

NFPA[®]

551

Guide for the Evaluation of Fire Risk Assessments

2019



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NFPA® 551

Guide for the

Evaluation of Fire Risk Assessments

2019 Edition

This edition of NFPA 551, *Guide for the Evaluation of Fire Risk Assessments*, was prepared by the Technical Committee on Fire Risk Assessment Methods. It was issued by the Standards Council on March 15, 2018, with an effective date of April 4, 2018, and supersedes all previous editions.

This edition of NFPA 551 was approved as an American National Standard on April 4, 2018.

Origin and Development of NFPA 551

In the mid-1990s, it was recognized that the application of fire risk assessment methods in developing fire and life safety solutions continued to increase. However, a set of rules or a framework that described the properties of an acceptable fire risk assessment method was lacking. Additionally, there were no guidance documents available to those responsible for approving or evaluating fire and life safety solutions that were based on a fire risk assessment. In response, NFPA established a new project and technical committee on fire risk assessment methods in 1999. NFPA 551, 2004 edition, was the first document prepared by the committee in response to the growing need for guidance documents on fire risk assessment methods.

The 2007 edition included a number of enhancements, and new information on the subject. Certain terms were revised for consistency with other documents that address performance-based design and fire risk assessment methods, and further guidance was provided on applying risk-informed decision making for various fire safety goals, including the preservation of cultural resources. More detail on selecting fire scenarios; identifying and grouping representative challenging scenarios into clusters for conducting more effective consequence analysis; addressing uncertainty; and the impact of the changing effectiveness of fire protection equipment, features, programs, and procedures were added. The capabilities of those conducting a fire risk assessment, the key factors to consider when conducting or reviewing a fire risk assessment, and the role of an operations and maintenance manual were addressed. An expanded discussion on the role of qualitative, semiquantitative likelihood, semiquantitative consequence, and quantitative methods in a fire risk assessment and cost-benefit analysis was included, as was more detail on proper documentation and elements of a fire risk assessment, and the importance of using checklists that address both likelihood and consequence.

The 2010 edition contained a reorganization of Chapter 7 to provide further guidance on documentation requirements for the fire risk assessment concept report.

The 2013 edition included minor updates to add explosions to the list of fire stimuli in Chapter 4.

The 2016 edition was a reconfirmation of the 2013 edition, with minor updates. It introduced a new definition of the term *hazard*, used throughout the document, as well as updates to other definitions and referenced publications.

The 2019 edition is a reconfirmation of the 2016 edition, with minor additions. Explanatory material is added to refer the user to documents that provide additional guidance. These documents are added to Annex B.



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Committee Scope: This Committee shall have primary responsibility for documents covering the following: (1) frameworks that identify the relationships of fire safety concepts used for fire prevention and fire control, including codes, standards, and recommended practices, and (2) frameworks that describe the properties of risk assessment methods for use in regulations.

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NFPA 551

Guide for the

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2019 Edition

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NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates that explanatory material on the paragraph can be found in Annex A.

A reference in brackets [] following a section or paragraph indicates material that has been extracted from another NFPA document. As an aid to the user, the complete title and edition of the source documents for extracts in mandatory sections of the document are given in Chapter 2 and those for extracts in informational sections are given in Annex B. Extracted text may be edited for consistency and style and may include the revision of internal paragraph references and other references as appropriate. Requests for interpretations or revisions of extracted text shall be sent to the technical committee responsible for the source document.

Information on referenced publications can be found in Chapter 2 and Annex B.

Chapter 1 Administration

1.1 Scope. This guide is intended to provide assistance, primarily to authorities having jurisdiction (AHJs), in evaluating the appropriateness and execution of a fire risk assessment (FRA) for a given fire safety problem. While this guide primarily addresses regulatory officials, it also is intended for others who review FRAs, such as insurance company representatives and building owners.

1.2 Purpose. This guide is intended to assist with the evaluation of FRA methods used primarily in a performance-based regulatory environment. While the primary audience is anticipated to be authorities having jurisdiction, it is expected that the guide will be a useful resource for anyone conducting an FRA. This guide does not mandate the methods for use in demonstrating acceptable risk; rather, it describes the technical review process and documentation that are needed in evaluating an FRA.

1.3 Application. This guide is intended to be applied to the assessment of performance-based solutions, studies, code equivalencies, or regulatory compliance evaluations developed using FRA methods.

1.4 Qualifications for Practitioners. Persons undertaking FRAs, as anticipated by this guide, should document their qualifications and make them available to the authority having jurisdiction. Depending on the FRA being undertaken, the documentation could include educational background, past experience with FRAs, and professional registration. The form of the documentation should meet the needs of the authority having jurisdiction within the context of applicable laws and regulations.

