is the Target?

A recommendation needs to be translated into a desired change in conditions in the field.

In the example, the recommendations were intended to prevent or reduce the likelihood of a future multi-casualty fire at a nightclub. The target therefore is nightclubs, which should be made safer, and fire departments with nightclubs in their protected communities, which should be made better able to fight fires at nightclubs and maintain safety improvements at nightclubs. Although the target is nightclubs, it is reasonable to expect that other types of assembly occupancies would also benefit from the recommendations, whether they are aimed at changing behavior of the owners and managers (thereby increasing the safety of the buildings), the occupants (thereby reducing the risks they create or are exposed to), or the first responders (thereby better mitigating the losses in fires when they occur or reinforcing safer behaviors through inspection, enforcement, education or other means).

Targeting a group of properties. For recommendations defined by a class of properties, Step 1 starts with identifying the number of such establishments in the country, followed by looking for any clustering of establishments that would permit a narrower focus in the evaluation (e.g., most properties located in certain states or in communities of a certain size).

For the example, this means starting with an estimate of the number of nightclubs.

It will typically be the case that different data sources use different definitions or draw the boundaries differently, and that is the case in the example. In any evaluation, it will be important to examine these differences carefully so that the evaluation will be targeted on a group of properties that is appropriate for the evaluation. That is, if the evaluation is favorable or unfavorable for the group of properties selected for analysis, one can be reasonably sure that evaluation would have been similarly favorable or unfavorable for the precise group of properties targeted by the requirement or recommendation, if it had been possible to match the evaluation to that group exactly.

The industry (which refers to itself variously as the bar, nightclub and drinking establishment industry or the nightlife and club industry trade organization industry) estimates roughly 65,000 establishments that derive their revenue primarily from the sale of alcoholic beverages.[2] However, only 8.6% of the revenue for these establishments is said to be from **nightclubs**, with taverns, bars and lounges, drinking places, and cocktail lounges accounting for the rest. There does not appear to be a formal industry definition for "nightclub". Dictionary definitions typically mention nighttime operations and music and/or dancing as defining characteristics.[3] It is reasonable to expect that a nightclub will tend to be larger than a tavern or bar, with higher revenue per establishment, which means the night club share of establishments is likely smaller than the nightclub share of revenue. The actual number of true nightclubs is therefore probably lower than the 5,600 establishments estimated by applying 8.6% to 65,000.

At the same time, "nightclub" also is not specifically defined or separately addressed in either the national fire incident database or the principal model codes and standards. For example, NFIRS code 162 for Property Use includes all types of drinking establishments. In *NFPA 101®, Life Safety Code*, "nightclub" is not defined and

[2] NCIAA (which claims to be the Nightlife & Club Industry's Official Trade Organization), *Our Industry*, 2011-2012 statistics from diverse sources particularly IbisWorld studies conducted by MarketResearch.com, published at http://www.nciaa.com/content.aspx?page_id=22&club_id=160641&module_id=29898.
[3] See, for example, *Merriam-Webster's Collegiate Dictionary*, Springfield (MA): Merriam-Webster, Incorporated, 10th edition, 1997.

requirements are stated not only for all drinking establishments but for all assembly properties, sometimes with a minimum occupancy threshold. Therefore, changes in response to the NIST recommendations and available data on fires and on local practices may address all drinking establishments. Certain non-drinking establishments such as concert halls are also likely to be impacted by some of the NIST recommendations.

The NFPA survey asked about the number of nightclubs in the community but only surveyed fire departments protecting communities with at least 50,000 population. This provided a manageable test of the survey protocols, while also offering the possibility of capturing a large share of the nightclubs or drinking establishments in the country. NFPA had not conducted an analysis of the distribution of nightclubs and drinking establishments by size of community prior to designing the survey.

For the analysis phase of this project, estimates of total nightclubs or drinking establishments in communities with at least 50,000 population were developed from the survey and compared to the national numbers developed from industry sources above (i.e., 65,000 total drinking establishments and less than 5,600 true nightclubs). The goal was twofold:

- Try to determine whether respondents were reporting on all drinking establishments or only true nightclubs, and
- Estimate what share of total U.S. nightclubs or drinking establishments are located in communities with at least 50,000 population.

Responses to the survey were given in terms of ranges for the number of nightclubs in the community. To estimate the number of nightclubs in these communities, it is necessary to pick a specific number to represent a range. For the closed-end ranges (2 to 5 and 6 to 10), one can run one set of analyses using the lower end of the range and one set using the upper end of the range. For the open-ended top range (11 or more), one can still run an analysis using the bottom end of the range, but it is necessary to select a number to represent the high end of the range.

An exploratory analysis was done in which the upper number for those open-ended top ranges was defined as 1 nightclub per 5,000 population combined with the high end of the population range. The figure of 1 nightclub per 5,000 population is roughly equivalent to 65,000 drinking establishments spread evenly over a U.S. population of around 320 million. For example, communities with populations in the range of 50,000 to 100,000 and reporting 11 or more nightclubs were estimated to have 20 nightclubs (20 = 100,000 x 1/5000). For the open-ended highest population range, which starts at 500,000 population, a figure of 1,000,000 population was used.

Using the bottom ends of the ranges produces an estimate of 6,700 nightclubs just from communities of 50,000 or more population, which is already higher than the nightclub-only portion of total establishments calculated above. Using the top ends of the ranges produces an estimate of 30,900 nightclubs, which is nearly half the total of 65,000 drinking establishments.

It seems clear that the survey respondents were using the drinking establishment definition rather than the narrower nightclub definition, because even the lowest estimate of total nightclubs in communities of 50,000 or more population is higher than the industry's estimate of total nightclubs in the country.

Also, as the population size of the communities declines, the number of nightclubs per community declines, but the number of such communities increases. Using the bottom ends of the ranges, the smaller communities account for more total nightclubs than the larger communities. Using the higher ends of the ranges, there is no clear relationship between size of community and share of total nightclubs.

The implications of this exploratory analysis are that a full evaluation of the impact of the NIST recommendations should include communities of all sizes. As further evidence of this point, The Station nightclub fire occurred in West Warwick, Rhode Island, a community of less than 30,000 population. The deadliest nightclub fire of the past half-century – the Beverly Hills Supper Club fire in 1977 – took place in Southgate, Kentucky, a town of less than 4,000 population. On the other hand, the deadliest U.S. nightclub fire of all time took place in Boston, Massachusetts, a large city with population protected in the top population group of the NFPA survey.

Success in implementation of recommendations will often be dependent on success in smaller communities. **Ideally, an evaluative survey should cover all sizes of communities.**

For the example, the argument in favor of including all communities is based on the fact that nightclubs can be found anywhere and appear to be very widely distributed. In general, the argument in favor of including all communities is based on the importance of capturing all or most of the targets and the fact that most of the targets may be spread across the many small communities where target density is quite low but share of total targets is collectively large.

There is a separate argument in favor of including all communities based on the possibility that new rules are less likely to be adopted, less likely to be adopted quickly, and less likely to be effectively enforced in smaller communities.

The fact that an all-community survey would be best for evaluation and may even be necessary for evaluation does not mean that such a survey will be practical or affordable.

The first concern is that response rates will drop with smaller communities.

Table A. Percent of Departments Responding to NFPA Nightclub Survey

Size of community	Percentage
500,000 or more	38%
250,000 to 499,999	42%
100,000 to 249,999	32%
50,000 to 99,999	33%
Total	34%

This looks like a fairly modest decline in response rate by size of community, but that is probably a reflection of the exclusion of communities with less than 50,000 population. For comparison's sake, consider the percent of departments responding to the third NFPA fire service needs assessment survey.[4]

Table B. Percent of Departments Responding to Third Fire Service Needs Assessment Survey

Size of community	Percentage
500,000 or more	58%
250,000 to 499,999	61%
100,000 to 249,999	59%
50,000 to 99,999	59%
25,000 to 49,999	48%
10,000 to 24,999	36%
5,000 to 9,999	23%
2,500 to 4,999	19%
Under 2,500	15%
Total	23%

As with the nightclub survey, response rates change little down to 50,000 population, but they decline sharply as community size shrinks below 50,000.

In addition, the smaller the community, the less likely it is to have any nightclubs. Table C presents results from Q1 of the nightclub survey, which asked how many nightclubs a responding community has. (See Table 1 for complete results from Q1.)

Table C. Percent of Responding Departments Having No Nightclubs

Size of community	Percent
500,000 or more	0%
250,000 to 499,999	3%
100,000 to 249,999	11%
50,000 to 99,999	24%
Total	17%

[4] *Third Needs Assessment of the U.S. Fire Service*, National Fire Protection Association, June 2011, p.179

> As may be seen, the percentage of departments with no nightclubs rises rapidly as community size declines. Consider how this percent might continue to decline if the survey had included smaller communities. If the national average is 1 nightclub per 5,000 population, then more than half of communities under 2,500 population would have no nightclubs.
>
> Put these two factors together. The response rates for the nightclub survey were roughly 2/3 the response rates for comparable sized communities in the third fire service needs assessment survey. This means that if the nightclub survey had pursued all communities, it might have achieved only a 10% response rate for communities with less than 2,500 population (10% = 2/3 of 15% response rate for those communities in the third needs assessment survey). There are about 13,000 communities (defined as fire department protection areas) with less than 2,500 population, and the average population for such communities is about 1,300. Therefore, communities of that size would average about 1 nightclub for every 4 communities (4 = 5,000/1,300), and only about 2-3% of communities with less than 2,500 population would be expected to respond to the survey and report having at least one nightclub. That translates into fewer than 300 communities. Survey forms would need to be mailed to most of the 13,000 communities to hope to obtain results from 200 rural departments with nightclubs.

These kinds of calculations would need to be made in order to determine the cost of a survey with sufficient statistical power to provide credible results for all sizes of communities.

Step 2. Evaluating Targeted Conditions

General protocol. An evaluation is built around best estimates of answers to three questions, for a particular recommended feature or practice that was called for in a recommendation.

Question 1. To what extent do communities have *requirements* related to the feature or practice?

Typically, a requirement will be set forth in an adopted code provision or standard or other legislative authorization. The “condition” could be a characteristic (e.g., system, feature) of the property that enhances safety, or it could be a practice of the fire department that reinforces the property characteristics (e.g., enforcement) or improves ability to mitigate incidents when they occur. Did we ask about a law or ordnance? I think Connecticut put their revision in a state law- not actually in the code.

Question 2. What is the degree of *compliance* with those requirements in the communities?

For property characteristics, there may be no existing basis for direct measurement of compliance because many, possibly most, communities do not have annual fire code inspections of all properties or of a representative sample of properties. A special survey of properties could be used, but in most cases, the only practical measurement will be best estimates by community authorities.

For fire department practices to improve mitigation ability (such as communications at the fire scene, deployment and staffing, incident management), the fire department is involved directly in adoption, which means the entity that needs to implement the requirements and assure compliance is not a separate entity, which might require more persuasion or motivation to comply with a requirement that they had nothing to do with creating.

In both cases, an audit involving direct observation of practices and conditions by an independent third party would provide more evidence of compliance, but at considerably greater cost per community.

Question 3. Did the requirements *change after the major event* that led to the recommendations?

This is the best high-level indicator of impact of the recommendations. It is not necessarily the case that improvements in safety introduced after a major event were made in response to that event, let alone that they were made in accordance with specific recommendations emerging from that event, but it is a reasonable premise for a first-order evaluation of the impact of recommendations, and a more detailed evaluation would be much more expensive.

These three questions are associated with more detailed follow-up questions:

a) For question 1, *are the requirements in place well-aligned with the requirements that were recommended*? Data on this point will allow the evaluation to estimate relative success in implementation instead of a more rigid and inflexible either/or assessment.

b) For question 2, *are communities using inspections, tests and other means to achieve and assure compliance*? If no, then the best estimates by community authorities may not be accurate. Also if no, this points to programs where more active enforcement programs would be an obvious path to higher levels of compliance.

   Going to a deeper level of detail, are community estimates of compliance higher in places that are using particular means to achieve and assure compliance?

   If estimates are higher in places that are using more effective means, like inspections and tests, then that is evidence of the potential value of such means in improving compliance and can be used in designing follow-up programs and related advocacy arguments.

If estimates are actually lower in places that are using more effective means, then that is evidence that community authorities may be overly optimistic about their levels of compliance, in the absence of any real data. That supports a different kind of follow-up and different kinds of related arguments.

c) For questions 1 and 3, is adoption of requirements or full adoption of recommended requirements and practices associated more with one or another source of model codes and standards? This can be useful in designing follow-up programs to improve adoption rates.

Applying the three questions to the example.

Table D shows how specific survey questions are used to provide estimates for each of the three questions (row numbers 1 to 3) and each of the four nightclub features and practices identified for evaluation.

Table D. Questions Used in Estimating Evaluative Metrics, by [Nightclub] Feature or Practice

Question to be answered	Sprinklers	Interior finish	Indoor pyrotechnics	Occupancy limits and egress requirements
#1. Do communities have requirements? Yes/No	Q. 6	Q. 9	Q. 14	Q. 17
#1a. Which of several requirements do they have?	Q. 6, asks about occupancy threshold	Q. 11, on use of visual vs. testing confirmation	Q. 14, on use or non-use of NFPA 1126 in setting restrictions	Q. 17 on source of requirements, either local or a particular model code, which may imply different requirements
#2. How many [nightclubs] are in compliance? All, Most, Half, Some, None	Q. 8	Q. 13	Q 16	Q. 19
#2a. What enforcement activities with what frequencies and coverages are used to check compliance?	Q. 7	Q. 12	Q. 15	Q. 18
#3. Did the requirements change after [The Station nightclub fire occurred?] Yes/No	Q. 6a	Q. 9h	Q. 14e	Q. 17f

Table E shows how specific survey questions are used to provide estimates for each of the two questions (where as noted Question #2 is moot) and each of the three fire department practices identified for evaluation.

Table E. Questions Used in Estimating Evaluative Metrics, by Fire Department Practice

Question to be answered	Adoption of model code and existence of inspection program	Public emergency services communications systems re NFPA 1221	Emergency service incident management system re NIMS or NFPA 1561	Organizational, operational and deployment procedures re NFPA 1710 or 1720
#1. Does department follow indicated practice? Yes/No	Q. 2-4	Q. 20	Q. 21	Q. 22
#3. Did the requirements change after [The Station nightclub fire occurred?] Yes/No	Q. 5	Q. 20a	Q. 21a	Q. 22a

Adoption of Model Code and Enforcement Through Inspection

Part III in the NFPA survey asked about adoption of model codes, for new or existing occupancies, with or without amendments or other modifications, and the existence of an inspection program, for new or existing occupancies. These questions provide some information relevant to NIST Recommendation 1, which called for all state and local jurisdictions to:

a) adopt a building and fire code covering nightclubs based on one of the national model codes as a minimum requirement (and update local codes as the model codes are revised);
b) implement "aggressive and effective" fire inspection and enforcement programs that address:
   - all aspects of the codes,
   - documentation of building permits and alterations,
   - means of egress inspection and record keeping,
   - frequency and rigor of fire inspections, including follow-up and auditing procedures, and
   - guidelines on recourse available to the inspector for identified deviations from code provisions; and
c) ensure that enough fire inspectors and building plan examiners are on staff to do the job and that they are professionally qualified to a national standard such as NFPA 1031.

Question 1 (requirements) applied to code adoption and inspection program: Have building and fire codes based on national model codes been adopted? Table F is based on two columns each from Tables 2 and 3, which are based on Q's 2 and 3 from the NFPA nightclub survey. No department reported having no codes for either newly constructed or existing nightclubs, and so Table F is describing only communities with a local code not based on any national model code.

Table F. Percent of Departments Having No Local Code Based on National Model Code, for Newly Constructed and Existing Nightclubs

	Percentage of Departments Having No Code or A Local Code Not Based on a National Model Code	
Size of community	**Newly Constructed Nightclubs**	**Existing Nightclubs**
500,000 or more	15%	15%
250,000 to 499,999	0%	8%
100,000 to 249,999	7%	7%
50,000 to 99,999	8%	9%
Total	8%	9%

Note: Multiple responses were permitted, and that may affect the results. In the unlikely event that a department reported both "no code" and "local code not based on a model code", there will be double counting. This calculation also assumes that "local code not based on a model code" implies no local use of a model code, even if the department also checked off a model code as being in use.

Table 2 shows that 81% of departments (protecting communities of 50,000 or more population) use the *International Building Code*® (IBC) for newly constructed nightclubs, 35% use NFPA 101, *Life Safety Code*®, and 30% use an "other" model code, which when specified was almost always a state code based on one of the national model codes. (Note that multiple responses were permitted and communities could and often did select more than one code.)

Table 3 shows that 66% of departments (protecting communities of 50,000 or more population) use the *International Fire Code*® (IFC) for existing nightclubs, 45% use NFPA 101, *Life Safety Code*®, either as part of NFPA 1 (22%) or not as part of NFPA 1 (23%), and 18% use an "other" model code, which when specified was almost always a state code based on one of the national model codes. (Note that multiple responses were permitted and communities could and often did select more than one code.)

Question 3 (change after the major event) for Recommendation 1a. The Station nightclub fire occurred in 2003. By the 2006 edition, both NFPA 101 and the *International Building Code* (IBC) had adopted requirements consistent with the NIST recommendations for newly constructed nightclubs (sprinklers regardless of occupancy), and NFPA 101 had adopted requirements consistent with the NIST recommendations for existing nightclubs (sprinklers for occupancy of 100 or more). It should be noted that the NFPA 101 changes were actually processed as Tentative Interim Amendments (TIA) for the 2003 edition of the code, a form of emergency code changes at NFPA, in July of 2003. The survey did not ask specifically about this TIA but instead asked about any changes made after 2003.

Table 4 indicates that only 3% of departments reporting use of the IBC for newly constructed buildings were using a 2003 or earlier edition. Table 5 indicates that 28% of departments reporting use of NFPA 101 for newly constructed buildings were using a 2003 or earlier edition. Note that 23% of departments use both documents.

Table 6 indicates that only 2% of departments reporting use of the IFC for existing buildings were using a 2003 or earlier edition. However, even the most current edition of the IFC does not include any specific sprinkler requirements for existing nightclubs. Table 7 indicates that 10% of departments reporting use of NFPA 101 for existing buildings (as part of NFPA 1) were using a 2003 or earlier edition. Note that 12% of departments use both documents.

Based on combining these results, **up to 20% of departments are in communities that have not fully implemented the NIST recommendations regarding use of an updated national model code for newly constructed buildings**, consisting of:

- 8% (from Table F) that have no local code based on a model code at all and

- up to another 12% whose local code may reference only model code editions that precede implementation of requirements like those called for by the NIST recommendations (3% of the 81% using IBC and 28% of the 35% using NFPA 101, assuming that the departments using an older edition of either the IBC or NFPA 101 are not departments that also use an updated edition of the other code).

Also, based on combining these results, **up to 60% of departments are in communities that have not fully implemented the NIST recommendations regarding use of an updated national model code for existing buildings**, consisting of:

- 9% (from Table F) that have no local code based on a model code at all,
- another 5% using an outdated edition of NFPA 101 (10% of the 45% using NFPA 101, assuming the distribution of edition ages for departments using NFPA 101 as part of NFPA 1 is the same as the distribution of edition ages for departments using NFPA 101 not as part of NFPA 1, the latter shown in Table 7), and
- up to all of the 46% of departments whose local code is based on a model code that has not (IFC) or is not known to have ("other" code) implemented requirements like those called for by the NIST recommendations (assuming that a local code based on the IFC or an "other" code is not also based on a current edition of NFPA 101).

Table 8 indicates that 32% of departments have local amendments in place, 9% that have not been changed since 2003, the year of The Station nightclub fire, and the other 23% with local amendments that have been changed since 2003. The remaining 68% of departments have no local amendments. Local amendments can be used to remove requirements from a model code or, much less often, to provide stricter requirements. Code and standard development bodies recommend against the use of local amendments or other modifications that make the requirements less stringent.

Question 1 for Recommendation 1b: Inspections. Before examining estimates of degree of compliance and programs intended to assure compliance for specific property requirements, it is useful to have an overview of the general provisions for compliance assurance in the communities. Specifically, it is useful to ask whether there are any provisions for inspections to check on compliance.