1.5* Risk.

1.5.1 The perception of risk, and therefore the acceptance of risk, is influenced by the values of the stakeholders. Thus, the values of the stakeholders should be established in the risk metrics, which may include life safety, property, business interruption, and intangibles. The metrics associated with these values may be people affected, dollars of loss, acreage, and so forth. The expression of the metric is usually rate based (e.g., frequency, or probability of occurrence over a specified time period). The stakeholders may attach different weights to a given risk, based on their perspective. Each AHJ may have its own weighting, depending on its role.

1.5.2 For fire safety, the hazards are generally fire, explosion, smoke, and toxicity associated with fire products. The likelihoods and corresponding consequences are derived from fire scenarios associated with these hazards. The impacts or harm from the fire scenarios are expressed in the metrics associated with the values, such as number of people affected per location per year.

Chapter 2 Referenced Publications

2.1 General. The documents or portions thereof listed in this chapter are referenced within this guide and should be considered part of the recommendations of this document.

2.2 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 101A, *Guide on Alternative Approaches to Life Safety*, 2016 edition.

NFPA 550, *Guide to the Fire Safety Concepts Tree*, 2017 edition.

Fire Protection Handbook, 20th edition, 2008.

2.3 Other Publications.

2.3.1 SFPE Publications. Society of Fire Protection Engineers, 9711 Washington Blvd, Suite 380, Gaithersburg, MD 20878.

SFPE Handbook of Fire Protection Engineering, 5th edition, 2015.

2.3.2 Other Publications. Bornhuetter, R. L., and R. E. Ferguson, 1972. “The Actuary and IBNR,” *Proceedings of the Casualty Actuarial Society*, 59, 181–195.

Merriam-Webster’s Collegiate Dictionary, 11th edition, Merriam-Webster, Inc., Springfield, MA, 2003.

2.4 References for Extracts in Advisory Sections. (Reserved)

Chapter 3 Definitions

3.1 General. The definitions contained in this chapter apply to the terms used in this guide. Where terms are not defined in this chapter or within another chapter, they should be defined using their ordinarily accepted meanings within the context in which they are used. *Merriam-Webster's Collegiate Dictionary*, 11th edition, is the source for the ordinarily accepted meaning.

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

3.2.3 Guide. A document that is advisory or informative in nature and that contains only nonmandatory provisions. A guide may contain mandatory statements such as when a guide can be used, but the document as a whole is not suitable for adoption into law.

3.2.4 Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

3.2.5* Listed. Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

3.2.6 Should. Indicates a recommendation or that which is advised but not required.

3.3 General Definitions.

3.3.1 Acceptance Criteria. Acceptance criteria are the units and threshold values against which a fire risk assessment is judged.

3.3.2 Consequence. The outcome of an event, which may be expressed qualitatively or quantitatively.

3.3.3* Deterministic Model. A model whose outputs are not probabilities or probability distributions; that is, they do not quantify uncertainty.

3.3.4 Event. The occurrence of a particular set of circumstances, whether certain or uncertain and whether singular or multiple.

3.3.5* Fire Protection Engineering Design Brief. A description of the planned project approach that includes a discussion on conducting the fire risk assessment.

3.3.6 Fire Risk Assessment (FRA). A process to characterize the risk associated with fire that addresses the fire scenario or

fire scenarios of concern, their probability, and their potential consequences. Other documents may use other terms, such as *fire risk analysis*, *fire hazard*, *hazard analysis*, and *fire hazard analysis assessment*, to characterize fire risk assessment as used in this guide.

3.3.7* Fire Scenario. As used in this document, a fire scenario is a set of conditions and events that characterizes the development of fire, the spread of combustion products, the reactions of people, and the effect of combustion products.

3.3.8 Frequency. The average number of times an event is repeated in a given period.

3.3.9 Hazard. A condition that presents the potential for harm or damage to people, property, environment, mission, or cultural heritage.

3.3.10 Likelihood. Frequency, probability, or their combination.

3.3.11 Method. A process or technique to help resolve a model.

3.3.12 Model. A simulation of an event.

3.3.12.1* Probabilistic Model. A model whose outputs are probabilities or probability distributions.

3.3.13 Probability. The likelihood of an occurrence as expressed as a number between 0 and 1, and the basis of which is often expressed over a period of time or number of trials.

3.3.14* Risk. The paired probabilities and consequences for possible undesired events associated with a given facility or process.

3.3.15* Scenario Cluster. A group of scenarios having some, but not all, defining characteristics in common.

3.3.16* Semiquantitative Methods. Methods that are based on the ability or need to quantify either the likelihood or the consequence of a fire event or events.