In the example, this is also the only information currently available for communities with less than 50,000 population. For comparison's sake, consider the percent of departments for which no one provides fire code inspections, according to the third NFPA fire service needs assessment survey.[5]

Table G indicates that 100% of departments in communities large enough to be included in the NFPA nightclub survey (i.e., at least 50,000 population) have someone who conducts fire code inspections. For smaller communities, particularly communities under 10,000 population, this is not the case. For rural communities (under 2,500 population), more than a third of communities have no one performing fire code inspections.

Also, while not shown in Table G, for communities under 5,000 population, the most frequently cited source of fire code inspections is "Other", not the fire department or a building department or a separate inspection department. "Other" might include inspections by the state fire marshal's office or an insurance service. "Other" might also include contract inspection personnel reporting to a local authority.

If the nightclub survey had been extended to smaller communities, it is likely that the majority of fire departments serving those communities would report no fire code inspections at all or no fire code inspections under the control and supervision of the fire department.

Table G. Percent of Departments Responding to Third Fire Service Needs Assessment Survey Reporting No One Provides Fire Code Inspections

Size of community	No Fire Code Inspections
500,000 or more	0%
250,000 to 499,999	0%
100,000 to 249,999	0%
50,000 to 99,999	0%
25,000 to 49,999	1%
10,000 to 24,999	3%
5,000 to 9,999	10%
2,500 to 4,999	24%
Under 2,500	36%
Total	24%

[5] *Third Needs Assessment of the U.S. Fire Service*, National Fire Protection Association, June 2011, p.106

Table 9 indicates that no departments protecting communities with at least 50,000 population report that there are no inspections in their community. For building code inspections of buildings under construction, 64% of departments reported conducting such inspections, and for the other departments, most if not all may have had inspection programs conducted by the building department, a separate inspection department, or another entity. For fire code inspections of existing buildings, 77% of departments report conducting inspections with at least annual frequency, and 23% report conducting inspections with a less-than-annual frequency. A total of 66% report conducting inspections in response to complaints, which may be instead of or in addition to inspections on a defined schedule and frequency.

NFPA has conducted two major studies of measures of fire code inspection effectiveness, one published in 1979 and the other in 2008.[6] The first study found that none of the departments studied (all protecting populations of at least 250,000), all of which claimed to be achieving annual fire code inspections, were in fact conducting inspections at least once a year. The departments that came closest were using in-service firefighters – who did not have all the training normally required of full-time fire inspectors – to conduct most inspections, which would not comply with NIST Recommendation 1c

The second study found that requirements for professional certification of all inspectors had reduced the use of in-service firefighters, thereby also sharply reducing the volume of inspections conducted, and departments were increasingly reduced to inspections triggered by complaints and inspections only for special categories of properties (such as inspections in support of permits, where there was a revenue stream associated with the permits to offset costs).

The bottom line is that Table 9 (and Q.5 it is based on) do not show the extent of problems and shortfalls that more detailed studies have consistently and increasingly found.

Summary of evaluation of Recommendation 1.

1. 90+% of departments protecting communities of 50,000 or more have local codes based on national model codes for both newly constructed and existing nightclubs.
2. Up to 12% of departments fall short of Recommendation 1a for newly constructed nightclubs because they are using an older edition of the code,

---

[6] *Fire Code Inspections and Fire Prevention: What Methods Lead to Success?*, NFPA and Urban Institute, 1979; and *Measuring Code Compliance Effectiveness for Fire-Related Portions of Codes*, NFPA and Fire Protection Research Foundation, 2008.

dating from a time before restrictions based on analysis of The Station nightclub fire became part of the code.

3. A large share of departments appear to fall short of Recommendation 1a for existing nightclubs because they are relying exclusively on a model fire code (the *International Fire Code*) which had not adopted the recommended requirements for existing nightclubs. In this context, the use of outdated codes appears to be of lesser importance.
4. 100% of departments protecting communities of 50,000 or more report having some inspections for newly constructed and/or existing buildings. However, other studies have indicated that the situation is sharply different for smaller communities, which were not included in the nightclub survey, or have indicated that the coverage and frequency of inspections are often much less than fire departments believe and report. Notwithstanding the favorable data from the NFPA survey, the true rating on Recommendation 1b is probably quite low.

Summary of protocol for evaluation of recommendations like Recommendation 1.

1. Recommendations that are both very broad and very detailed are often difficult or impossible to evaluate using affordable data that can be obtained from a distance. This is especially true when the only available data consists of summary characterizations by local managers who may not have access to detailed records and analysis to support their estimates and characterizations.
2. An evaluation plan for NIST recommendations should begin by identifying data and analysis options for each recommendation and (often) each detailed sub-recommendation. For some sub-recommendations, meaningful evaluation may not be possible at any price. For others, it may be necessary to choose between (a) evaluating a less detailed version of the sub-recommendation using affordable survey data or other remotely available data, or (b) evaluating a more detailed version of the sub-recommendation using more expensive on-site methods applied to what will inevitably be a small sample of communities.
3. In many cases, it may be possible to distinguish major versus minor obstacles to successful implementation even when direct quantification of the degree of implementation is prohibitively difficult. For example, when a NIST recommendation has not been adopted by the most widely used national model code, questions about local adoption of the national model, use of updated editions, and compliance assurance through inspections, all become moot.
4. Evaluation is likely to be more expensive and more difficult in smaller communities. Programs to improve the level of implementation are also likely to be more difficult in smaller communities because of the lack of economies of scale in all aspects – much lower rates of targets per community, more distinct entities and

steps to be dealt with per target reached, lower geographic density and the higher costs of contacting targets, and so forth. At the same time, smaller communities may account for a large share of the total problem to be addressed by the recommendations.

5. Therefore, an evaluation plan should probably be set separately for large communities (like the communities included in the example, with populations of at least 50,000 each), middle-sized communities (say, in the 10,000 to 50,000 population range), and small communities (say, under 10,000 population). It may make sense to scale back the scope of the evaluation for smaller communities and to set less ambitious goals for degree of implementation in those communities.

Sprinklers

Part IV of the NFPA survey asked about requirements for, inspection of, and usage of sprinklers in nightclubs. The data from Part IV addresses part of Recommendation 2 was for sprinkler system requirements to be adopted by national model codes and then adopted and "aggressively" enforced by state and local authorities:

a) for all new nightclubs regardless of size; and
d) for existing nightclubs with an occupancy limit greater than 100 people.

This recommendation, like Recommendations 3-5, is well structured for evaluation using the three questions, as detailed in Table D.

Question 1 (requirements) for Sprinklers: Are there sprinkler requirements, and how do they compare to Recommendation 2? Table D refers to Q.6 for an evaluation of the existence of sprinkler requirements and for characteristics of those requirements.

Q.6 does not distinguish newly constructed nightclubs from existing nightclubs. In hindsight, it would have been better to split Q.6 to provide information directly for these two situations.

For newly constructed nightclubs, the requirements in both major national model codes correspond to the NIST recommendations, requiring sprinklers in all such nightclubs. As noted in the evaluation of Recommendation 1 (Table F), only 8% of the departments have a local code that is not based on one of these two codes. Some of the 8% may have the same requirements in their local code, however, and some of the other departments may have removed that requirement through local amendment.

Table 10 shows that 9% of departments have no sprinkler requirements for nightclubs, and another 11% have requirements that do not apply below an occupancy load of 200. Therefore, 20% of departments do not have requirements that conform to the NIST recommendations. Table H provides the same statistics by size of community.

Table H. Percent of Departments
Without Sprinkler Requirements Consistent With NIST Recommendation 2

	Percentage of Departments Without Sprinkler Requirements Consistent with Recommendation 2		
Size of community	Combined No or Less Strict Requirements	No Requirements	Requirements Less Strict Than in Recommendation 2
500,000 or more	38%	9%	29%
250,000 to 499,999	12%	3%	8%
100,000 to 249,999	17%	9%	8%

50,000 to 99,999	20%	9%	11%
Total	20%	9%	11%

Question 2 (compliance) for Sprinklers: What is the perceived level of compliance with the local requirements? Table D refers to Q.8 for an evaluation of the estimated level of compliance with the requirements in place. Q.7 can be used for estimation of the extent of enforcement programs (e.g., inspections) specifically directed at compliance assurance for these requirements. Some additional analysis has been conducted to check whether the estimated level of compliance varies depending on the strictness of the requirements.

After proportional allocation of "Don't Know" responses, Table 11 shows that 81% of responding departments estimate that all or most nightclubs are in compliance with local sprinkler requirements. Table I shows that this percentage does not vary much by size of community, but there is a clear trend toward higher estimated percentages of full compliance (All but not Most) as the size of the community declines.

Table I. Percent of Departments Estimating All or Most Nightclubs in Compliance with Sprinkler Requirements, by Size of Community

	Percentage of Departments Estimating All or Most Nightclubs in Compliance		
Size of community	**All or Most**	**All**	**Most**
500,000 or more	78%	33%	46%
250,000 to 499,999	65%	35%	31%
100,000 to 249,999	77%	44%	33%
50,000 to 99,999	85%	60%	25%
Total	81%	51%	30%

Table J shows that estimated compliance declines as the requirements become less strict.

Table J. Percent of Departments Estimating All or Most Nightclubs in Compliance with Sprinkler Requirements, by Requirement

	Percentage of Departments Estimating All or Most Nightclubs in Compliance		
Size of community	**All or Most**	**All**	**Most**
Regardless of occupancy	92%	67%	25%
Occupancy of 50 or more	88%	69%	19%
Occupancy of 100 or more	78%	49%	29%
Occupancy of 200 or more	81%	35%	46%
Total	81%	51%	30%

Table 12 shows that 35% of departments report they conduct inspections "just to check compliance with sprinkler requirements", and the other 65% report that they do not. There is no clear trend up or down in the percentages conducting inspections as community size shrinks. Therefore, the increase in estimated full compliance by smaller communities in the survey is not a reflection of their having more or less direct information on compliance from inspections. It may be a reflection of smaller communities having only one or two true nightclubs (as opposed to 10-20 drinking establishments generally), making it possible for authorities to focus their attention on the status of only a couple establishments.

Question 3 (change after the major event) for Sprinklers: Did the requirements change after 2003 (the year of The Station nightclub fire)? Table D refers to Q.6a for a determination of the timing of changes to the requirements, which is the only direct information available from a distance that would suggest a change based on reaction to The Station nightclub fire and the lessons learned from it. Table 13 shows that half the communities changed their requirements after 2003 and half did not.

The NFPA nightclub survey was designed to test the ability of generic survey questions to provide useful evaluative information for diverse findings. This particular question may illustrate the limitations of such an approach, because the communities that reported no change could be reporting at least three very different developments:

- ➢ It is possible that the local requirements changed when the referenced model code or state code changed, but because that change was not initiated by the community, they do not think of it as a change within the scope of the question.
- ➢ It is possible that the local requirements did not change because the community already had stricter requirements in place, and so the changes to the model codes after The Station nightclub fire did not affect them and did not result in any changes to their local requirements.
- ➢ It is possible that the local requirements did not change because the community opted out of the changes to the referenced model or state code, through local amendments or failure to adopt updated editions.
- ➢ It is possible that communities were aware of the numerous code violations present at the time of The Station fire and they simply redoubled their enforcement efforts for the requirements in effect in their adopted code.

In all of these situations, the issuance of the NIST requirements would not have made any direct difference in the local requirements. However, NIST's goal is to have their recommendations in place in all communities, not to be the reason why those recommendations are in place. Therefore, the evaluation should focus primarily on the answers to Questions 1 and 2 and less on the answer to Question 3.

Summary of evaluation for sprinklers

- 80% of communities with at least 50,000 population have sprinkler requirements in place that are consistent with the NIST recommendations for existing nightclubs. It is likely that 90+% have sprinkler requirements in place that are consistent with the NIST recommendations for newly constructed nightclubs.
- 81% of communities with at least 50,000 population estimate that All (51%) or Most (30%) nightclubs are in compliance with their local requirements. Most communities do not have inspections just to check on these requirements, and so the accuracy of these estimates is uncertain.
- Half of communities with at least 50,000 population and with sprinkler requirements report that their requirements changed after 2003, the year of The Station nightclub fire.

Summary of protocol for evaluation of recommendations like Recommendation 2.

1. Such evaluations are built around answers to three generic questions:
    - the existence of local requirements that are consistent with the NIST recommendations;
    - local estimates of the degree of compliance with local requirements; and
    - whether local requirements changed after the event that formed the basis for the NIST recommendations.
2. The NFPA nightclub survey represented an attempt to answer these questions for several recommendations using generic questions and affordable data collection methods.
3. Recommendation 2 is relatively short and clear-cut, which makes it relatively easy to assess the existence of local requirements that conform with NIST recommendations. Even then, going forward there should be more clear differentiation of newly constructed versus existing establishments.
4. If resources and priorities permit, there would be value in the use of a small sample of site visits or more detailed surveys (including requests for copies of supporting records) to elaborate and spot check local estimates of degree of compliance.
5. Direct questions about changes to requirements after the precipitating event have a very limited ability to assess the impact of NIST recommendations or any other information or actions triggered by the event. If resources and priorities permit, there would be value in the use of a small sample of site visits to produce more detailed and more fully verified descriptions of how requirements and compliance with requirements developed and the role of different factors in those developments.

Interior Finish

Part V of the NFPA survey asked about requirements for, inspection of, and status of interior finish in nightclubs. The data from Part V addresses part of Recommendation 3, which recommended appropriate authorities:

a) adopt and aggressively enforce [relevant] existing provisions of model codes;
b) make sure that non-FR flexible PU foam and any materials with similar ignition or fire propagation properties are clearly identifiable to building owners, operators, contractors, and authorities, and forbid their use in all newly constructed and existing nightclubs; and
c) review and revise the standard test procedures to assure that they will identify undue hazards and will incorporate best measurement and prediction practices.

Parts of this recommendation are directed to the standards development organizations and to the researchers who support their work. This project is concerned with the evaluation of conditions in targeted properties (nightclubs) and fire departments.

Therefore, this recommendation will be evaluated here using the three questions, as detailed in Table D, solely in terms of whether local enforcement actions are well designed to check on and remove hazardous materials even if they are not so identifiable as Recommendation 3 seeks to make them.

Question 1 (requirements) for Interior Finish: Are there interior finish requirements, and how do they compare to Recommendation 3? Table D refers to Q.9 for an evaluation of the existence of interior finish requirements and to Q.11 for analysis of the use of various measurement methods to check on compliance with the requirements.

Table 14 shows that all departments have interior finish requirements for nightclubs.

- 62% cite the *International Building Code* (which has requirements for newly constructed buildings only) as the source;
- 59% cite the *International Fire Code* (which references the IBC requirements for newly constructed buildings and has nothing specific for existing buildings) as the source;
- 32% cite NFPA 101, *Life Safety Code* (which has requirements for newly constructed and existing buildings) as the source;
- 17% cite NFPA 1 (which derives its requirements from NFPA 101) as the source;
- 10% cite “other” model codes as the source, and based on answers to other questions, those “other” codes are probably nearly all state codes; and
- 3% cite local requirements not based on any model code.

Table 14 provides results by community size. Table 15, based on Q.10, indicates that 93% of communities reference a standard test in their requirements, while 7% do not. No information was requested on how the 7% determine compliance, but it is possible that some or many of these communities require a certification of compliance with an appropriate test but leave the choice of test or other proof of compliance to the discretion of the parties requesting approval.

Question 2 (compliance) for Interior Finish: What is the perceived level of compliance with the local requirements? Table D refers to Q.13 for an evaluation of the estimated level of compliance with the requirements in place. Q.12 can be used for estimation of the quality of the evidence used to check compliance for these requirements. Some additional analysis has been conducted to check whether the estimated level of compliance varies depending on the type of evidence used.

After proportional allocation of "Don't Know" responses, Table 16 shows that 88% of responding departments estimate that all or most nightclubs are in compliance with local interior finish requirements. Table K shows that this percentage does not vary much by size of community, but there is a clear trend toward higher estimated percentages of full compliance (All but not Most) as the size of the community declines.

Table K. Percent of Departments Estimating All or Most Nightclubs in Compliance with Interior Finish Requirements, by Size of Community

	Percentage of Departments Estimating All or Most Nightclubs in Compliance		
Size of community	**All or Most**	**All**	**Most**
500,000 or more	90%	15%	75%
250,000 to 499,999	91%	25%	66%
100,000 to 249,999	87%	28%	58%
50,000 to 99,999	87%	42%	45%
Total	88%	34%	53%

Table 17 shows that 19% of departments report they conduct inspections "just to check compliance with interior finish requirements", and the other 81% report that they do not. There is a clear trend that conducting these inspections becomes more likely as community size shrinks.

Table 18 shows what percentage of departments are using each of four sources of fire performance information to identify compliant versus non-compliant interior finish.

- 51% of departments protecting populations of 50,000 or more report using visual inspection "only";
- 79% report using review of specification sheets and technical data for materials;
- 15% use routine testing of materials, and 12% conduct testing based on an initial visual screening, presumably of suspect materials.

A question that can probably be answered only with site visits or other more detailed conversations with communities would be how well these methods work to identify non-compliant materials that were installed in an existing nightclub, as was the case in The Station nightclub. It is not clear what would trigger visual screening or trigger review of specification sheets and technical data if the inspectors have no indication that anything has changed.

Table L shows that estimated compliance does not vary much as the nature and quality of the evidence changes from visual inspection only to the use of testing data, from specification sheets, routine testing, or testing triggered by visual observation screening.

Table L. Percent of Departments Estimating All or Most Nightclubs in Compliance with Interior Finish Requirements, by Type of Evidence of Compliance

	Percentage of Departments Estimating All or Most Nightclubs in Compliance		
Size of community	**All or Most**	**All**	**Most**
Visual inspection only	84%	32%	52%
Review of spec sheets and other technical data	90%	36%	54%
Testing based on visual screening	93%	35%	59%
Routine testing	91%	33%	58%
Total	88%	34%	53%

Question 3 (change after the major event) for Interior Finish: Did the requirements change after 2003 (the year of The Station nightclub fire)? Table D refers to Q.9h for a determination of the timing of changes to the requirements, which is the only direct information available from a distance that would suggest a change based on reaction to The Station nightclub fire and the lessons learned from it. Table 19 shows that 29% of the communities changed their requirements after 2003 and the other 71% did not.

The NFPA nightclub survey was designed to test the ability of generic survey questions to provide useful evaluative information for diverse findings. This particular question may illustrate the limitations of such an approach, because the communities that reported no change could be reporting at least three very different developments:

- It is possible that the local requirements changed when the referenced model code or state code changed, but because that change was not initiated by the community, they do not think of it as a change within the scope of the question.
- It is possible that the local requirements did not change because the community already had stricter requirements in place, and so the changes to the model codes after The Station nightclub fire did not affect them and did not result in any changes to their local requirements.

- It is possible that the local requirements did not change because the community opted out of the changes to the referenced model or state code, through local amendments or failure to adopt updated editions.
- It is possible that communities were aware of the numerous code violations present at the time of The Station fire and they simply redoubled their enforcement efforts for the requirements in effect in their adopted code.

In all of these situations, the issuance of the NIST requirements would not have made any direct difference in the local requirements. However, NIST's goal is to have their recommendations in place in all communities, not to be the reason why those recommendations are in place. Therefore, the evaluation should focus primarily on the answers to Questions 1 and 2 and less on the answer to Question 3.

Summary of evaluation for interior finish:

- All communities with at least 50,000 population have interior finish requirements in place, but more than half the departments (those not citing NFPA 101 or NFPA 1 as a source, assuming no overlap) appear to have no requirements in place for existing buildings. Nearly all (93%) reference a standard test, and the others may have requirements that indirectly reference a standard test, such as by referencing a certification requirement that will be handled by entities that use standard tests.
- 88% of communities with at least 50,000 population estimate that All (34%) or Most (53%) nightclubs are in compliance with their local requirements. Most (81%) communities do not have inspections just to check on these requirements, and so the accuracy of these estimates is uncertain. Most inspections are limited to visual inspection and/or review of spec sheets and other technical data on materials, but it is not clear that any departments have a reliable mechanism – or

an applicable requirement – that will trigger identification of hazardous conditions added to an existing nightclub.
- 29% of communities with at least 50,000 population and with interior finish requirements report that their requirements changed after 2003, the year of The Station nightclub fire.

Summary of protocol for evaluation of recommendations like Recommendation 3.

1. Such evaluations are built around answers to three generic questions:
   - the existence of local requirements that are consistent with the NIST recommendations;
   - local estimates of the degree of compliance with local requirements; and
   - whether local requirements changed after the event that formed the basis for the NIST recommendations.

2. The NFPA nightclub survey represented an attempt to answer these questions for several findings using generic questions and affordable data collection methods.
3. Recommendation 3 is complex in that it can only be fully assessed through data that characterize the fire properties in all new and existing nightclubs. No community has such data or anything close to it. In terms of achieving the nightclub conditions intended by this recommendation, the key might be the recommendation that all interior finish materials be easily identifiable as to their compliance. Even that would not be sufficient to assure compliance in existing nightclubs unless there were a mandatory trigger – such as a permit requirement – for compliance assurance whenever interior finish is modified. In the absence of such a trigger and of a sub-recommendation that would have that effect, it is difficult to determine from available data how successfully a community is in monitoring interior finish in its nightclubs.
4. If resources and priorities permit, there would be value in the use of a small sample of site visits to elaborate and spot check local estimates of degree of compliance.
5. Direct questions about changes to requirements after the precipitating event have a very limited ability to assess the impact of NIST recommendations or any other information or actions triggered by the event. If resources and priorities permit, there would be value in the use of a small sample of site visits to produce more detailed and more fully verified descriptions of how requirements and compliance with requirements developed and the role of different factors in those developments.

Indoor Pyrotechnics

Part VI of the NFPA survey asked about requirements for, inspection of, and status of indoor use of pyrotechnics in nightclubs. The data from Part VI addresses part of

Recommendation 4, which called for jurisdictions to adopt and aggressively enforce NFPA 1126. A further part of the recommendation centers around strengthening some of the provision in NFPA 1126. The recommendations for strengthening were directed at NFPA and are outside the scope of this project, which focuses on recommended changes in conditions in the field.

Therefore, this recommendation will be evaluated here using the three questions, as detailed in Table D, solely in terms of whether NFPA 1126 has been adopted and is being enforced through inspections.

Question 1 (requirements) for Indoor Pyrotechnics: Are there indoor pyrotechnics requirements, and how do they compare to Recommendation 4? Table D refers to Q.14 for an evaluation of the existence of indoor pyrotechnics requirements and for the conformance of those requirements to Recommendation 4 (i.e., specific reference to NFPA 1126).

Table 20 shows that 66% of departments protecting communities of 50,000 or more population have local restrictions based on NFPA 1126, and 98% have some kind of local restrictions on indoor use of pyrotechnics in nightclubs. Table 20 also provides results by community size.

Question 2 (compliance) for Indoor Pyrotechnics: What is the perceived level of compliance with the requirements? Table D refers to Q.16 for an evaluation of the estimated level of compliance with the requirements in place.

After proportional allocation of "Don't Know" responses, Table 21 shows that 97% of responding departments estimate that all or most nightclubs are in compliance with local indoor pyrotechnics requirements. Table M shows that this percentage does not vary much by size of community, but there is a clear trend toward higher estimated percentages of full compliance (All but not Most) as the size of the community declines.

Table M. Percent of Departments Estimating All or Most Nightclubs in Compliance with Indoor Pyrotechnics Requirements, by Size of Community

	Percentage of Departments Estimating All or Most Nightclubs in Compliance		
Size of community	**All or Most**	**All**	**Most**
500,000 or more	100%	55%	45%
250,000 to 499,999	92%	60%	32%
100,000 to 249,999	96%	81%	15%
50,000 to 99,999	98%	85%	13%
Total	97%	79%	18%

Table 22 shows that 85% of departments report they conduct inspections "just to check compliance with indoor pyrotechnics requirements", and the other 15% report that they do not. There is a clear trend that conducting these inspections becomes more likely as community size increases.

Table 22 also shows what percentage of departments are using each of three triggers for inspections.

- 64% of departments protecting populations of 50,000 or more report conducting inspections at events;
- 50% report conducting inspections with managers in advance of events;
- 51% report conducting inspections based on complaints, concerns or requests received in advance of or at events.

Table N shows that estimated compliance does not vary much based on the use or non-use of inspections or the type of inspections used. Departments reporting no inspections were more likely to report "Don't Know" for compliance – 20% versus 2-4% for the three options with inspections – but when estimating, they were more likely to estimate full compliance by all nightclubs than the other three options.

Table N. Percent of Departments Estimating All or Most Nightclubs in Compliance with Interior Pyrotechnics Requirements, by When and Why Inspections Are Conducted

When or Why Inspection Conducted	Percentage of Departments Estimating All or Most Nightclubs in Compliance		
	All or Most	All	Most
Inspections at events	97%	75%	22%
Inspections with managers in advance of events	97%	75%	22%
Inspections based on complaints, concerns or requests	97%	72%	25%
No inspections	96%	89%	7%
Total	97%	79%	18%

Question 3 (change after the major event) for Indoor Pyrotechnics: Did the requirements change after 2003 (the year of The Station nightclub fire)? Table D refers to Q.14e for a determination of the timing of changes to the requirements, which is the only direct information available from a distance that would suggest a change based on reaction to The Station nightclub fire and the lessons learned from it. Table 23 shows that 18% of the communities changed their requirements after 2003 and the other 82% did not.

The NFPA nightclub survey was designed to test the ability of generic survey questions to provide useful evaluative information for diverse recommendations. This particular question may illustrate the limitations of such an approach, because the communities that reported no change could be reporting at least three very different developments:

- It is possible that the local requirements changed when the referenced model code or state code changed, but because that change was not initiated by the community, they do not think of it as a change within the scope of the question.
- It is possible that the local requirements did not change because the community already had stricter requirements in place, and so the changes to the model codes after The Station nightclub fire did not affect them and did not result in any changes to their local requirements.
- It is possible that the local requirements did not change because the community opted out of the changes to the referenced model or state code, through local amendments or failure to adopt updated editions.
- It is possible that communities were aware of the numerous code violations present at the time of The Station fire and they simply redoubled their enforcement efforts for the requirements in effect in their adopted code.

In all of these situations, the issuance of the NIST requirements would not have made any direct difference in the local requirements. However, NIST's goal is to have their recommendations in place in all communities, not to be the reason why those recommendations are in place. Therefore, the evaluation should focus primarily on the answers to Questions 1 and 2 and less on the answer to Question 3.

Summary of evaluation for indoor pyrotechnics

- 98% of communities with at least 50,000 population have indoor pyrotechnics requirements in place, and 66% of communities specifically reference NFPA 1126.
- 97% of communities with at least 50,000 population estimate that All (79%) or Most (18%) nightclubs are in compliance with their local requirements. Most (85%) communities conduct inspections to reinforce compliance, using some combination of inspections at events, inspections with managers in advance of events, and inspections based on complaints, concerns or requests. Estimates of compliance show almost no difference based on the type of inspection conducted or even whether there are any inspections at all.
- 18% of communities with at least 50,000 population and with indoor pyrotechnics requirements report that their requirements changed after 2003, the year of The Station nightclub fire.

Summary of protocol for evaluation of recommendations like Recommendation 4.

1. Such evaluations are built around answers to three generic questions:
   - the existence of local requirements that are consistent with the NIST recommendations;
   - local estimates of the degree of compliance with local requirements; and
   - whether local requirements changed after the event that formed the basis for the NIST recommendations.
2. The NFPA nightclub survey represented an attempt to answer these questions for several recommendations using generic questions and affordable data collection methods.
3. Recommendation 4 is complex in that it seeks to control potentially hazardous practices and not fixed, installed hazards. Communities probably do not have databases that routinely track violations by monitoring of all or a representative sample of events, and so direct assessment of compliance is not possible with existing data. Even site visits would be unable to acquire this kind of data.

Occupancy Limits and Egress Requirements

Part VII of the NFPA survey asked about requirements for, inspection of, and status of occupancy limits and egress requirements in nightclubs. The data from Part VII addresses part of Recommendation 5, which recommended strengthening code and standard development organizations (which are outside the scope of this project, which focuses on recommended changes in conditions in the field), adopting model code requirements, and using inspections to achieve compliance with those requirements.

Question 1 (requirements) for Occupancy Limits and Egress Requirements: Are there occupancy limits for nightclubs, and how do they compare to Recommendation 5? Table D refers to Q.17 for an evaluation of the existence of occupancy limit requirements and for the sources of those requirements, which is the only information available on how those requirements compare to Recommendation 5.

Table 24 shows that all departments have egress requirements and/or occupancy limits requirements for nightclubs.

- 76% cite the *International Building Code* (which has requirements for newly constructed buildings only) as the source;
- 34% cite NFPA 101, *Life Safety Code* (which has requirements for newly constructed and existing buildings) as the source;
- 30% cite "other" model codes as the source, and based on answers to other questions, those "other" codes are probably nearly all state codes; and
- 5% cite local requirements not based on any model code.

Question 2 (compliance) for Occupancy Limits and Egress Requirements: What is the perceived level of compliance with the requirements? Table D refers to Q.19 for an evaluation of the estimated level of compliance with the requirements in place.

After proportional allocation of "Don't Know" responses, Table 25 shows that 96% of responding departments estimate that all or most nightclubs are in compliance with local occupancy requirements.

Table O. Percent of Departments Estimating All or Most Nightclubs in Compliance with Occupancy Requirements, by Size of Community

	Percentage of Departments Estimating All or Most Nightclubs in Compliance		
Size of community	**All or Most**	**All**	**Most**
500,000 or more	100%	15%	85%
250,000 to 499,999	100%	33%	67%
100,000 to 249,999	92%	36%	56%
50,000 to 99,999	97%	51%	46%
Total	96%	42%	54%

Table O shows that this percentage does not vary much by size of community, but there is a clear trend toward higher estimated percentages of full compliance (All but not Most) as the size of the community declines.

Table 26 shows that 56% of departments report they conduct inspections “just to check compliance with egress requirements and/or occupancy limits for nightclubs”, and the other 44% report that they do not. There is a clear trend that conducting these inspections becomes more likely as community size increases.

Table 26 also shows the frequency of these special inspections:

- 1% of departments protecting populations of 50,000 or more report conducting inspections roughly every evening;
- 6% report conducting inspections at least weekly;
- 49% report conducting inspections on a less than weekly frequency.

Table P shows that estimated compliance is lower with less frequent inspections. Departments conducting no inspections gave estimates of compliance that were similar to those from departments with weekly inspections and better than those from departments with less than weekly inspections. This looks like a pattern of excessive optimism on the part of departments that do not conduct inspections. Departments reporting no inspections were more likely to report “Don’t Know” for compliance – 12% versus 0-1% for the three options with inspections.

Table P. Percent of Departments Estimating All or Most Nightclubs in Compliance with Occupancy Requirements, by Frequency of Inspections

	Percentage of Departments Estimating All or Most Nightclubs in Compliance		
Frequency of Inspections	**All or Most**	**All**	**Most**
Inspections roughly every evening	100%	67%	33%
Inspections at least weekly	100%	54%	46%
Inspections with less than weekly frequency	95%	33%	62%
No special inspections	98%	51%	47%
Total	96%	42%	54%

Question 3 (change after the major event) for Occupancy Limits and Egress Requirements: Did the requirements change after 2003 (the year of The Station nightclub fire)? Table D refers to Q.17f for a determination of the timing of changes to the requirements, which is the only direct information available from a distance that would suggest a change based on reaction to The Station nightclub fire and the lessons learned from it. Table 27 shows that 12% of the communities changed their requirements after 2003 and the other 88% did not.

- It is possible that communities were aware of the numerous code violations present at the time of The Station fire and they simply redoubled their enforcement efforts for the requirements in effect in their adopted code.

Summary of evaluation for occupancy limits and egress requirements

- 100% of communities with at least 50,000 population have occupancy limits in place, and 95% of communities reference a model code, either directly or indirectly. However, Recommendation 5 anticipated changes to the rules used to calculate occupancy limits, and those changes, other than sizing of the main entrance/exit to be of a width that accommodates two-thirds of the total occupant load do not appear to have made their way into the model codes and standards, let alone local requirements and practices.

- 96% of communities with at least 50,000 population estimate that All (42%) or Most (54%) nightclubs are in compliance with their local occupancy limit requirements. The majority (56%) of communities conduct inspections to reinforce compliance, but most (49% of the 56%) conduct these inspections less often than weekly. More frequent inspections are associated with higher estimates of full compliance, and departments with no inspections appear to be over-estimating levels of compliance because they are estimating compliance levels better than those achieved with less-than-weekly special inspections. 12% of communities with at least 50,000 population and with occupancy limit requirements report that their requirements changed after 2003, the year of The Station nightclub fire.

Summary of protocol for evaluation of recommendations like Recommendation 5.

1. Such evaluations are built around answers to three generic questions:
    - the existence of local requirements that are consistent with the NIST recommendations;
    - local estimates of the degree of compliance with local requirements; and
    - whether local requirements changed after the event that formed the basis for the NIST recommendations.

   When the model codes have not changed in all of the areas yet to better align with the NIST recommendations, all three of these questions about local conditions become moot.

2. Recommendation 5 is complex in that it seeks to control potentially hazardous practices and not fixed, installed hazards. Most communities do not check all or a representative sample of daily practices, and so direct assessment of compliance is not possible with existing data.

Fire Department Emergency Response

Part VIII of the NFPA survey asked about adoption of and adherence to four NFPA standards for emergency response – NFPA 1221, *Standard for the Installation, Maintenance, and Use of Emergency Communications Systems*; NFPA 1561, *Standard on Emergency Services Incident Management Systems*; NFPA 1710, *Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments*; and NFPA 1720, *Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Volunteer Fire Departments*. Because these recommendations are for changes in fire department practices, the adoption and compliance steps are not separate.

Question 1 (requirements) for Emergency Communications Systems: Does the department adopt and adhere to NFPA 1221? Table E refers to Q.20 for information on the use of NFPA 1221. Table 28 indicates that 55% of departments protecting communities of 50,000 or more population are using NFPA 1221, and the percentage does not vary much as the size of community decreases.

Question 3 (change after the major event) for Emergency Communications Systems: Did the requirements change after 2003 (the year of The Station nightclub fire)? Table E refers to Q.20a for a determination of the timing of changes to the requirements, which is the only direct information available from a distance that would suggest a change based on reaction to The Station nightclub fire and the lessons learned from it. Table 29 shows that 14% of the communities changed their requirements after 2003 and the other 86% did not.

Question 1 (requirements) for Incident Management Systems: Does the department adopt and adhere to NFPA 1561? Table E refers to Q.21 for information on the use of NFPA 1561 or the National Emergency Management System (NIMS). Table 30 indicates that 94% of departments protecting communities of 50,000 or more population are using NFPA 1561 or NIMS, and the percentage does not vary much as the size of community decreases.

Question 3 (change after the major event) for Incident Management Systems: Did the requirements change after 2003 (the year of The Station nightclub fire)? Table E refers to Q.21a for a determination of the timing of changes to the requirements, which is the only direct information available from a distance that would suggest a change based on reaction to The Station nightclub fire and the lessons learned from it.. Table 31 shows that 15% of the communities changed their requirements after 2003 and the other 85% did not.

Question 1 (requirements) for Organization and Deployment for Career and Volunteer Departments: Does the department adopt and adhere to NFPA 1710 or 1720? Table E refers to Q.22 for information on the use of NFPA 1710 or 1720. Table 32 indicates that 80% of departments protecting communities of 50,000 or more population are using NFPA 1710 or 1720, and the percentage does not vary much as the size of community decreases.

Question 3 (change after the major event) for Organization and Deployment for Career and Volunteer Departments: Did the requirements change after 2003 (the year of The Station nightclub fire)? Table E refers to Q.22a for a determination of the timing of changes to the requirements, which is the only direct information available from a distance that would suggest a change based on reaction to The Station nightclub fire and the lessons learned from it.. Table 33 shows that 12% of the communities changed their requirements after 2003 and the other 88% did not.

Summary of evaluation for fire department emergency response practices

- 55% of communities with at least 50,000 population are using NFPA 1221.
- 94% of communities with at least 50,000 population are using NFPA 1561 or NIMS.
- 80% of communities with at least 50,000 population are using NFPA 1710 or 1720.
- 12-15% of communities with at least 50,000 population report that their use of these standards changed after 2003, the year of The Station nightclub fire.

Summary of protocol for evaluation of recommendations like Recommendation 7.

1. Such evaluations are built around answers to two generic questions:
    - whether local departments have adopted the standards and practices recommended by NIST (or more likely, incorporated them into fire department standard operating practices);
    - whether local requirements changed after the event that formed the basis for the NIST recommendations.

Task 3: Analysis of Changes to Model Codes and Standards

The impact of NIST recommendations 2-5 and 7 occurs in multiple stages. First, model codes and standards must incorporate the recommendations. Second, the codes and standards adopted by states must incorporate the changes to the model codes and standards. Finally, local practices must incorporate the changes to state codes and standards. Task 3 addresses the first stage of this process (Task 2 addressed the second and third stages).

The purpose of this task was to evaluate the extent to which model codes and standards incorporated recommendations 2-5 of the NIST NCST Report on The Station Nightclub Fire. This involved analyzing the changes that have been made to model codes and standards related to these recommendations.

Recommendation 2 – Sprinklers

The NIST investigation report makes the following recommendations related to sprinkler protection in nightclubs:

Recommendation 2. Sprinklers: *NIST recommends that model codes require sprinkler systems according to NFPA 13 (Standard for the Installation of Sprinkler Systems), and that state and local authorities adopt and aggressively enforce this provision:*

> *a) for all new nightclubs regardless of size, and*
>
> *b) for existing nightclubs with an occupancy limit greater than 100 people.*

The model codes considered for this recommendation were the NFPA model codes (NFPA 1, *Fire Code*, NFPA 101, *Life Safety Code*, and NFPA 5000, *Building Construction and Safety Code*) and the International Code Council's *International Building Code* (IBC), *International Existing Building Code* (IEBC) and *International Fire Code* (IFC). The editions of these model codes that were focused on were the editions issued directly before The Station Nightclub fire and the editions issued after the fire.

In the 2003 editions, NFPA model codes required sprinklers in new assembly occupancies with occupant loads greater than 300. For existing assembly occupancies, the 2003 editions require automatic sprinkler systems in existing assembly occupancies used or capable of being used for exhibition or display purposes where the display area exceeds 15,000 square feet, but no specific requirement for existing nightclub occupancies.

NFPA has a process for issuing emergency code amendments called Tentative Interim Amendments (TIAs). The following TIAs went into effect August 14, 2003:

- Requirement for sprinklers to be installed in all new nightclub-type occupancies (bars, dance halls, discotheques, nightclubs, and assembly occupancies with festival seating).

- Requirement for sprinklers to be installed in existing nightclub-like assemblies with occupant loads greater than 100.

The above TIAs were issued for the 2003 editions of the NFPA 1, NFPA 101, and NFPA 5000. These new requirements were then approved into the 2006 versions of these codes.

The 2003 editions of the IBC and IFC requires sprinklers for new Group A-2 occupancies (assembly uses intended for food and/or drink consumption) where one of the following conditions exist:

- The fire area exceeds 5,000 square feet
- The fire area has an occupant load of 300 or more
- The fire area is located on a floor other than the level of exit discharge

The 2006 editions of the IBC and IFC changed the requirements for sprinklers for new Group A-2 occupancies. Sprinklers are required where one of the following conditions exist:

- The fire area exceeds 5,000 square feet
- The fire area has an occupant load of **100 or more**
- The fire area is located on a floor other than the level of exit discharge

The IBC covers existing structures in Chapter 34, which details the requirements for alteration, repair, addition, and change of occupancy of existing structures. The evaluation process used in Chapter 34 is based on the requirements for new construction for all categories (including presence of automatic sprinklers).

Both the 2003 and 2006 editions of the IEBC address automatic sprinklers requirements based on the level of change occurring in the building. No change was made between the editions related to requirements for automatic sprinklers for existing assembly occupancies. For assembly occupancies undergoing Level 2 and 3 alterations, sprinklers are required when the occupant load is greater than 30, the work area exceeds 50% of the floor area, and there is sufficient municipal water supply to the floor.

In the 2006 edition of the IEBC for changes in occupancy in existing buildings, there was a change related to sprinkler systems. Where a change in occupancy occurs that requires a sprinkler system to be provided for new construction per the IBC, a sprinkler system must be installed. This is a change from the 2003 edition, which required changes in occupancy in the same manner as Level 3 alterations.

Recommendation 3 – Finish Materials

The NIST investigation report makes the following recommendations related to interior finish and contents in nightclubs:

Recommendation 3. Finish Materials and Building Contents: *NIST recommends that:*

a) state and local authorities adopt and aggressively enforce the existing provisions of the model codes;

b) non-fire retarded flexible polyurethane foam, and other materials that ignite as easily and propagate flames as rapidly as non-fire retarded flexible polyurethane foam: (i) be clearly identifiable to building owners, operators, contractors and authorities having jurisdiction (regulatory agencies); and (ii) be specifically forbidden, with no exceptions, as finish materials from all new and existing nightclubs;

c) NFPA 286 (Standard Methods of Fire Tests for Evaluating Contribution of Wall and Ceiling Interior Finish to Room Fire Growth) be modified to provide more explicit guidance for when large-scale tests are required to demonstrate that materials (other than those already forbidden in b above) do not pose an undue hazard for the use intended; and

d) ASTM E-84 (Standard Test Method for Surface Burning Characteristics of Building Materials), NFPA 255 (Standard Method of Test of Surface Burning Characteristics of Building Materials), and NFPA 286 be modified to ensure that product classification and the pass/fail criteria for flame spread tests and large-scale tests are established using the best measurement and prediction practices available.

The model codes considered for this recommendation were the NFPA model codes (NFPA 1, *Fire Code*, NFPA 101, *Life Safety Code*, and NFPA 5000, *Building Construction and Safety Code*) and the International Code Council's *International Building Code* (IBC) and *International Fire Code* (IFC). The editions of these model codes that were focused on were the editions issued directly before The Station Nightclub fire and the editions issued after the fire.

Part A of the above recommendations is covered by Task 2.

Related to Part B, based on the NIST investigation report, the model codes already prohibited the use of foam plastic insulation as an interior finish material without passing a large scale test that replicates end-use conditions. There were no changes in Chapter 26 of the IBC, which regulates the use of plastics, between the 2003 and 2006 editions. There were also no changes to Chapter 48 of NFPA 5000, which regulates use of plastics, between the 2003 and 2006 editions.

One change was made in the 2006 edition of the IFC (from the 2003 edition). This change allows foam plastics as an interior wall or ceiling finish if separated from the interior of the building by a thermal barrier in accordance with the IBC. No changes were made between the 2003 and 2006 editions of NFPA 1 related to use of foam plastics or interior finish requirements for assembly occupancies.

The interior finish requirements for Group A-1 and A-2 occupancies (which includes nightclubs) in the IBC did not change from the 2003 to the 2006 edition except for one small change in the

2006 edition, which added a compliance item for those interior finish materials tested in accordance with NFPA 286**,** *Standard Methods of Fire Tests for Evaluating Contribution of Wall and Ceiling Interior Finish to Room Fire Growth.* This addition requires that the peak rete of heat release throughout the NFPA 286 test not exceed 800 kW. This same change was made between the 2003 and 2006 editions of NFPA 5000 and NFPA 101. No other changes related to interior finish requirements were made between the 2003 and 2006 editions of NFPA 5000 or NFPA 101.

For Part C, no specific changes were made to NFPA 286 that included more explicit guidance for when large scale tests are required. The same applies to Part D, no specific changes as specified in the NIST recommendations were made to ASTM E-84, *Standard Test Method for Surface Burning Characteristics of Building Materials*, NFPA 255, *Standard Method of Test of Surface Burning Characteristics of Building Materials*, or NFPA 286.

Recommendation 4 – Pyrotechnics

The NIST investigation report makes the following recommendations related to the use of indoor pyrotechnics:

Recommendation 4. Indoor Use of Pyrotechnics: *NIST recommends that NFPA 1126 (Use of Pyrotechnics before a Proximate Audience) be strengthened as described below, and that state and local authorities adopt and aggressively enforce the revised standard.*

> *a) Pyrotechnic devices should be banned from indoor use in new and existing nightclubs not equipped with an NFPA 13 compliant automatic sprinkler system.*
>
> *b) NFPA 1126 should be modified to include a minimum occupancy and/or area for a nightclub below which pyrotechnic devices should be banned from indoor use, irrespective of the installation of an automatic sprinkler system.*
>
> *c) Plans for the use of indoor pyrotechnics in new and existing nightclubs should be posted on site; and in addition to the items listed in paragraph 4.3.2 of NFPA 1126, should describe the measures that have been established to provide crowd management, security, fire protection, and other emergency services.*
>
> *d) Section 6.6.2 of NFPA 1126 should be modified to require the minimum clearance between (i) the nearest fixed or moveable contents, and (ii) any part or product (igniter, spark, projectile, or debris) of a pyrotechnic device permitted for indoor use in new and existing places of assembly, to be twice the designed projection of the device, until such time that studies show that a smaller minimum clearance can guarantee safe operation in spite of the possibility that building decorations or temporary features that greatly exceed flame spread or fire load provisions of the fire code may occur.*

No specific changes were made in NFPA 1126, *Use of Pyrotechnics before a Proximate Audience*, owing to the NIST recommendations. The standard has requirements for permits, checklists, and demos of all effects. The separation distances also remained the same.

Recommendation 5 – Occupancy Limits

The NIST investigation report makes the following recommendations related to the occupancy limits and emergency egress in nightclubs:

Recommendation 5. Occupancy Limits and Emergency Egress: *NIST recommends that the factor of safety for determining occupancy limits of all new and existing nightclubs be increased in the model codes in the following manner, and that state and local authorities adopt and aggressively enforce the following provisions:*

> *a) Within the model codes, establish the threshold building area and occupant limits for egress provisions using best practices for estimating tenability and evacuation time; and, unless further studies indicate another value is more appropriate, use 1-1/2 minutes as the maximum permitted evacuation time for nightclubs similar to or smaller than The Station.*
>
> *b) Compute the number of required exits and the permitted occupant loads assuming at least one exit (including the main entrance) will be inaccessible in an emergency evacuation.*
>
> *c) For nightclubs with one clearly identifiable main entrance, increase the minimum capacity of the main entrance to accommodate two-thirds of the maximum permitted occupant level (based upon standing space or festival seating, if applicable) during an emergency.*
>
> *d) Eliminate trade-offs between sprinkler installation and factors that impact the time to evacuate buildings.*
>
> *e) Require staff training and evacuation plans for nightclubs that cannot be evacuated in less than 1-1/2 minutes.*
>
> *f) Provide improved means for occupants to locate emergency routes—such as explicit evacuation directions prior to the start of any public event, exit signs near the floor, and floor lighting—for when standard exit signs become obscured by smoke.*

The model codes considered for this recommendation were the NFPA model codes (NFPA 1, *Fire Code*, NFPA 101, *Life Safety Code*, and NFPA 5000, *Building Construction and Safety Code*) and the International Code Council's *International Building Code* (IBC) and *International Fire Code* (IFC). The editions of these model codes that were focused on were the editions issued directly before The Station Nightclub fire and the editions issued after the fire.

For Part A and B for recommendation 5, there are no specific requirements in the model codes on maximum permitted evacuation time for nightclubs and no provisions on computing the number of required exits assuming at least one exit is inaccessible.

A change was made to the 2006 editions of the NFPA model codes relating to Part C. Specifically, the main entrance/exit width for new nightclubs was increased from a minimum of one-half to two-thirds of the total occupant load. The other exits are still required to accommodate a minimum of one-half the total occupant load. Both the 2003 and 2006 editions of the IBC require the main exit to accommodate not less than one-half of the total occupant load.

No specific changes were made to the model codes for Part D of the recommendation. The capacity factors used for calculating exit width remained the same in all model codes. The IBC uses different factors for sprinklered and unsprinklered buildings. NFPA uses the same factors for both. In addition, maximum travel distances remained the same in all model codes with longer distances allowed for sprinklered buildings.

Several provisions in the model codes address crowd managers, staff emergency training, and evacuation plans and relate to Part E. Both the 2003 and 2006 versions of the IFC require fire safety and evacuation plans for all assembly occupancies (other than those used for religious worship) with a requirement for training of employees in the fire emergency procedures at orientation and annually thereafter. Fire and evacuation drills required quarterly for employees.

NFPA model codes have similar requirements for emergency plans for assembly occupancies and requirements for all staff of assembly occupancies to be trained and drilled in the duties they are expected to perform in the event of an emergency.

One change of note related to Part E was that the 2006 NFPA model codes instituted a provision that requires at least one trained crowd manager to be present for all gatherings, except religious services. For gatherings larger than 250 occupants, additional crowd managers are required at a ratio of 1:250 occupants. The 2003 NFPA model codes only require a crowd manager where the occupant load exceeds 1000.

The recommendation in Part F did not result in any specific changes in the model code requirements. Both the 2003 and 2006 editions of the IBC requires illumination of the means of egress of 1 foot candle at the walking surface and require assembly occupancies with occupant loads greater than 1,000 to have an emergency voice/alarm communication system per NFPA 72, *National Fire Alarm and Signaling Code*.

The illumination levels in the NFPA model codes also did not change from the 2003 to the 2006 editions, which require illumination of 10 foot candle in new stairs and 1 foot candle for all other walking surfaces. In addition, both editions require floor proximity exit signs for both new and existing assemblies. For both new and existing assembly occupancies, the 2003 and 2006 editions of the NFPA model codes require occupant notification through visible signals and by voice communication, either live or prerecorded.

Summary

The NIST recommendations had some impact on changes in the model codes and standards. This was especially true of automatic sprinkler requirements for assembly occupancies. The 2006 editions of the IBC and IFC require sprinklers in all new nightclubs with an occupant load of 100 or more (previous edition was 300 or more). The 2006 editions of the NFPA model codes require sprinklers for all new nightclub occupancies and for existing nightclubs where the occupant load is more than 100.

Specific changes related to interior finish requirements and indoor use of pyrotechnics were not found that relate to the NIST recommendations.

Two changes were made to the 2006 editions of the NFPA model codes related to the occupancy limit and emergency egress recommendations made by NIST. Specifically, the capacity of the main exit/entrance was increased to accommodate two-thirds of the total occupant load. The second change was a requirement for crowd managers for all gatherings, except religious services.

Task 4: Literature Review of Research-Based Recommendations

A literature review approach was used to address recommendations 6 & 8-10 of the NIST NCST Report on The Station Nightclub Fire. These recommendations are related to research on fire-related phenomena and mitigation methods, human behavior in emergencies, and tools to aid in response to emergencies. Specifically, the sub-bullets under each recommendation were the focus of the literature review. Materials that were reviewed for this task included:

- Published research (e.g., academia, government laboratories, private industry)
- Programs, plans and agendas for research not yet completed;
- Research assembled or conducted as input to revisions of model codes, standards, and similar documents (e.g., ASTM, ICC, ISO, NFPA, SFPE)
- Research on the effectiveness of model codes, standards, and similar documents

The research recommendations are intended to lead to research that will in turn lead to new rules and practices. To provide some assessment of the degree of progress toward this goal, the literature sources were evaluated on the following:

- Quality (e.g., originality, depth, peer-reviewed), including notes on availability (e.g., proprietary vs. non-proprietary)
- Relevance (e.g., relevance to topic, degree of progress toward eventual goal of recommendations on rules and practices)

Each source is summarized and notes are provided related to the originality of the data for each study (i.e. original data collected or study done with existing data from other studies), whether the literature source is peer reviewed, whether the source references the NIST NCST Report on The Station Nightclub Fire, and each relevant piece of literature is provided with a relevancy score. The relevancy score is based on a scale from 1 to 3 to the specific recommendation made in the NIST report. Literature that is rated a 3 has the most relevancy to the NIST recommendation, which means that it best addresses the research need identified by NIST. Since the recommendations were published in June of 2005, only literature published after this publication date was considered.

Recommendation 6 – Portable Fire Extinguishers

Recommendation 6 of the NIST NCST investigation report relates to portable fire extinguishers:

Recommendation 6. Portable Fire Extinguishers: *NIST recommends that a study be performed to determine the minimum number and appropriate placement (based upon the time required for access and application in a fully occupied building) of portable fire extinguishers for use in new and existing nightclubs, and the level of staff training required to ensure their proper use.*

The literature was reviewed related to the use of portable fire extinguishers by the general public because literature on use of extinguishers in nightclubs was limited. Each relevant source is listed and summarized below.

1. Grosshandler, William, Editor. “The Use of Portable Fire Extinguishers in Nightclubs: Workshop Summary.” NISTIR 7419. National Institute of Standards and Technology, Gaithersburg, MD. April 2007.

Summary: This publication is a summary of a workshop that was held at NIST in Gaithersburg, MD on January 17, 2007. The following topics were discussed:

- Existence of data on the effectiveness of portable fire extinguishers
- Level of training on use of fire extinguishers that is needed and available
- Size of fire that a portable fire extinguisher can be expected to handle
- Appropriate spacing of fire extinguishers at nightclubs and other assembly occupancies
- Role of new technology in increasing effectiveness and efficiency of maintenance of portable fire extinguishers

The summary proposes actions for many groups including NFPA, ICC, NIST, UL, and others to help provide answers to the five questions discussed.

2. Ghosh, Biswadeep. “Assessment of the benefits of Fire Extinguishers as fire safety precautions in New Zealand Buildings”. Fire Engineering Research Project, University of Canterbury. December 2008.

Summary (excerpt from source): “This report uses historical data available from 1990 – 2007 from the New Zealand Fire Service Fire Incident Reporting System (NZFS FIRS) database and usage statistics generated from conducting a survey of fire service agencies for fire extinguishers in New Zealand. This report also evaluates prescriptive requirements existing in New Zealand and compares with prescriptive requirements outside of New Zealand.”

URL: http://www.civil.canterbury.ac.nz/fire/pdfreports/Deep%20Ghosh%20-%20project%20final.pdf

3. Poole, Brandon et al. "Ordinary People and Effective Operation of Fire Extinguishers." Worcester Polytechnic Institute/Eastern Kentucky University. April 2012.

Summary (excerpt from source): “This research investigated how effectively an untrained person would be able to extinguish a small or incipient fire. Specifically, the study posed two main questions that were answered by defining the four aspects that represent effective use of a fire extinguisher: usage, technique, safety, and extinguishment simulation. These aspects were represented by variables that can be measured.”

URL: http://www.femalifesafety.org/docs/WPIStudyFinal.pdf

4. Okimoto, Maria Lucia, Maicon Puppi, Sabrina Oliveira, and Vanessa Macedo. "Usability of portable fire extinguisher: perspectives of ergonomics and intuitive use." In Digital Human Modeling and Applications in Health, Safety, Ergonomics, and Risk Management. Healthcare and Safety of the Environment and Transport, pp. 355-364. Springer Berlin Heidelberg, 2013.

Summary (excerpt from source): “The present study aims to explore the usage of portable fire extinguishers usability from the interaction with non-specialists in emergency context. In order to simulate the emergency context, a usability test was applied with addition stress stimuli. The study allows to conclude that the portable fire extinguisher evaluated present a low level of intuitive use induction, revealing the need to state better standards from Brazilian authorities towards the label and handles of this product. This paper presents the importance of evaluating ergonomic and intuitive factors related to products required on emergency contexts. This study conducted in Brazil is the starting point for other research that explore the theme and aim to improve these devices, assisting designers to take into account aspects of intuitive use and ergonomic principles during the configuration of industrial products.”

5. Tasmania Fire Service. “Guide to the Selection and Location of Portable Fire Extinguishers and Fire Blankets.” April 2007.

Summary: This guide provides advice to aid in the selection and location of extinguishers and fire blankets in and around buildings. The focus of this guide is on new buildings, but also provides guidance for identification of suitable fire extinguishers for existing buildings.

URL: http://www.fire.tas.gov.au/publications/fireExtinguisherGuide.pdf

Table 1: Literature Summary for Recommendation 6

Source	**Data Source**	**Peer reviewed?**	**References NIST report?**	**Relevancy Score**
1	Review of existing information	No (workshop summary)	Yes	3
2	Original data (survey)	University project	No	2
3	Original data	University project	No	2
4	Original data	Yes	No	2
5	Review of existing information	No	No	1

Recommendation 8 – Human Behavior in Emergency Situations

Recommendation 8 of the report focuses on several aspects related to better understanding human behavior in emergency situations:

Recommendation 8. Research on Human Behavior: *NIST recommends that research be conducted to better understand human behavior in emergency situations, and to predict the impact of building design on safe egress in fires and other emergencies (real or perceived), including the following:*

a) the impact of fire products (gases, heat, and obscuration) on occupant decisions and egress speeds;

b) exit number, placement, size and signage;

c) conditions leading to and mitigating crowd crush;

d) the role of crowd managers and group interactions;

e) theoretical models of group behavior suitable for coupling to fire and smoke movement simulations; and

f) the level of safety that model codes afford occupants of buildings.

Review on this topic still being developed

Recommendation 9 – Fire Spread and Suppression

Recommendation 9 relates to research recommendations aimed to better understand fire spread and suppression in order to provide tools to designers:

Recommendation 9. Research on Fire Spread and Suppression: *NIST recommends that research be conducted to understand fire spread and suppression better in order to provide the tools needed by the design profession to address recommendations 2, 3 and 5, above. The following specific capabilities require research:*

a) prediction of flame spread over actual wall, ceiling and floor lining materials, and room furnishings;

b) quantification of smoke and toxic gas production in realistic room fires; and

c) development of generalized models for fire suppression with fixed sprinklers and for firefighter hose streams.

Literature was reviewed for each of the above sub-categories for this recommendation, so the discussion below is split into three sections.

For recommendation 9a related to prediction of flame spread over wall, ceiling and floor lining materials, the following relevant literature was identified.

1. Canjun Liang, Xudong Cheng, Kaiyuan Li, Hui Yang, Heping Zhang and Kwok K Yuen. “Experimental study on flame spread behavior along poly(methyl methacrylate) corner walls at different altitudes.” Journal of Fire Sciences 2014 32: 84.

Summary (excerpted from text): “The effects of altitude and intersection angle on the flame spread behavior and pyrolysis front characteristics along corner walls were experimentally studied. The experiments were conducted using mock corners made of poly(methyl methacrylate) slabs with intersection angles varying from 60to 120 at two altitudes of 29.8 and 3658.0 m. Measurements were taken for the upward and lateral flame spread rates, the flame heights, the flame heat flux to the fuel surface, and the mass loss rates of the tested slabs.”

2. Hjohlman, Maria, Andersson, Petra, van Hees, Patrick. “Flame Spread Modelling of Complex Textile Materials”, Fire Technology, 47, 85–106, 2011.

Summary (excerpted from text): “Flame spread in textile materials was modelled using two different simulation programs: the semi-empirical area-based code ConeTools, and the computational fluid dynamics, CFD, code Fire Dynamics Simulator, FDS, (version 5). Two textile products were selected for study, they show a large difference in composition and application area, one material is developed to function as a protecting layer for the underlying structure in case of fire while the other is an insulating material with no requirements on fire performance. Two FDS-models were developed for the simulations.”

3. Tsai, Kuang-Chung. “Using cone calorimeter data for the prediction of upward flame spread rate.” Journal of Thermal Analysis and Caliorimetry, Volume 112, Issue 3, pp 1601-1606.

Summary (excerpted from text): “In a cone calorimeter, the specimen receives uniformly distributed irradiance from the cone heater. Producing a heating environment simulating the heating intensity in real fires, this apparatus consequently is capable of providing information of materials relevant to their fire performance. This study introduces an alternative protocol of the cone calorimeter and a sample holder by which the following differences were made, including specimen turned 42° before ignition, lower ignition source before ignition, heater removed after ignition, and specimen moved back to vertical orientation after ignition. The prediction of flame spread rate using the alternative test protocol is closer to the measured flame spread rate than standard test methods.”

4. Ren, Ning, Wang, Yi, Trouvé, Arnaud. “Large eddy simulation of vertical turbulent wall fires.” 9th Asia-Oceania Symposium on Fire Science and Technology. Procedia Engineering 62, pp 443- 452. 2013.

Summary (excerpted from text): “The objective of the present study is to evaluate the ability of wall-resolved large eddy simulations (LES) to accurately simulate wall fires. The focus of the study is on the flame-to-wall heat transfer. The LES performance is evaluated via comparisons with a previously developed experimental database. LES simulations are performed using FireFOAM."

URL: http://www.sciencedirect.com/science/article/pii/S187770581301268X

5. Weng, W. G. and Hasemi, Y. "A numerical model for flame spread along combustible flat solid with charring material with experimental validation of ceiling flame spread and upward flame spread." Fire and Materials, Volume 32, Issue 2, pp 87-102. March 2008.

Summary (excerpted from text): "This paper gives a numerical model for flame spread along combustible flat solid with charring materials. The presented model consists of a one-dimensional flame spread model coupled with a one-dimensional pyrolysis model. The existing experimental data (the ceiling flame spread beneath medium density fibreboard) are used for comparison to validate the model. In addition, the model can also be used to predict upward flame spread."

6. Shih, Hsin-Yi and Wu, Hong-Chih. "An Experimental Study of Upward Flame Spread and Interactions Over Multiple Solid Fuels." Journal of Fire Sciences, Volume 26, Number 5, pp 435-453. September 2008.

Summary (excerpted from text): "Upward flame spread and flame interactions over multiple solid fuels are experimentally studied, and the effects of flame interactions on the flame spreading rates are analyzed. Flame spreading characteristics and spreading rates are measured and compared for six different geometric arrangements of thin solids at different solid width and separation distance between solids."

7. Galea, Edwin R., Wang, Zhaozhi, Veeraswamy, Anand, Jia Fuchen, Lawrence, Peter J., and Ewer, John. "Coupled Fire/Evacuation Analysis of the Station Nightclub Fire." Fire Safety Science, Proceedings of the Ninth International Symposium, pp 465-476. 2008.

Summary (excerpted from text): "In this paper, coupled fire and evacuation simulation tools are used to simulate the Station Nightclub fire. This study differs from the analysis conducted by NIST in three key areas; (1) an enhanced flame spread model and (2) a toxicity generation model are used, (3) the evacuation is coupled to the fire simulation. Three evacuation scenarios are then considered, two of which are coupled with the fire simulation. The coupled fire and evacuation simulation suggests that 180 fatalities result from a building population of 460. With a 15 sec delay in the fire timeline, the evacuation simulation produces 84 fatalities which are in good agreement with actual number of fatalities. An important observation resulting from this work is that traditional fire engineering ASET/RSET calculations which do not couple the fire and evacuation simulations have the potential to be considerably over optimistic in terms of the level of safety achieved by building designs."

URL: http://www.iafss.org/publications/fss/9/465/view

8. Lai, Chi-Ming, Ho, Ming-Chin, and Lin, Ta-Hui. "Experimental Investigations of Fire Spread and Flashover Time in Office Fires." Journal of Fire Sciences, Volume 28, pp 279-302. May 2010.

Summary (excerpted from text): "The characteristics of, prediction models for, and experimental data pertaining to flashover in full-scale room fires were first reviewed. Then, initiation, growth, full development, and decay of three office fire scenarios were experimentally explored using a 10 MW fire test facility and continuous online combustion gas analysis. The conditions for flashover were investigated and compared with correlations in the literature. The model office compartment is an aerated lightweight concrete structure with dimensions of 5 m × 6 m and with a net room height of 2.4—3.3 m."

9. Consalvia, J. L., Pizzoa, B., Porterie, B. "Numerical analysis of the heating process in upward flame spread over thick PMMA slabs." Fire Safety Journal, Volume 43, pp 351–362. 2008.

Summary (excerpted from text): "A detailed analysis of the unburned material heat-up during upward flame spread over small slabs of PMMA is provided using a numerical model. The two-dimensional time-dependent Favre-averaged Navier–Stokes equations coupled with sub-models for turbulence, combustion, soot formation, and radiation are solved for the gas phase. The modelling of condensed phase processes is based on the one-dimensional heat conduction equation and pyrolysis is treated as a phase change using the latent heat approach."

10. Kwon, Jae-Wook, Dembsey, Nicholas A., and Lautenberger, Christopher W. "Evaluation of FDS v. 4: upward flame spread." Fire technology, Volume 43, No. 4, pp 255-284. 2008.

Summary (excerpted from text): "In this work three simulations are conducted to evaluate FDS V.4's capabilities for predicting upward flame spread. The FDS predictions are compared with empirical correlations and experimental data for upward flame spread on a 5 m PMMA panel. A simplified flame spread model is also applied to assess the FDS simulation results. Capabilities and limitations of FDS V.4 for upward flame spread predictions are addressed, and recommendations for improvements of FDS and practical use of FDS for fire spread are presented."

11. Cheng, Hao and Hadjisophocleous, George V. "Dynamic modeling of fire spread in building." Fire Safety Journal, Volume 46, pp 211–224. 2011.

Summary (excerpted from text): "In this paper, a dynamic model of fire spread considering fire spread in both horizontal and vertical directions is described. The algorithms for simulating the fire spread process in buildings and calculating dynamic probability of fire spread for each compartment at each time step of simulation are proposed. The formulae used in calculating the input data for the dynamic fire spread model are derived. The dynamic fire spread model can easily be applied for any building including high-rise buildings. A detailed example of calculation of fire spread in a two-storey office building is described."

12. Li, Liming, Zhang, Heping, Xie, Qiyuan, Chen, Long, and Xu, Chunming. "Experimental study on fire hazard of typical curtain materials in ISO 9705 fire test room." Fire and Materials, Volume 36, pp 85-96. 2012.

Summary (excerpted from text): "In this paper, fire hazard of three typical curtain materials with different pleat rates were tested in an ISO 9705 fire test room. Fire parameters such as temperature field, flame spread rate, heat release rate (HRR), and emitted gases, and the influences of pleat rate and cotton content on flame spread rate were investigated. The correlation between flame spread rate and HRR was discussed. Fire parameters such as temperature field, flame spread rate, heat release rate (HRR), and emitted gases, and the influences of pleat rate and cotton content on flame spread rate were investigated. The correlation between flame spread rate and HRR was discussed."

13. Hofmann, Anja and Muediger, Muehlnikel. "Experimental and numerical investigation of fire development in a real fire in a five-storey apartment building." Fire and Materials, Volume 35, pp 453-462. 2011.

Summary (excerpted from text): "A fire in a five-storey apartment building was investigated experimentally and numerically. The room of origin of the fire was a living room in the second floor and the fire was started by a candle on a television set. The fire spread externally over the building façade and internally along the staircase and affected all the flats above leading to two fatalities. By this time large sections of the façade were on fire already. The rapid fire that spread over the façade and the staircase necessitated detailed investigations."

14. Chen, Chien-Jung, Hsieh, Wie-Dong, Hub, Wei-Cheh, Lai, Chi-Ming, and Lin, Ta-Hui. "Experimental investigation and numerical simulation of a furnished office fire." Building and Environment, Volume 45, pp 2735-2742. 2010.

Summary (excerpted from text): "Experiments were conducted in a full-scale model room equipped with both movable and fixed fire loads to explore fire growth and spread via heat release rates, indoor air temperature and species concentration. Numerical simulations with parameter adaptation were carried out using FDS software to predict the fire features and were compared with the experimental results. In this study, the material properties and oxygen limit settings in the FDS software were tested to explore their influence on the tendency of heat release rate and on the total amount of heat release. The results show that the heat release rate from the FDS simulations is comparable to the full-scale experiment results during the fire growth period. Temperature profile near ceiling can be modeled well. In the full-involvement burning and decaying periods, the qualitative trends were identical, although the simulated value differed greatly from the experimental result."

15. Sunahara, Hiroyuki, Ishihara, Takahiro, Kikkawa, Akimitsu, Mizuno, Masayuki, Ohmiya, Yoshifumi, and Morita, Masahiro. “Fire Behavior under a Ceiling in Growing Fire Part 1 Fire Spread and Ceiling Temperature Distribution.” Fire Science and Technology, Volume 26, Number 4, Special Issue, pp. 473-478. 2007.

Summary (excerpted from text): “In general, a fire develops gradually from the smallest source of a fire to a fully developed fire. The growth in this period is commonly described with a model in the form of αt2. When a fire develops in a general building, it reaches the ceiling at a certain point and spreads beneath the ceiling horizontally. However, in the most experiments, a fire is steadily ignited by a burner, and therefore, there are only few full scale experiments conducted with respect to the ceiling temperature and flame length in growing fire that has reached the ceiling. Therefore, an experiment was conducted to measure the spreading speed of fire, ceiling temperature, air velocity and flame length with an actual-sized fire experiment using a wood crib.”

16. Harish, K. and Venkatasubbaiah, K. “Numerical simulation of turbulent plume spread in ceiling vented enclosure.” European Journal of Mechanics B/Fluids, Volume 42, pp 142-158. 2013.

Summary (excerpted from text): “The buoyancy-induced turbulent flow generated by a heat source in a square enclosure with single and multiple ceiling vents has been studied numerically. A two-dimensional, turbulent natural convection flow is investigated in stream function and vorticity formulation approach. The effects of heat source location, vent location and multiple vents on flow characteristics in enclosure are presented. The heat transfer characteristics, ambient entrainment flow rate and the oscillatory nature of the penetrative and recirculating flow inside the vented enclosure are reported.”

17. Zhang, Xia and Yu, Yong. “Experimental studies on the three-dimensional effects of opposed-flow flame spread over thin solid materials.” Combustion and Flame, Volume 158, Issue 6, pp 1193–1200. June 2011.

Summary: The paper presents and experimental study of the three-dimensional effects of flame spread over thin solid materials using a natural-convection-suppressing horizontal narrow-channel. The effects of gas flow speed, oxygen concentration, material width, and flow tunnel size on flame spread are considered.

18. Xie, Wei and DesJardin, Paul E. “An embedded upward flame spread model using 2D direct numerical simulations.” Combustion and Flame, Volume 156, Number 2, pp 522-530. 2009.

Summary (excerpted from text): “A fully coupled 2D fluid–solid direct numerical simulation (DNS) approach is used to simulate co-flow flame spread over poly(methyl methacrylate) (PMMA) at different angles of inclination. Comparison of simulations and experimental measurements are conducted over a range of flame spread rates. Results show that the heat flux to the preheating region varies considerably in time — contradicting often employed assumptions used in established flame spread theories. Accounting for the time dependent behavior is essential in accurate predictions of flame spread, however, a universal characterization in terms of easily defined parameters is not found. Alternatively, a reaction progress variable based embedded flame model is developed using mixture fraction, total enthalpy and surface temperature. State maps of the gas-phase properties and surface heat flux are constructed and stored in pre-computed lookup tables. The resulting model provides a computationally efficient and a local formulation to determine the flame heat flux to the surface resulting in excellent agreement to DNS and experiments for predictions of flame spread rate and position of the pyrolysis front."

19. Pizzo, Y., Consalvi, J. L., and Porterie, B. "A transient pyrolysis model based on the *B*-number for gravity-assisted flame spread over thick PMMA slabs." Combustion and Flame, Volume 156, Number 9, pp 1856-1859. September 2009.

Summary (excerpted from text): "This work developed a transient pyrolysis model based on the modified mass transfer number determined from experiments on the steady-state burning rate of vertical PMMA slabs. It allowed satisfactory concordance with experiments on upward flame spread. A good agreement for the rate of spread was also observed for inclination angles below the critical angle."

20. Olson, S. L., Miller, F. J., Jahangirian, S., and Wichman, I. S. "Flame spread over thin fuels in actual and simulated microgravity conditions." Combustion and Flame, Volume 156, Number 6, pp 1214-1226. June 2009.

Summary (excerpted from text): "In this study, the flame spreads in a narrow gap, as occurs in fires behind walls or inside electronic equipment. Two sets of experiments are described, one involving flame spread in a Narrow Channel Apparatus (NCA) in normal gravity, and the others taking place in actual microgravity. Three primary variables are considered: flow velocity, oxygen concentration, and gap size (or effect of heat loss). Flammability maps are constructed that delineate the uniform regime, the flamelet regime, and extinction limits for thin cellulose samples. Good agreement is found between flame and flamelet spread rate and flamelet size between the two facilities. The experiments show that in normal gravity the flamelets are a fire hazard since they can persist in small gaps where they are hard to detect. The results also indicate that the NCA quantitatively captures the essential features of the microgravity tests for thin fuels in opposed flow."

21. Jiang, Yun. "Decomposition, Ignition, and flame spread on furnishing materials", Yun Jiang, Ph.D. Thesis, Centre for Environment Safety and Risk Engineering, Victoria University, Australia. 2006.

Summary (excerpted from text): "The general aim of this research is to find an effective and applicable method for prediction of pyrolysis and ignition of certain furnishing materials in a real fire environment. In current study, certain furnishing materials, timbers, polyurethane foams and fabrics, were chosen for research purpose. Series of bench-scale tests were carried out to construct a physical platform for modelling and provide test results for validating of the modeling. Through modelling, various criteria for ignition were investigated and compared with the test results."

URL: http://vuir.vu.edu.au/481/1/02whole.pdf

22. Zhang, Ying, Huang, Xinjie, Wang, Quigsong, Ji, Jie, Sun, Jinhua, and Yin, Yi. "Experimental study on the characteristics of horizontal flame spread over XPS surface on plateau." Journal of Hazardous Materials, Volume 189, pp 34–39. May 2011.

Summary (excerpted from text): "A series of comparative laboratory-scale experiments were carried out in the Lhasa plateau and the Hefei plain respectively to investigate the characteristics of flame spread over the extruded polystyrene (XPS) foam, a typical thermal insulation material. Flame shape and the temperature profile in solid phase were monitored, and the effects of altitude on the heat transfer process were analyzed. Comparing of the temperature change rate curve on plateau with that in plain, it is found that the peak characteristics of the curves in the pyrolysis stage changed from single peak to multi-peaks, which suggests that the altitude difference might change the pyrolysis mechanisms of XPS material. Moreover, the sample scale effects on flame spread are also explored. Two different regimes are found in flame spread behavior with sample scale at the both altitudes. The spread rate drops with sample scale in convection regime and rises in radiation regime."

23. Zhang, Jianping, Dembele, Siaka, Karwatzki, John, and Wen, Jennifer X. "Effect of Radiation Models on CFD Simulations of Upward Flame Spread.", Jianping Zhang, Siaka Dembele, John Karwatzki, and Jennifer X Wen, Fire Safety Science – Proceedings of the Eighth International Symposium, pp 421-432. 2005.

Summary (excerpted from text): "The objective of this study is to examine the effect of radiation models on CFD predictions of flame spread. To this end, a statistical narrow band (SNB) model and the WSGG model are employed for the simulation of two upward flame spread scenarios, one being a large scale flame spread over a vertical PMMA wall while the other representing flame spread along vertical corner walls. Quantitative comparison is made between the prediction results obtained with the SNB model and the WSGG model as well as the experimental data. Results clearly show that the SNB model yields more accurate results than the WSGG approach. However, the SNB model is about four to five times more time consuming than the WSGG model. Therefore, for simulations of complex engineering applications a compromise between accuracy and numerical efficiency should be taken into account."

URL: http://www.iafss.org/publications/fss/8/421/view

24. Collier, PCF. “Fire Properties of Floor Coverings: New Fire Test Methods and Acceptable Solutions.” BRANZ Study Report 181. BRANZ Ltd, Judgeford, New Zealand. 2007.

Summary (excerpted from text): “This project trailed the current reaction to fire test requirements for flooring and compared this with two alternative test methods on a range of flooring products. The findings indicated that the current test method of the Hot Metal Nut (HMN) required by the NZBC Compliance Documents does not adequately identify the flooring products that present a hazard. Alternative test methods – the Flooring Radiant Panel Test (FRPT) and the cone calorimeter (CC) – were shown to identify flooring products that do present a hazard when the HMN had indicate the same products to be in the low hazard category.”

URL: http://www.branz.co.nz/cms_show_download.php?id=0d2ebab737a645d7f1f5608789b3ed16705815d4

25. Collier, PCR, Whiting, PN, and Wade, CA. “Fire Properties of Wall and Ceiling Linings: Investigation of Fire Test Methods for Use in NZBC Compliance Documents.” BRANZ Study Report 160. BRANZ Ltd, Judgeford, New Zealand. 2006.

Summary (excerpted from text): “This project has demonstrated the effectiveness of the ISO 9705 room corner test method and the AS/NZS 3837/ISO 5660 Cone Calorimeter in evaluating the reaction-to-fire performance of a selection of surface lining materials as applied to walls and ceilings. The measurement of heat release rate (HRR) and smoke production rate (SPR) are direct indicators of the hazard. The growth of the HRR enables a lining material to be classified with respect to time based on if or when flashover occurs. The measurements of gas species, percentage of flame spread area over the lining surface, and compartment temperatures and smoke layer height, are compared to confirm that the conditions generated are consistent with the primary parameters of HRR and SPR and accurately reflect the fire hazard. Recommendations are made for changes to the fire test methods in NZBC Compliance Documents.”

URL: http://www.branz.co.nz/cms_show_download.php?id=7652db415e65acf4391dcaffb8edb87fac3784ff

26. Robbins, AP. “Simplified Reaction to Fire for Interior Wall, Ceiling and Floor Linings.” BRANZ Study Report 301. BRANZ Ltd, Judgeford, New Zealand. 2014.

Summary (excerpted from text): “The focus for the overall project was to investigate the possibility of providing simplified ‘deemed to comply’ solutions to demonstrate code

compliance for fire properties of surface coatings and other interior finishes in the New Zealand regulatory context. The approach used for this literature review has been to collect together published test results that may be (directly or indirectly) relevant to the fire testing procedures required for compliance with the New Zealand Building Code, and to provide guidance for designing a test program."

URL:
http://www.branz.co.nz/cms_show_download.php?id=5b356fa1555e3f55b844b0a4f17a51e9d589bc21

Table 2 - Literature Summary for Recommendation 9a

Source	Data Source	Peer reviewed?	References NIST report?	Relevancy Score
1	Original Data	Yes	No	3
2	Existing Data	Yes	No	3
3	Original Data	Yes	No	3
4	Original Data	Yes	No	3
5	Existing Data	Yes	No	3
6	Original Data	Yes	No	3
7	Existing Data	Yes	Yes	3
8	Original Data	Yes	No	2
9	Original Data	Yes	No	2
10	Original Data	Yes	No	2
11	Existing Data	Yes	No	2
12	Original Data	Yes	No	2
13	Original Data	Yes	No	2
14	Original Data	Yes	No	2
15	Original Data	Yes	No	2
16	Existing Data	Yes	No	2
17	Original Data	Yes	No	2
18	Existing Data	Yes	No	2
19	Existing Data	Yes	No	2

20	Original Data	Yes	No	2
21	Original Data	Ph.D. Thesis	No	2
22	Original Data	Yes	No	1
23	Existing Data	Yes	No	1
24	Existing Data (literature review)	No (BRANZ report)	No	1
25	Existing Data (literature review)	No (BRANZ report)	No	1
26	Existing Data (literature review)	No (BRANZ report)	No	1

For recommendation 9b related to quantification of smoke and toxic gas production, the following relevant literature was identified.

1. Stec, Anna A., Hull, T. Richard. "Assessment of the fire toxicity of building insulation materials." Energy and Buildings, Volume 43, pp 498–506. February-March 2011.

Summary (excerpted from text): "A significant element in the cost of a new building is devoted to fire safety. Energy efficiency drives the replacement of traditional building materials with lightweight insulation materials, which, if flammable can contribute to the fire load. Most fire deaths arise from inhalation of toxic gases. The fire toxicity of six insulation materials (glass wool, stone wool, expanded polystyrene foam, phenolic foam, polyurethane foam and polyisocyanurate foam) was investigated under a range of fire conditions. Two of the materials, stone wool and glass wool failed to ignite and gave consistently low yields of all of the toxic products. The toxicities of the effluents, showing the contribution of individual toxic components, are compared using the fractional effective dose (FED) model and LC50 (the mass required per unit volume to generate a lethal atmosphere under specified conditions). For polyisocyanurate and polyurethane foam this shows a significant contribution from hydrogen cyanide resulting in doubling of the overall toxicity, as the fire condition changes from well-ventilated to under-ventilated. These materials showed an order of increasing fire toxicity, from stone wool (least toxic), glass wool, polystyrene, phenolic, polyurethane to polyisocyanurate foam (most toxic)."

2. Zhang, Jiaqing, Lu, Shouxiang, Li, Qiang, Yuen, Ricahrd Kwok Kit, Chen, Bing, Yuan, Man, and Li, Changhai. "Smoke filling in closed compartments with elevated fire sources." Fire Safety Journal, Volume 54, pp 14–23. November 2012.

Summary (excerpted from text): "An experimental study on smoke filling in closed compartments with elevated fire sources is presented. Experiments were conducted with elevated fires in a closed compartment with interior dimensions of 3.000 m (L)×3.000 m

(W)×1.950 m (H). Various parameters, such as the light extinction coefficient, the oxygen concentration and the gas temperature, showed distinct stratification phenomena, and the interface of the stratification was the fuel surface level. The results indicated that the smoke layer descended to the fuel surface level but did not descend directly to the floor at the center of the compartment; rather, it continued the filling process by wall jets. A similar stratification was observed in a closed burning compartment with interior dimensions of 1.000 m (L)×1.000 m (W)×0.750 m (H) through tracking the smoke by a laser sheet. A visualization showed that the wall jets penetrated the interface, traveled along the wall, concentrated at the floor and then rose from the center of the floor. With continuous burning, the smoke filled the lower layer."

3. Hull, T. Richard and Paul, Keith T. "Bench-scale assessment of combustion toxicity—A critical analysis of current protocols." Fire Safety Journal, Volume 42, pp 340–365. July 2007.

Summary (excerpted from text): "This paper reviews current fire effluent toxicity tests, their relevance to fire, and the ways of assessing and applying their results to reduce fire hazards. There are a large number of different methods for determination of the toxic potency of fire effluents from materials or products. These different methods yield apparently inconsistent data because they represent different fire scenarios; measure product yields either as a function of material flammability or independent of it; base the toxicity assessment on the concentrations of different species; or use animal exposure to generate an overall estimate of toxic potency without knowledge of the relative contributions of the chemical species."

4. Pierce, J.B.M. and Moss, J.B. "Smoke production, radiation heat transfer and fire growth in a liquid-fuelled compartment fire." Fire Safety Journal, Volume 42, pp 310–332. June 2007.

Summary (excerpted from text): "A detailed investigation is described of the interaction between fire development, smoke production and radiative exchange in a half-scale ASTM compartment in which the source is a heptane pool fire. Measurements of heat flux, fuel mass loss rate, ventilation flow rates, and temperature and soot volume fraction are reported for the compartment for varying door widths. Data from the compartment are compared with open pool fire measurements using the same equipment. The confined geometry is shown to exert a strong influence on pool fire development and suggests that considerable caution is needed in employing open pool fire data as boundary conditions for CFD simulation. Numerical simulations based on the direct calculation of radiative exchange between the liquid fuel surface, the smoke-laden environment and bounding walls do reproduce the behavior observed when combustion, soot production and radiation are modelled in detail and finely resolved spatially."

5. Wang, Z., Jia, F., and Galea, E. R. “Predicting toxic gas concentrations resulting from enclosure fires using local equivalence ratio concept linked to fire field models.” Fire and Materials, Volume 31, Issue 1 pp 27–51. January/February 2007.

Summary (excerpted from text): “A practical CFD method is presented in this study to predict the generation of toxic gases in enclosure fires. The model makes use of local combustion conditions to determine the yield of carbon monoxide, carbon dioxide, hydrocarbon, soot and oxygen. The local conditions used in the determination of these species are the local equivalence ratio (LER) and the local temperature. The heat released from combustion is calculated using the volumetric heat source model or the eddy dissipation model (EDM). The model is then used to simulate a range of reduced-scale and full-scale fire experiments. The model predictions for most of the predicted species are then shown to be in good agreement with the test results.”

6. Stec, A. A., Hull, T. R., Purser, J. A., and Purser, D. A. “Comparison of toxic product yields from bench-scale to ISO room.” Fire Safety Journal, Volume 44, pp 62–70. January 2009.

Summary (excerpted from text): “The steady-state tube furnace (ISO TS 19700) allows individual fire stages to be replicated and shows a good general agreement with product yield data (measured for CO_2, CO, HCN, NO_x, total hydrocarbons and smoke particulates) obtained from large-scale ISO room tests for the five materials considered here and expressed as functions of equivalence ratio and CO_2/CO ratio. The closest direct agreement between the large- and small-scale data were obtained for pool fires involving PP and nylon 6.6 product yield. For materials burned as wall linings, with varying decomposition conditions at different room locations, and/or when a propane flame is also present, direct comparison with tube-furnace data is more problematic. Nevertheless MDF, MDF-FR and PS show reasonable agreement for CO, CO_2, HCN and hydrocarbon yields between the scales. Smoke yields tended to be more variable and may be influenced by the presence of different areas of flaming and non-flaming decomposition.”

7. Chow, W. K. and Yin, R. “Smoke Movement in a Compartmental Fire.” Journal of Fire Sciences, Volume 24, Number 6 pp 445-463. November 2006.

Summary (excerpted from text): “Transport of larger smoke particles generated by a fire in a compartment is studied. An atrium fire with three different heat release rates is taken as an example. The air flow pattern and temperature contours are predicted by a fire field (or application of computational fluid dynamics (CFD) model. The paths of smoke particles are modeled by the Lagrangian method coupled with the air movement induced by hot smoke. Distribution of smoke particles and their trajectories are then calculated. By superimposing the trajectories of particles of different sizes, the shape of the smoke plume is observed.”

8. Lizhong, Yang, Wenxing, Feng, and Junqi, Ye. "Experimental Research on the Spatial Distribution of Toxic Gases in the Transport of Fire Smoke." Journal of Fire Sciences, Volume 26, Number 1, pp 45-62. January 2008.

Summary (excerpted from text): "This study, through experiments conducted in a reduced-scale compartment—corridor model, examines the assumption and explores the characteristics of spatial distribution of toxic gases in smoke transport from a fire hazard. The results suggest that the toxic gases in the upper layer in the corridor are characterized by uniform expansion, while those in the lower layer are not. It has also been found that evolutions of the gases in different layers are not synchronous, while they are identical at the same height where the densities are close. Further analyses indicate that the formation of CO from the deoxidization of O_2, CO_2, and the unburned hydrocarbon in the smoke movement delays the time of the maximum concentration."

9. Remesh, K. and Tan, K. H. "Field Model Analysis and Experimental Assessment of Fire Severity and Smoke Movement in a Partitioned and a Non-partitioned Dwelling Unit." Journal of Fire Sciences, Volume 24, Number 5, pp 365-391. September 2006.

Summary (excerpted from text): "To study the smoke movement and gas temperature evolution, computational fluid dynamics (CFD) analysis is carried out for a partitioned and a non-partitioned dwelling unit for the same fire load. The model predictions in terms of gas temperatures are then compared with the experimental measurements for both units. The gas temperatures inside the units are measured using K-type mineral insulated thermocouples, positioned at various elevations in the room of fire origin, and at other locations that were in the path of anticipated smoke movement. Also, to study the effectiveness of fire suppression methods, water spray and water mist methods are employed in the partitioned and non-partitioned units, respectively, when the fire reached decay stage."

10. Crewe, Robert J., Stec, Anna A., Walker, Richard G., Shaw, John E. A., Hull, T. Richard. "Experimental Results of a Residential House Fire Test on Tenability: Temperature, Smoke, and Gas Analyses." Journal of Forensic Science, Volume 59, Number 1. January 2014.

Summary (excerpted from text): "A fire experiment conducted in a British 1950s-style house is described. Measurements of temperature, smoke, CO, CO2, and O2 were taken in the Lounge, stairwell, and front and back bedrooms. The front bedroom door was wedged open, while the door to the back bedroom was wedged closed. Contrary to expectations and despite the relatively small fire load, analysis and hazard calculations show permeation of toxic fire gases throughout the property with lethal concentrations of effluent being measured at each sampling point. A generally poor state of repair and missing carpets in the upper story contributed to a high degree of gas and smoke permeation. The available egress time was calculated as the time before the main escape route became impassable. Given known human responses to fire, such an incident could have caused fatalities to sleeping or otherwise immobile occupants."

11. Chow, W. K., Chow, C. L., and Li, S. S. "Simulating Smoke Filling in Big Halls by Computational Fluid Dynamics." Modelling and Simulation in Engineering, Volume 2011, Article ID 781252. 2011.

Summary (excerpted from text): "An update on applying Computational Fluid Dynamics (CFD) in smoke exhaust design will be presented in this paper. Key points to note in CFD simulations on smoke filling due to a fire in a big hall will be discussed. Mathematical aspects concerning of discretization of partial differential equations and algorithms for solving the velocity-pressure linked equations are briefly outlined. Results predicted by CFD with different free boundary conditions are compared with those on room fire tests. Standards on grid size, relaxation factors, convergence criteria, and false diffusion should be set up for numerical experiments with CFD."

URL: http://www.hindawi.com/journals/mse/2011/781252/

12. Wang, Z., Jia, F., Galea, E. R., and Patel, M. K. "Predicting toxic gas concentrations at locations remote from the fire source." Fire and Materials, Volume 35, Issue 7, pp 505–526. November 2011.

Summary (excerpted from text): "A toxicity model capable of predicting toxic gas concentrations within fire enclosures utilizing the concept of the local equivalence ratio (LER) was recently developed. This paper describes an enhancement of the original model that improves its accuracy in predicting species concentrations at remote locations from the room of fire origin. The enhanced technique involves dividing the CFD computational domain into two regions for species calculation, a control region (CR) and a transport region. Toxic gas concentrations in the CR are calculated using the formulation developed in the earlier study whereas in the transport region, gas concentrations are determined as a result of the mixing of hot combustion gases with fresh air. The concept of a critical equivalence ratio, which is derived from the effective heat release rate (or combustion efficiency) of the fire scenario being simulated, is introduced to perform the domain division. Predictions of temperatures and species concentrations at various locations made by the new model are compared with the results from two experiments. Compared with the earlier model, the modified model provides considerable improvements in the predictions of toxic species levels."

13. Lai, Chi-ming, Chen, Chien-Jung, Tsai, Ming-Ju, Tsai, Meng-Han, and Lin, Ta-Hui. "Determinations of the fire smoke layer height in a naturally ventilated room." Fire Safety Journal, Volume 58, pp 1–14. May 2013.

Summary (excerpted from text): "According to the case-based reasoning of natural ventilation designs in recommended Green Buildings, an investigated model space was proposed in this study. FDS simulations and full-scale experiments were carried out to measure the impact of natural ventilation conditions and the installation of a natural ventilation shaft on smoke layer descent during different fire scenarios. The feasibility of using the N-percentage rule to determine the fire smoke layer height in a naturally ventilated space was also investigated."

14. Xie, Qiyuan, Yuan, Hongyong, Song, Liwei, and Zhang, Yongming. "Experimental studies on time-dependent size distributions of smoke particles of standard test fires." Building and Environment, Volume 42, Issue 2, pp 640–646. February 2007.

Summary (excerpted from text): "In this paper, the time-dependent size distributions of smoke particles are measured using the SMPS spectrometers for four typical standard test fires in the field of fire detection. The changing trend of the normalized number distributions of smoke aerosol as experiments go on is analyzed for each fire."

15. Kang, Kai. "Verification of CFD Modeling for Smoke Control Using Two Compartment Fire Experiments." ASHRAE Transactions, Volume 115, Issue 1, p 254. 2009.

Summary (excerpted from text): "This paper compares the numerical predictions from computational fluid dynamics (CFD) to two sets of selected compartment fire experimental data. Using a Reynolds-averaged approach for turbulence in the first compartment fire comparison, it is shown that the numerical results of the heat and mass exchange through the compartment opening are in good agreement with the experimental measurements. Overall, a difference within approximately 10% is observed for the centerline flow velocity and temperature, as well as the upper layer height and the temperature at one corner of the compartment. In addition, the results suggest that far-field predictions would not be sensitive to the modeling approach of the fire inside the compartment when the fire-associated transport phenomena are taken into account. The second comparison verified the prediction of the compartment interior wall surface temperature using large eddy simulation. The discrepancy in the numerical results is between 10% to 25% for a pool fire from 170 to 390 kW. From these results, the practical implications of CFD modeling for smoke control are discussed."

16. Staubli, O., Sigg, C., Peikert, R., Gubler, D., and Gross, Markus. "Volume rendering of smoke propagation CFD data." Proceedings IEEE Visualization. October 2005.

Summary (excerpted from text): "This paper presents real-time volume rendering of transient smoke propagation conforming to standardized visibility distances. It visualized time dependent smoke particle concentration on unstructured tetrahedral meshes using a direct volume rendering approach. A simple absorption-based lighting model is evaluated in a preprocessing step using the same rendering approach. Back-illuminated exit signs are commonly used to indicate the escape route. As light emitting objects are visible further than reflective objects, the transfer function in front of illuminated exit signs must be adjusted with a deferred rendering pass."

17. Stec, A. A., Hull, T. R., Lebek, K., Purser, J. A., and Purser, D. A. “The effect of temperature and ventilation condition on the toxic product yields from burning polymers.” Fire and Materials, Volume 32, Issue 1, pp 49-60. January/February 2008.

Summary (excerpted from text): “This work presents combustion product yields generated using a small-scale fire model. The Purser Furnace apparatus (BS7990 and ISO TS 19700) enables different fire stages to be created. Identification and quantification of combustion gases and particularly their toxic components from different fire scenarios were undertaken by continuous Fourier transform infrared spectroscopy. The relationship between type of the fire particularly the temperature and ventilation conditions and the toxic product yields for four bulk polymers, low-density polyethylene, polystyrene (PS), Nylon 6.6 and polyvinyl chloride (PVC) is reported.”

18. Amundsen, D. E., Hadjisophocleous, G., Kashef, A., and Zhu, X. “Algorithm for smoke modeling in large, multi-compartmented buildings--implementation of the hybrid model.” ASHRAE Transactions, Volume 117, Issue 1, p777. May 2011.

Summary (excerpted from text): “This paper presents the implementation of a hybrid model to simulate fires in different building geometries. The hybrid model combined two independent models: a zone model and a network model. The solution procedure consisted of two parts: simulation of two-zone model, which dealt with the room of fire-origin and neighboring rooms, and simulation of the network model, which included rooms far away from the fire. The two-zone and network models were first tested individually; then the performance of the integrated model was investigated in different types of applications. Finally, the models were integrated, where the solutions (temperature and mass flow rate) of the two-zone model become input source for the network model.”

19. Vaux, S. and Pretrel, H. “Relative effects of inertia and buoyancy on smoke propagation in confined and forced ventilated enclosure fire scenarios.” Fire Safety Journal, Volume 62, Part B, pp 206-220. November 2013.

Summary (excerpted from text): “This study focuses on smoke propagation in confined and forced ventilated enclosure fire scenarios as it is a source of possible hazardous situations. The objective of the present contribution is to investigate the effect of the three physical mechanisms (buoyancy, gas expansion and forced ventilation) on diverse examples of smoke flow through transfer elements. Three types of pool fire scenario have been considered with several transfer elements typical of nuclear industry. Each scenario and the smoke propagation are analyzed on the basis of large scale representative fire tests performed during the PRISME project and numerical simulations with a zone-modelling code, SYLVIA of IRSN. The results show ventilation is the driving mechanism for smoke propagation in the one-room configuration whereas buoyancy plays the major role for the doorway flow. Finally, depending on the kind of leakages, mechanical ventilation can act on the buoyancy-induced smoke propagation."

20. Kaye, N. B. and Hunt, G. R. "Smoke filling time for a room due to a small fire: The effect of ceiling height to floor width aspect ratio." Fire Safety Journal, Volume 42, Issue 5, pp 329–339. July 2007.

Summary (excerpted from text): "The research considered the filling of a room with smoke from a small, centrally located floor fire. It presented theoretical arguments for the behavior of the filling time relative to the idealized 'filling box time' as a function of the room height to width aspect ratio. Initially, the rate at which the smoke layer deepens is shown to be more rapid for relatively wide rooms (large aspect ratio). However, at larger times, relatively tall rooms (small aspect ratio) fill more rapidly due to large scale overturning and engulfing of ambient fluid. A series of experiments were performed to verify these results and showed good qualitative agreement with our theoretical predictions. The experiments were also used to evaluate the extent of deviation of the actual smoke front position from the idealized filling box model as a function of the aspect ratio."

21. Johansson, Nils and van Hees, Patrick. "A correlation for predicting smoke layer temperature in a room adjacent to a room involved in a pre-flashover fire." Fire and Materials, Volume 38, Issue 2 pp 182–193. March 2014.

Summary (excerpted from text): "In this paper, a correlation for predicting gas temperatures in a room adjacent to a room involved in a pre-flashover fire is developed. The correlation is derived from results from computer simulations and the external validity is studied by comparing results from the correlation with full-scale test data."

Table 3 - Literature Summary for Recommendation 9b

Source	Data Source	Peer reviewed?	References NIST report?	Relevancy Score
1	Existing Data	Yes	No	3
2	Original Data	Yes	No	3
3	Existing Data	Yes	No	3
4	Original Data	Yes	No	3
5	Original Data	Yes	No	3
6	Original Data	Yes	No	2
7	Existing Data	Yes	No	2
8	Original Data	Yes	No	2

9	Original Data	Yes	No	2
10	Original Data	Yes	No	2
11	Original Data	Yes	No	2
12	Existing Data	Yes	No	2
13	Original Data	Yes	No	1
14	Original Data	Yes	No	1
15	Original Data	Yes	No	1
16	Existing Data	Yes	No	1
17	Original Data	Yes	No	1
18	Existing Data	Yes	No	1
19	Existing Data	Yes	No	1
20	Original Data	Yes	No	1
21	Existing Data	Yes	No	1

For recommendation 9c related to development of models for fire suppression with sprinklers and hose streams, the following relevant literature was identified.

1. Bryner, Nelson P., Madrzykowski, Daniel, and Grosshandler, William. "Reconstructing The Station Nightclub Fire – Computer Modeling Of The Fire Growth And Spread." 11th International Interflam Conference Proceedings, September 2007.

Summary: This report documents a study undertaken at NIST to simulate The Station fire using a computer model. The data input into the model was taken from investigation photographs, site visits, floor plans, small scale material testing, and real-scale mock up experiments. The model simulation is consistent with the video footage of the fire. A second simulation included automatic sprinklers to study the impact they could have had on the fire.

URL: http://www.nist.gov/customcf/get_pdf.cfm?pub_id=900085

2. Yoon, Sam S., Figueroa, Victor, Brown, Alexander L., and Blanchat, Thomas K. "Experiments and Modeling of Large-scale Benchmark Enclosure Fire Suppression." Journal of Fire Sciences, Volume 28, Number 2, pp 109-139. March 2010.

Summary (excerpted from text): "This article presents a series of experiments on benchmark fire suppression. The experiments were performed in a controlled environment, utilizing a cylindrical object or calorimeter centered above a 2 m diameter pan filled with kerosene-based hydrocarbon fuel, JP8. The experimental setup and procedure for gathering data on water suppression performance are presented. The characteristics of the nozzles used in the experiments are presented as well. The experimental results provide the boundary condition and temporal data necessary for validation of the fire suppression models used. The article also includes simulation results on the fire suppression experimental tests. The suppression simulations were carried out using a numerical model based on a Temporally Filtered Navier-Stokes (TFNS) formulation coupled with a Lagrangian model for droplets, which includes detailed descriptions of the interaction between the water droplets and the fire plume."

3. Yang, Dong, Huo, Ran, Hu, Longhua, Li, Sicheng, and Li, Yuanzhou. "A Fire Zone Model Including the Cooling Effect of Sprinkler Spray on Smoke Layer." Fire Safety Science – Proceedings of the Ninth International Symposium, pp. 919-930. 2008.

Summary (excerpted from text): "A fire zone model which includes the cooling effect of sprinklers is developed. Heat transfer from the smoke layer to sprinkler water spray was considered as an additional heat loss term in energy balance equation. In the absence of a sprinkler, the predicted temperature of this model matched that of CFAST6.0, while when sprinkler effects were included, the model predicted the temperature profile of the smoke layer with good agreement with published experiments. This model was applied to a hypothetical compartment fire. Results showed that a higher heat release rate of fire led to a significant decrease in smoke temperature following sprinkler activation, while only a small decrease in smoke layer temperature is predicted when increasing sprinkler pressure from 0.05MPa to 0.1MPa."

URL: http://www.iafss.org/publications/fss/9/919/view

4. de Vries, J., Meredith, K., and Xin, Y. "An Experimental Study of Fire Suppression Physics for Sprinkler Protection." Fire Safety Science – Proceedings of the Tenth International Symposium, pp. 429-442. 2011.

Summary (excerpted from text): "An experimental study was conducted to investigate the key physics of sprinkler-based fire suppression and associated water-film transport. The objective was to evaluate experimental methods for their appropriateness in studying the key physics, and provide validation data for numerical modeling. The numerical model is currently under development to simulate sprinkler-based suppression of large-scale, rack-storage fires. Individual experimental techniques were explored to study water absorption, surface flow, evaporation, and suppression on vertically arranged, corrugated cardboard surfaces. In addition, water transport was investigated in full-scale rack storage configurations. The experimental results show that the tested experimental techniques are appropriate to study the key phenomena related to sprinkler-based fire suppression."

URL: http://www.iafss.org/publications/fss/10/429/view

5. Li, S.C., Chen, Y., and Li, K.Y. “A mathematical model on adjacent smoke filling involved sprinkler cooling to a smoke layer.” Safety Science, Volume 49, Issue 5, pp 670–678. June 2011.

Summary (excerpted from text): “Conventional two-zone model determines the smoke filling time in buildings without considering the cooling effect of sprinkler spray on the smoke layer. In order to improve the prediction, the current zone model is revised with a new mathematical model developed by taking the sprinkler cooling effect into account. The heat transfer between smoke layer and sprinklers spray was mathematically calculated. By using the mathematical model, the smoke filling time in an adjacent space under the sprinkler cooling effect are calculated. A set of experiments were carried out to validate the model. The smoke layer height was experimentally measured. Results show that the model predictions agree well with the experimental results. The smoke filling becomes slower due to the reduced volumetric smoke flow under sprinkler cooling. The variation of sprinkler operating pressure has little influence on the smoke filling since the cooling gets less effective as the operating pressure increases.”

6. Hu, L. H. et al. “A mathematical model on interaction of smoke layer with sprinkler spray.” Fire Safety Journal, Volume 44, Issue 1, pp 96– 105. January 2009.

Summary (excerpted from text): “A mathematical model was developed for predicting the downward descending behavior of the buoyant smoke layer under sprinkler spray. The behavior of the smoke layer was determined by considering the interaction between the drag force of the sprinkler spray and the buoyancy force of the hot smoke layer itself in the spray region. The smoke layer may be pulled down with its thickness increased at the center of the spray region due to the cooling and drag effects of the sprinkler spray, thus to form a downward “smoke logging” plume. In the mathematical model developed in this paper, the critical condition under which the smoke layer lost its stability, as a serious concern, was predicted. Additionally, the length of the downward plume, which was rarely investigated before, was also further calculated. Full-scale experiments were carried out to validate the model. Results showed that the predictions, including the critical condition and the length of the plume, by the mathematical model agreed well with that observed and measured in the experiments. The length of the downward plume was shown to increase with the sprinkler operating pressure by an approximately linear correlation.”

7. Robbins, AP. “Automatic Water-Based Fire Suppression System Experiments-Literature Summary for Model Validation Purposes.” BRANZ Study Report 257, BRANZ Ltd, Judgeford, New Zealand. 2011.

Summary (excerpted from text): “A BRANZ project was conducted that aimed to identify the current state of the data available for validation of fire models incorporating suppression algorithms for suppression and post-suppression conditions in buildings, which are largely ignored in current performance-based design practices. This report contains a summary of collated water-based fire suppression test data and guidance on the important parameters, and variables for consideration when performing validation evaluations of models incorporating suppression algorithms."

URL: http://www.branz.co.nz/cms_show_download.php?id=bd2e89c5197dadfe117a7f94f395d5d4fedf49fe

8. Li, S.C., Yang, D., Huo, R., Hu, L.H., Li, Y.Z., Li, K.Y. and Wang, H.B. "Studies of Cooling Effects of Sprinkler Spray on Smoke Layer." Fire Safety Science – Proceedings of the Ninth International Symposium, pp. 861-872. 2008.

Summary (excerpted from text): "An experimental study was performed to measure the cooling of a smoke layer by water sprays. This was followed by the development of a mathematical model based on the theory of Chow and Tang. The predictions of the model agree well with the experimental measurements. Water sprays investigated in the present work provided significant cooling of the smoke layer. We observed little effect of increasing the water pressure from 50 to 100 kPa on the cooling of the smoke layer."

URL: http://www.iafss.org/publications/fss/9/861/view

9. Schwille, John A. and Lueptow, Richard M. "A Simplified Model of the Effect of a Fire Sprinkler Spray on a Buoyant Fire Plume." Journal of Fire Protection Engineering, Volume 16, Issue 2, pp 131-153. May 2006.

Summary (excerpted from text): "A simple modification of the theory by Morton et al. for buoyant plumes has been made to incorporate a fire sprinkler spray by adding a term in the momentum equation to reflect the momentum of a uniform disperse droplet field. Of course, actual fire sprinkler sprays do not have uniform droplet fields. The results of this model agree with previous complex CFD simulations even though thermal effects of the droplet phase are not included in the model. Thus, given the agreement of the momentum-based model with previous work, it appears that momentum plays a key role in the interaction between droplet sprays and buoyant plumes."

10. O'Grady, N. and Novozhilov, V. "Large Eddy Simulation Of Sprinkler Interaction With A Fire Ceiling Jet." Combustion Science and Technology, Volume 181, pp 984–1006. 2009.

Summary (excerpted from text): "A large eddy simulation (LES) CFD model is used to predict water sprinkler spray interaction with a fire environment. The emphasis is on computing gas temperatures and velocities induced by sprinkler discharge onto the ceiling jet flow. Results are presented for two different water discharge rates, in addition to simulation of free-burning fire. Extensive variation of physical and numerical parameters is performed to investigate the robustness of the predictions. The results of the computations compare favorably to measurements from full-scale fire tests reported in the literature, indicating good accuracy of LES approach in application to practical fire design problems. Results are also compared with the earlier treatment of the same problem using the Reynolds-averaged Navier–Stokes (RANS) approach.”

11. Ren, N., Blum, A., Zheng, Y., Do, C. and Marshall, A. “Quantifying the Initial Spray from Fire Sprinklers”, Fire Safety Science – Proceedings of the Ninth International Symposium, pp. 503-514. 2008.

Summary (excerpted from text): “A Sprinkler Atomization Model (SAM) has been developed based on these physics to predict the initial drop velocity, location, and size based on the nozzle geometry and injection conditions. The initial spray from a simplified yet realistic sprinkler geometry has been quantified through detailed measurements to provide insight into these atomization processes and to evaluate SAM performance. The measured and predicted breakup locations and drop sizes follow We-1/3 scaling laws, previously established by other researchers in similar canonical configurations. However, SAM over predicts the volume median drop diameter by as much as 40%, probably due to the absence of models to characterize the orthogonal stream underlying the radially expanding sheet. This orthogonal stream generated by the spaces was measured to consist of nearly 50% of the flow and produces smaller drops than the radially expanding sheet.”

URL: http://www.iafss.org/publications/fss/9/503/view

Table 4 - Literature Summary for Recommendation 9c

Source	**Data Source**	**Peer reviewed?**	**References NIST report?**	**Relevancy Score**
1	Original Data	Yes	Yes	3
2	Original Data	Yes	No	3
3	Original Data	Yes	No	3
4	Original Data	Yes	No	3
5	Original Data	Yes	No	3
6	Original Data	Yes	No	3
7	Existing Data (literature review)	No (BRANZ report)	No	3
8	Original Data	Yes	No	2
9	Existing Data	Yes	No	2
10	Existing Data	Yes	No	2

11	Original Data	Yes	No	1

Recommendation 10 – Computer Aided Decision Tools

Recommendation 10 relates to research on developing and refining computer models and tools to assist in determining the costs and benefits of code changes and fire safety and to aid communities in allocating resources for large emergencies:

Recommendation 10. Research on Computer-aided Decision Tools: *NIST recommends that research be conducted to:*

> *a) refine computer-aided decision tools for determining the costs and benefits of alternative code changes and fire safety technologies; and*
>
> *b) develop computer models to assist communities in allocating resources (money and staff) to ensure that their response to an emergency with a large number of casualties is effective.*

Literature was reviewed for each of the above sub-categories for this recommendation, but very little was found. The following discussion includes some general developments in these research areas.

Panel members – we would appreciate any input related to research related to recommendation 10. We are having trouble finding any.

Extensive work on improving Geographic Information Systems (GIS) has occurred since the NIST NCST investigation report was issued. A GIS is a system designed to capture, analyze, manage, and display geographic information to inform decision making. Two new proposed related standards are currently under development at NFPA: NFPA 950, *Standard for Data Development and Exchange for the Fire Service*, and NFPA 951, *Guide to Building and Utilizing Digital Information*. While these developments will certainly assist communities in allocating resources for emergencies, they are not directly related to the NIST recommendation.

Summary of Literature Review

The best indicator of a link between the relevant literature and the NIST recommendations is a direct citation of the NIST NCST investigation report. However, this was only found in a handful of sources. Therefore, the next best indicator is the relevancy of a particular literature source to the NIST recommendations. Although this approach is subjective, it provides additional context and categorization to the literature around each of the research needs identified by the investigation report.

The literature review revealed limited impact from the recommendation on research around use of portable fire extinguishers in new and existing nightclubs. The only source found that focused on nightclubs was a workshop summary published by NIST. However, more general research has been done investigating how the general public uses extinguishers, which is helpful for all assembly type occupancies. However, it is difficult to link these studies back to the NIST recommendation.

More literature was found related to the research recommendations on fire spread and suppression (recommendation 9). Although not many cite the NIST NCST report, there are several that are given a relevancy score of a 3, which means that they directly relate to one of the specific sub-bullets for recommendation 9. It could be postulated that the NIST recommendations may have had some impact on this research being completed. For recommendation 9a, research on prediction of flame spread over actual wall, ceiling, and floor lining materials, and room furnishings, seven references were given the highest relevancy score. Five sources were rated a three related to relevancy to recommendation 9b, research on the quantification of smoke and toxic gas production in realistic room fires. There were seven references found that directly address recommendation 9c, research on the development of generalized models for fire suppression with fixed sprinklers and for firefighter hose streams.

Add discussion on recommendation 8 and 10.

Table 1
How many nightclubs are in your community? [Q.1]

	None		1		2 to 5		6 to 10		More than 10		Total	
Size of community	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent
500,000 or more	0	0.0	0	0.0	0	0.0	3	5.5	52	94.5	55	100.0
250,000 to 499,999	2	3.2	3	4.8	5	8.1	4	6.4	48	77.4	62	100.0
100,000 to 249,999	26	10.5	0	0.0	0	0.0	34	13.8	186	75.3	247	100.0
50,000 to 99,999	113	23.9	13	2.7	0	0.0	101	21.4	246	52.0	473	100.0
Total	141	16.8	16	1.9	5	0.6	142	17.0	532	63.6	837	100.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Numbers may not add to totals due to rounding.

Note that the departments that reported no nightclubs were excluded from the remainder of the analyses in this report, and the analyses in the remainder of this report are based on an estimated 696 departments that protect 50,000 population or more and have at least one nightclub,

Table 2
What codes apply to newly constructed nightclubs in a community? [Q.2]

Size of community	NFPA 101 Life Safety Code Number Depts	NFPA 101 Life Safety Code Percent	International Building Code Number Depts	International Building Code Percent	Local code not based on model code Number Depts	Local code not based on model code Percent	Other model code* Number Depts	Other model code* Percent	None Number Depts	None Percent
500,000 or more	18	32.7	47	85.5	8	14.5	18	32.7	0	0.0
250,000 to 499,999	12	20.0	46	76.7	0	0.0	22	36.7	0	0.0
100,000 to 249,999	74	33.3	176	79.7	16	7.2	80	36.2	0	0.0
50,000 to 99,999	142	39.4	292	81.1	28	7.9	85	23.6	0	0.0
Total	246	35.3	561	80.6	52	7.5	205	29.5	0	0.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Departments were asked to circle all that apply, so departments could select multiple responses, which means it is not appropriate to add percents for a particular size community.

*This category is comprised almost entirely of state codes that were based on national model codes.

Table 3
What codes apply to existing nightclubs in the community? [Q.3]

	NFPA 1		NFPA 101 not as part of adoption of NFPA 1		International Fire Code		Local code not based on model code		Other model code*		No code	
Size of community	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent
500,000 or more	13	23.6	16	29.1	31	56.3	8	14.5	16	29.0	0	0.0
250,000 to 499,999	7	11.7	12	20.0	38	63.3	5	8.3	16	26.7	0	0.0
100,000 to 249,999	51	23.2	45	20.3	147	66.5	16	7.2	39	17.7	0	0.0
50,000 to 99,999	82	22.8	91	25.3	241	66.9	34	9.4	58	16.1	0	0.0
Total	154	22.1	163	23.4	458	65.8	63	9.1	128	18.4	0	0.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Departments were asked to circle all that apply, so departments could select multiple responses, which means it is not appropriate to add percents for a particular size community.

*This category is comprised almost entirely of state codes that were based on national model codes.

Table 4
(For departments that use the International Building Code, for newly constructed nightclubs in their community)
What edition of the code is used? [Q.2b]

	Prior to 2003		2003		2006		2009		2012		Total	
Size of community	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**
500,000 or more	0	0.0	3	6.4	16	34.0	19	40.4	9	19.1	47	100.0
250,000 to 499,999	0	0.0	0	0.0	10	21.7	29	63.0	7	15.2	46	100.0
100,000 to 249,999	4	2.3	0	0.0	35	19.9	74	42.0	63	35.8	176	100.0
50,000 to 99,999	3	0.9	6	2.1	68	23.2	158	54.1	56	19.2	292	100.0
Total	7	1.2	9	1.6	129	23.0	280	50.0	136	24.2	561	100.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Numbers may not add to totals due to rounding.

Table 5
(For departments that use the NFPA 101, Life Safety Code for newly constructed nightclubs in their community)
What edition of the code is used? [Q.2a]

	Prior to 2003		2003		2006		2009		2012		Total	
Size of community	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent
500,000 or more	7	38.9	0	0.0	0	0.0	7	38.9	4	22.2	18	100.0
250,000 to 499,999	12	100.0	0	0.0	0	0.0	0	0.0	0	0.0	12	100.0
100,000 to 249,999	7	9.5	0	0.0	7	9.5	45	60.8	15	20.3	74	100.0
50,000 to 99,999	36	25.3	7	4.9	0	0.0	74	52.1	26	18.3	142	100.0
Total	62	25.2	7	2.8	7	2.8	126	51.2	44	17.9	246	100.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Numbers may not add to totals due to rounding.

Table 6
(For departments that use the International Fire Code for existing nightclubs in their community)
What edition of the code is used? [Q.3c]

	Prior to 2003		2003		2006		2009		2012		Total	
Size of community	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**
500,000 or more	0	0.0	3	9.7	8	25.8	18	58.1	2	6.5	31	100.0
250,000 to 499,999	2	5.3	0	0.0	8	21.1	23	60.5	5	13.2	38	100.0
100,000 to 249,999	0	0.0	0	0.0	22	15.0	70	47.6	55	37.4	147	100.0
50,000 to 99,999	6	2.5	0	0.0	63	26.1	125	51.9	47	19.5	241	100.0
Total	8	1.8	3	0.6	100	21.9	236	51.6	110	24.1	458	100.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Numbers may not add to totals due to rounding.

Table 7
(For departments that use NFPA 1 for existing nightclubs in their community)
What edition of the code is used? [Q.3a]

	Prior to 2003		2003		2006		2009		2012		Total	
Size of community	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**
500,000 or more	0	0.0	0	0.0	3	23.1	6	53.8	4	23.1	13	100.0
250,000 to 499,999	3	42.9	0	0.0	0	0.0	4	57.1	0	0.0	7	100.0
100,000 to 249,999	0	0.0	0	0.0	5	9.8	31	60.8	15	29.4	51	100.0
50,000 to 99,999	8	9.8	4	4.8	4	4.8	55	67.1	12	13.4	82	100.0
Total	11	7.2	4	2.6	12	7.9	96	62.5	31	19.7	154	100.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Numbers may not add to totals due to rounding.

Table 8
Are there any local amendments or other requirements applicable to nightclubs? [Q.4]

	Yes, changed after 2003		Yes, not changed after 2003		No		Total	
Size of community	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent
500,000 or more	19	34.5	8	14.5	28	50.9	55	100.0
250,000 to 499,999	14	23.3	5	8.3	41	68.3	60	100.0
100,000 to 249,999	46	20.8	11	5.0	164	74.2	221	100.0
50,000 to 99,999	80	22.2	42	11.7	238	66.1	360	100.0
Total	160	23.0	65	9.3	471	67.7	696	100.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Numbers may not add to totals due to rounding.

Table 9
How are inspections used for enforcement? [Q5]

Size of community	No inspections conducted Number Depts	Percent	Building code inspections for new buildings Number Depts	Percent	Fire code inspections at least annually Number Depts	Percent	Fire code inspections less often than annually Number Depts	Percent	Inspections in response to complaints Number Depts	Percent
500,000 or more	0	0.0	50	90.9	52	94.5	13	23.6	3	6.0
250,000 to 499,999	0	0.0	36	60.0	41	68.3	22	36.7	38	63.3
100,000 to 249,999	0	0.0	128	57.9	170	76.9	64	29.0	157	76.0
50,000 to 99,999	0	0.0	230	63.9	275	76.4	62	17.2	258	71.7
Total	0	0.0	443	63.6	538	77.3	161	23.1	456	65.5

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Departments were asked to circle all that apply, so departments could select multiple responses, which means it is not appropriate to add percents for a particular size community.

Table 10
Are sprinklers required in nightclubs in the community? [Q.6]

	Yes, Regardless Of Occupancy		Yes, Occupancy of 50 or More		Yes, Occupancy of 100 or More		Yes, Occupancy of 200 or More		No		Total	
Size of community	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent
500,000 or more	3	5.5	5	9.1	26	47.3	16	29.1	5	9.1	55	100.0
250,000 to 499,999	10	16.7	2	3.3	41	68.3	5	8.3	2	3.3	60	100.0
100,000 to 249,999	17	7.7	7	3.2	160	72.4	17	7.7	20	9.0	221	100.0
50,000 to 99,999	46	12.7	31	8.6	209	58.0	40	11.1	34	9.4	360	100.0
Total	76	10.9	45	6.5	437	62.8	77	11.1	61	8.9	696	100.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Numbers may not add to totals due to rounding.

Table 11
How many nightclubs are in compliance with sprinkler requirements in the community? [Q.8]

	All		Most		Half		Some		None		Don't Know		Total	
Size of community	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent
500,000 or more	18	32.7	25	45.5	0	0.0	12	21.8	0	0.0	0	0.0	55	100.0
250,000 to 499,999	19	31.7	17	28.3	10	16.7	9	15.0	0	0.0	5	8.3	60	100.0
100,000 to 249,999	88	39.8	66	29.9	15	6.8	30	13.6	0	0.0	22	10.0	221	100.0
50,000 to 99,999	208	57.8	88	24.4	16	4.4	36	10.0	0	0.0	13	3.6	360	100.0
Total	334	48.0	195	28.0	40	5.7	87	12.5	0	0.0	40	5.7	696	100.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Numbers may not add to totals due to rounding.

Table 12

(For communities with sprinkler requirements)
Are inspections conducted just to check compliance with these requirements? [Q.7]

	Yes		No		Total	
Size of community	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent
500,000 or more	17	30.9	38	69.1	55	100.0
250,000 to 499,999	24	40.0	36	60.0	60	100.0
100,000 to 249,999	101	45.7	120	54.3	221	100.0
50,000 to 99,999	104	28.9	256	71.1	360	100.0
Total	246	35.3	450	64.7	696	100.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Numbers may not add to totals due to rounding.

Table 13
(For communities with sprinkler requirements)
Did requirements change after 2003 (year of The Station nightclub fire)? [Q.6a]

	Yes Requirements Changed		No Requirements Did Not Change		Total	
Size of community	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**
500,000 or more	26	47.3	29	52.7	55	100.0
250,000 to 499,999	32	55.2	26	44.8	58	100.0
100,000 to 249,999	125	62.2	76	37.8	201	100.0
50,000 to 99,999	135	41.4	191	58.6	326	100.0
Total	317	49.5	323	50.5	640	100.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Numbers may not add to totals due to rounding.

Table 14

Are there interior finish requirements for nightclubs in the community? [Q.9]

	Yes, from International Building Code		Yes, from NFPA 101, Life Safety Code		Yes, from NFPA 1		Yes, from International Fire Code		Yes, from other model code		Yes, local requirements not based on model code		No requirements	
Size of community	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**
500,000 or more	39	70.9	21	38.2	8	14.5	26	47.3	8	14.5	8	14.5	0	0.0
250,000 to 499,999	36	60.0	14	23.3	5	8.3	38	63.3	10	16.7	0	0.0	0	0.0
100,000 to 249,999	119	53.8	64	29.0	35	15.8	128	58.0	29	13.1	3	1.4	0	0.0
50,000 to 99,999	235	65.3	122	33.9	71	19.7	218	60.6	26	6.9	10	2.8	0	0.0
Total	429	61.6	221	31.8	119	17.1	411	59.1	72	10.3	21	3.0	0	0.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Departments were asked to circle all that apply, so departments could select multiple responses, which means it is not appropriate to add percents for a particular size community.

Table 15
(For communities with interior finish requirements for nightclubs)
Do the requirements reference a standard test for product and material performance?
[Q.10]

	Yes		No		Total	
Size of community	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**
500,000 or more	49	89.1	6	10.9	50	100.0
250,000 to 499,999	60	100.0	0	0.0	60	100.0
100,000 to 249,999	207	93.7	14	6.3	221	100.0
50,000 to 99,999	333	92.5	27	7.5	360	100.0
Total	648	93.1	48	6.9	696	100.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Numbers may not add to totals due to rounding.

Table 16
How many nightclubs (do you think) are in compliance with interior finish requirements? [Q.13]

	All		Most		Half		Some		None		Don't Know		Total	
Size of community	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent
500,000 or more	8	14.5	39	70.9	0	0.0	5	9.0	0	0.0	3	5.5	55	100.0
250,000 to 499,999	14	23.3	36	60.0	2	3.3	3	5.0	0	0.0	5	8.3	60	100.0
100,000 to 249,999	52	23.5	107	48.4	7	3.2	17	7.7	0	0.0	38	17.2	221	100.0
50,000 to 99,999	138	38.3	146	40.6	20	5.5	18	5.0	3	0.8	35	9.7	360	100.0
Total	212	30.4	329	47.3	29	4.2	43	6.2	3	0.4	81	11.6	696	100.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Numbers may not add to totals due to rounding.

Table 17
(For communities with interior finish requirements)
Are some inspections conducted where the sole purpose is to check compliance with these requirements? [Q.12]

	Yes		No		Total	
Size of community	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**
500,000 or more	5	9.1	50	90.9	55	100.0
250,000 to 499,999	5	8.3	55	91.7	60	100.0
100,000 to 249,999	33	14.9	188	85.1	221	100.0
50,000 to 99,999	86	23.9	274	76.1	360	100.0
Total	129	18.5	567	81.5	696	100.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Numbers may not add to totals due to rounding.

Table 18
How do inspectors check for nightclub compliance with interior finish requirements? [Q.11]

	Visual Inspection Only		Routine Testing of Materials		Testing Based on Visual Screening		Review of Specification Sheets and Technical Data for Materials	
Size of community	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**
500,000 or more	32	58.2	16	29.1	16	29.1	47	85.5
250,000 to 499,999	38	63.3	14	23.3	5	8.3	55	91.7
100,000 to 249,999	87	39.4	35	15.8	19	8.6	176	79.6
50,000 to 99,999	201	55.8	37	10.3	45	12.5	269	74.7
Total	358	51.4	102	14.7	85	12.2	548	78.7

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Departments were asked to circle all that apply, so departments could select multiple responses, which means it is not appropriate to add percents for a particular size community.

Table 19
(For communities with interior finish requirements)
Did requirements change after 2003 (year of The Station nightclub fire)? [Q.9h]

	Yes Requirements Changed		No Requirements Did Not Change		Total	
Size of community	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent
500,000 or more	11	20.0	44	80.0	55	100.0
250,000 to 499,999	32	53.3	28	46.7	60	100.0
100,000 to 249,999	60	27.1	161	72.9	221	100.0
50,000 to 99,999	98	27.2	262	72.8	360	100.0
Total	201	28.9	495	71.1	696	100.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Numbers may not add to totals due to rounding.

Table 20
Does the community have restrictions on indoor use of pyrotechnics by nightclubs? [Q.14]

	Yes, from NFPA 1126		Yes, from other model code		Yes, local restrictions not based on model code		No restrictions	
Size of community	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent
500,000 or more	39	70.9	18	32.7	21	38.2	0	0.0
250,000 to 499,999	46	76.7	17	28.3	14	23.3	0	0.0
100,000 to 249,999	151	68.3	80	36.2	58	26.2	3	1.4
50,000 to 99,999	221	61.4	74	20.6	139	38.6	9	2.5
Total	457	65.7	189	27.2	232	33.3	12	1.7

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Departments were asked to circle all that apply, so departments could select multiple responses, which means it is not appropriate to add percents for a particular size community.

Table 21
How many nightclubs are in compliance with restrictions on indoor use of pyrotechnics at nightclubs? [Q.16]

	All		Most		Half		Some		None		Don't Know		Total	
Size of community	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent
500,000 or more	30	54.5	25	45.4	0	0.0	0	0.0	0	0.0	0	0.0	55	100.0
250,000 to 499,999	36	60.0	19	31.7	5	8.3	0	0.0	0	0.0	0	0.0	60	100.0
100,000 to 249,999	162	73.3	31	14.0	0	0.0	4	1.8	4	1.8	21	9.5	221	100.0
50,000 to 99,999	283	78.6	45	12.5	0	0.0	0	0.0	6	1.7	27	7.5	360	100.0
Total	511	73.4	120	17.2	5	0.7	4	0.6	10	1.4	48	6.9	696	100.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Numbers may not add to totals due to rounding.

Table 22
Does the community conduct inspections that just check compliance with the restrictions on indoor use of pyrotechnics by nightclubs? [Q.15]

	Yes, at events		Yes, with managers in advance of event		Yes, based on complaints, concerns or requests received before or during event		No	
Size of community	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**
500,000 or more	45	81.8	37	67.3	34	61.8	3	5.4
250,000 to 499,999	50	83.3	29	48.3	31	51.6	5	8.3
100,000 to 249,999	138	62.4	106	48.0	112	50.6	32	14.5
50,000 to 99,999	210	58.3	176	48.9	176	48.9	62	17.2
Total	443	63.6	348	50.0	353	50.7	102	14.7

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Departments were asked to circle all that apply, so departments could select multiple responses, which means it is not appropriate to add percents for a particular size community.

Table 23
(For communities with restrictions on indoor use of pyrotechnics in nightclubs)
Did requirements change after 2003 (year of The Station nightclub fire)? [Q.14e]

Size of community	Yes Requirements Changed Number Depts	Percent	No Requirements Did Not Change Number Depts	Percent	Total Number Depts	Percent
500,000 or more	5	9.1	50	90.9	55	100.0
250,000 to 499,999	27	45.0	33	55.0	60	100.0
100,000 to 249,999	23	10.4	198	89.6	221	100.0
50,000 to 99,999	69	19.2	291	80.8	360	100.0
Total	122	17.5	574	82.5	696	100.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Numbers may not add to totals due to rounding.

Table 24
Does the community have egress requirements and/or occupancy limits for nightclubs? [Q.17]

Size of community	Yes, from International Building Code		Yes, from NFPA 101, Life Safety Code		Yes, from other model code		Yes, local requirements not based on model code		No requirements	
	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent
500,000 or more	37	67.3	21	38.2	24	43.6	8	14.5	0	0.0
250,000 to 499,999	43	71.7	12	20.0	19	31.7	0	0.0	0	0.0
100,000 to 249,999	163	73.8	61	27.6	67	30.0	10	4.5	0	0.0
50,000 to 99,999	283	78.7	142	39.4	96	26.7	20	5.5	0	0.0
Total	527	75.7	236	33.9	206	29.5	37	5.3	0	0.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Departments were asked to circle all that apply, so departments could select multiple responses, which means it is not appropriate to add percents for a particular size community.

Table 25
How many nightclubs are in compliance with occupancy and egress requirements? [Q.19]

	All		Most		Half		Some		None		Don't Know		Total	
Size of community	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**
500,000 or more	8	14.5	45	81.8	0	0.0	0	0.0	0	0.0	2	3.6	55	100.0
250,000 to 499,999	20	33.3	40	66.7	0	0.0	0	0.0	0	0.0	0	0.0	60	100.0
100,000 to 249,999	75	33.9	116	52.5	3	1.4	13	5.9	0	0.0	14	6.3	221	100.0
50,000 to 99,999	171	47.5	156	43.3	3	0.8	6	1.6	0	0.0	24	6.7	360	100.0
Total	274	39.4	357	51.2	6	0.9	19	2.7	0	0.0	40	5.7	696	100.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013

Numbers may not add to totals due to rounding.

Table 26
Does a department conduct special inspections more frequent than fire code inspections just to check compliance with egress requirements and/or occupancy limits? [Q.18]

Size of community	Yes, Roughly Every Evening Nightclubs Are Open Number Depts	Percent	Yes, At Least Weekly Number Depts	Percent	Yes, But Not Weekly Number Depts	Percent	No Number Depts	Percent	Total Number Depts	Percent
500,000 or more	0	0.0	5	9.1	33	60.0	17	30.9	55	100.0
250,000 to 499,999	2	3.3	5	8.3	34	56.7	19	31.7	60	100.0
100,000 to 249,999	3	1.4	21	9.5	107	48.4	90	40.7	221	100.0
50,000 to 99,999	3	0.8	9	2.5	170	47.2	179	49.7	360	100.0
Total	8	1.1	40	5.5	206	49.1	306	44.0	696	100.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Numbers may not add to totals due to rounding.

Table 27
(For communities with egress requirements and/or occupancy limits for nightclubs) Did requirements change after 2003 (year of The Station nightclub fire)? [Q.17f]

Size of community	Yes Requirements Changed Number Depts	Yes Requirements Changed Percent	No Requirements Did Not Change Number Depts	No Requirements Did Not Change Percent	Total Number Depts	Total Percent
500,000 or more	0	0.0	55	100.0	55	100.0
250,000 to 499,999	25	41.7	35	58.3	60	100.0
100,000 to 249,999	27	12.2	194	87.8	221	100.0
50,000 to 99,999	35	9.7	325	90.3	360	100.0
Total	86	12.3	610	87.7	696	100.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Numbers may not add to totals due to rounding.

Table 28
Does the community use NFPA 1221 in the operation, installation, and maintenance of public emergency services communication systems? [Q.20]

	Yes		No		Total	
Size of community	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent
500,000 or more	39	70.9	16	29.1	55	100.0
250,000 to 499,999	31	51.7	29	48.3	60	100.0
100,000 to 249,999	114	51.6	107	48.4	221	100.0
50,000 to 99,999	199	55.3	161	44.7	360	100.0
Total	383	55.0	313	45.0	696	100.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Numbers may not add to totals due to rounding.

Table 29
Did the department's use of NFPA 1221 change after 2003 (the year of The Station nightclub fire)? [Q.20a]

	Yes Requirements Changed		No Requirements Did Not Change		Total	
Size of community	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent
500,000 or more	8	14.5	47	85.5	55	100.0
250,000 to 499,999	19	34.5	41	74.5	60	100.0
100,000 to 249,999	30	13.6	191	86.4	221	100.0
50,000 to 99,999	42	11.7	318	88.3	360	100.0
Total	99	14.2	597	85.8	696	100.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Numbers may not add to totals due to rounding.

Table 30
Does the community use an emergency services incident system that complies with the National Incident Emergency System (NIMS) or NFPA 1561? [Q.21]

	Yes		No		Total	
Size of community	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**
500,000 or more	50	90.9	5	9.1	55	100.0
250,000 to 499,999	57	95.0	3	5.0	60	100.0
100,000 to 249,999	201	90.9	20	9.1	221	100.0
50,000 to 99,999	345	95.8	15	4.2	360	100.0
Total	653	93.8	43	6.2	696	100.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013

Numbers may not add to totals due to rounding.

Table 31
Did the department's use of an emergency services incident system change after 2003 (the year of The Station nightclub fire)? [Q.21a]

	Yes Requirements Changed		No Requirements Did Not Change		Total	
Size of community	**Number Depts**	**Percent**	**Number Depts**	**Percent**	**Number Depts**	**Percent**
500,000 or more	12	21.8	43	78.2	55	100.0
250,000 to 499,999	12	20.0	48	80.0	60	100.0
100,000 to 249,999	40	18.1	181	81.9	221	100.0
50,000 to 99,999	42	11.7	318	88.3	360	100.0
Total	106	15.2	590	84.8	696	100.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Numbers may not add to totals due to rounding.

Table 32
Does the community use NFPA 1710 (for career departments) or 1720 (for volunteer departments) in establishing organizational and deployment procedures? [Q.22]

	Yes		No		Total	
Size of community	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent
500,000 or more	43	78.2	12	21.8	55	100.0
250,000 to 499,999	48	80.0	12	20.0	60	100.0
100,000 to 249,999	173	78.3	48	21.7	221	100.0
50,000 to 99,999	294	81.7	66	18.3	360	100.0
Total	558	80.2	138	19.8	696	100.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Numbers may not add to totals due to rounding.

Table 33
Did the department's use of NFPA 1710 or NFPA 1720 change after 2003 (the year of The Station nightclub fire)? [Q.22a]

	Yes Requirements Changed		No Requirements Did Not Change		Total	
Size of community	Number Depts	Percent	Number Depts	Percent	Number Depts	Percent
500,000 or more	0	0.0	55	100.0	55	100.0
250,000 to 499,999	12	20.0	48	80.0	60	100.0
100,000 to 249,999	34	15.4	187	84.6	221	100.0
50,000 to 99,999	41	11.4	319	88.6	360	100.0
Total	87	12.4	609	87.6	696	100.0

Source: NFPA Survey of Fire Department Practices Related to Nightclub Fire Safety, 2013.

Numbers may not add to totals due to rounding.

APPENDIX A

NATIONAL FIRE PROTECTION ASSOCIATION
SURVEY OF FIRE DEPARTMENT PRACTICES
RELATED TO NIGHTCLUB FIRE SAFETY

PART I. IDENTIFYING INFORMATION

Name of person completing form:____________________________________ Date:________________
Title of person completing form:____
Non-emergency phone number: ( ) ______________________ Fax: ( ) ______________________
e-mail address: _________________________________
Population (Number of permanent residents your department has primary responsibility to protect, excluding mutual aid areas) ___________________

Please use enclosed postpaid envelope to return form to:
Fire Analysis & Research, NFPA, 1 Batterymarch Park, Quincy, MA 02269-9101
OR reduce form to 8½" x 11" and fax us the form at (617) 984-7478
OR e-mail us at fcsurvey@nfpa.org that you would like to respond electronically. We will send you an electronic form, which you can complete, save and submit to fcsurvey@nfpa.org.
Thank you for your participation!

PART II. NIGHTCLUBS IN YOUR COMMUNITY

1. How many nightclubs are in your community? ☐ None [*No need to go further; please return form*]
☐ 1 ☐ 2-5 ☐ 6-10 ☐ More than 10

PART III. BUILDING AND FIRE CODES APPLIED TO NIGHTCLUBS

2. What code applies to newly constructed nightclubs in your community? (check all that apply)
☐a. NFPA 101, *Life Safety Code* (which edition (year)? _________)
☐b. International Building Code (which edition (year)? _________)
☐c. Local code not based on model ☐d. Other model code (please specify _______________)
☐e. No code

3. What code applies to existing nightclubs in your community? (check all that apply)
☐a. NFPA 1 (which edition (year)? _________) ☐b. NFPA 101 not as part of adoption of NFPA 1
☐c. International Fire Code (which edition (year)? _________) ☐d. Local code not based on model
☐e. Other model code (please specify ________________________________) ☐f. No code

4. Are there any local amendments or other requirements applicable to nightclubs? (check one)
☐Yes, changed after 2003 ☐Yes, not changed after 2003 ☐No

5. How are inspections used for enforcement? (check all that apply) ☐a. No inspections conducted
☐b. Building code inspections for new buildings ☐c. Fire code inspections at least annually
☐d. Regular fire code inspections less often than annual ☐e. Inspections in response to complaints

PART IV. SPRINKLERS IN NIGHTCLUBS

6. Are sprinklers required in nightclubs in your community? (check one) ☐Yes, regardless of occupancy
☐Yes, occupancy 50 or more ☐Yes, occupancy 100 or more ☐Yes, occupancy 200 or more
☐No (*Go to Q.9.*)

   a. If you said yes, did your sprinkler requirements change after the Station nightclub fire in 2003?
   ☐Yes ☐No

7. Do you conduct inspections just to check compliance with sprinkler requirements? ☐Yes ☐No

8. How many nightclubs do you think are in compliance with your sprinkler requirements? (check one)
☐All ☐Most ☐Half ☐Some ☐None ☐Don't know

PLEASE CONTINUE SURVEY ON OTHER SIDE

PART V. INTERIOR FINISH IN NIGHTCLUBS

9. Do you have interior finish requirements for nightclubs? (check all that apply)
   a. Yes, from International Building Code b. Yes, from NFPA 101, *Life Safety Code*
   c. Yes, from NFPA 1 d. Yes, from International Fire Code
   e. Yes, from other model code (please specify _______________)
   f. Yes, local requirements not based on model g. No requirements (*Go to Q.14.*)
   h. If you have requirements, did they change after The Station nightclub fire in 2003? Yes No

10. Do these requirements reference a standard test for product and material fire performance (e.g., NFPA 286, NFPA 255, ASTM E84)? Yes No

11. How do inspectors check for compliance? (check all that apply)
    a. Visual inspection only b. Routine testing of materials c. Testing based on visual screening
    d. Review of specification sheets and technical data for materials

12. Do you conduct some inspections where the only purpose is to check compliance with these requirements? Yes No

13. How many nightclubs do you think are in compliance with your interior finish requirements? (check one) All Most Half Some None Don't know

PART VI. INDOOR USE OF PYROTECHNICS IN NIGHTCLUBS

14. Do you have restrictions on indoor use of pyrotechnics by nightclubs? (check all that apply)
    a. Yes, from NFPA 1126 b. Yes, from other model code (please specify _________________)
    c. Yes, local restrictions not based on model d. No restrictions (*Go to Q.17.*)
    e. If you have restrictions, did they change after The Station nightclub fire in 2003? Yes No

15. Do you conduct inspections just to check compliance with these restrictions? (check all that apply)
    a. Yes, at events (including inspections only for specific events or types of acts)
    b. Yes, with managers in advance of event
    c. Yes, based on complaints, concerns or requests received before or during event d. No

16. How many nightclubs do you think are in compliance with your indoor use of pyrotechnics restrictions? (check one) All Most Half Some None Don't know

PART VII. OCCUPANCY LIMITS AND EMERGENCY EGRESS

17. Do you have egress requirements and/or occupancy limits for nightclubs? (check all that apply)
    a. Yes, from International Building Code b. Yes, from NFPA 101, *Life Safety Code*
    c. Yes, from other model code (please specify _______________)
    d. Yes, local requirements not based on model e. No requirements (*Go to Q.20.*)
    f. If you have requirements, did they change after The Station nightclub fire in 2003? Yes No

18. Do you conduct special inspections, more frequent than your fire code inspections, just to check compliance with these requirements? (check one)
    Yes, roughly every evening clubs are open Yes, at least weekly Yes, but not weekly
    No

19. How many nightclubs do you think are in compliance with your occupancy and egress requirements? (check one) All Most Half Some None Don't know

PART VIII. EMERGENCY RESPONSE STANDARDS

20. Do you use NFPA 1221 in the operation, installation, and maintenance of public emergency services communications systems within your jurisdiction? Yes No
    a. Did your use of this Standard change after The Station nightclub fire in 2003? Yes No

21. Do you use an emergency services incident management system that complies with the National Incident Emergency System (NIMS) or NFPA 1561? Yes No
    a. Did your use of an emergency services incident management system change after The Station nightclub fire in 2003? Yes No

22. Do you use NFPA 1710 (for career departments) or 1720 (for volunteer departments) in establishing organizational, operational and deployment procedures? Yes No
    a. Did your use of these documents change after The Station nightclub fire in 2003?
       Yes No