3.3.17 Stakeholder. Any individual, group, or organization that might affect, be affected by, or perceive itself to be affected by the risk.

3.3.18 Validation. The process of determining the correctness of the assumptions and governing equations implemented in a method.

3.3.19 Verification. The process of determining the correctness of the calculations or the solution of governing equations in a method.

Chapter 4 Evaluating a Fire Risk Assessment (FRA)

4.1* General. This chapter addresses evaluating a fire risk assessment (FRA) by discussing the stakeholders, an overview of the review process by the authority having jurisdiction (AHJ), scope of FRAs, bounding the FRA, and uncertainty.

4.1.1* FRAs can be used as tools for focusing attention on what is important to fire safety. When results and findings of FRAs are considered together with other factors, this is often referred to as risk-informed decision making.

4.1.2 FRAs have broad applicability in addressing fire safety issues. Examples of applications are shown in Table 4.1.2.

Table 4.1.2 Examples of Applications

Category	Example
Building project evaluation	Demonstrate compliance of a performance-based design
	Demonstrate adequacy of an existing facility
	Demonstrate adequacy of an alternative design
	Demonstrate improvement in facility fire safety
Class-of-use problems	Demonstrate adequacy of a new material use (e.g., chair fabric)
	Determine required protection for an alternative-fuel vehicle
	Establish necessary protection to be required by a code or standard
	Demonstrate improvement in fire safety
General application	Establish emergency response needs (e.g., fire department staffing)
	Establish fire risk (typical facility or overall locale) for a city, county, or state in establishing regulations

4.2 Stakeholders. The stakeholders with interest in the scope and application of the FRA should be identified early in the process. The stakeholders include all those who have a financial, personnel safety, public safety, or regulatory interest in the fire risk. Stakeholders whose interests may apply include, among others, the following:

- (1) Regulators
- (2) Facility owners and operators
- (3) Employees
- (4) Emergency responders
- (5) Insurers
- (6) Neighbors
- (7) Community
- (8) Investors
- (9) Design and construction team
- (10) FRA preparers
- (11) Tenants

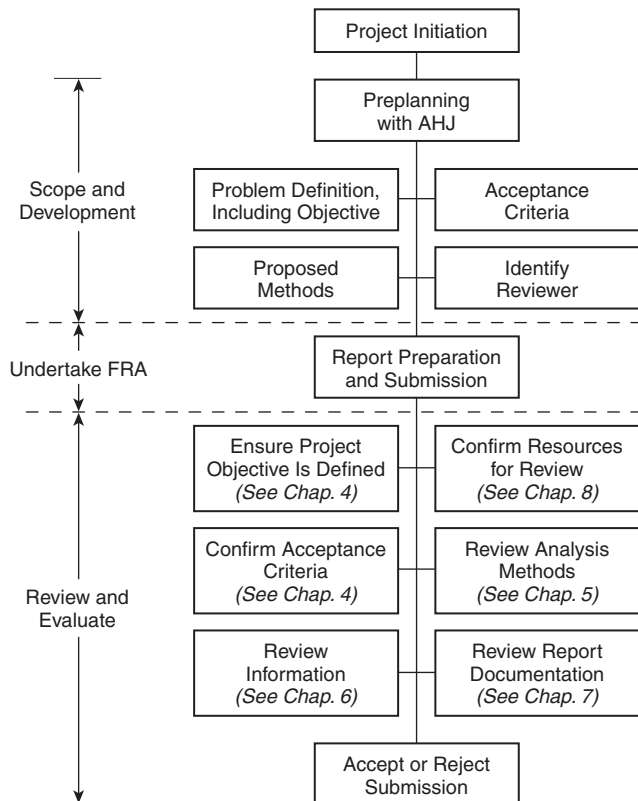
4.2.1 It is important to consider all possible stakeholders during planning, particularly when stakeholder interests conflict.

4.2.2 The stakeholders should participate in the establishment of the objectives of the FRA to ensure that the results provide proper and credible bases for decision making.

4.3 Role of the Authority Having Jurisdiction in the Process. For the purposes of this guide, it is anticipated that the review of a project will proceed using an FRA as provided in 4.3.1 through 4.3.2.3. The process is exemplified in Figure 4.3.

4.3.1 FRA Evaluation. The evaluation of an FRA should be a collaborative process among stakeholders. To evaluate an FRA properly, the reviewer should be introduced to the project as early as possible.

4.3.2 AHJ Participation. The AHJ should be involved in the following steps of the process: defining the problem, accept-

**FIGURE 4.3 Overview of Review Process.**

ance criteria, choice of method, review process, detailed review, and final approval.

4.3.2.1 Defining the Review Process. The AHJ should define its role in the direct review of the FRA. Depending on the FRA-related experience and resources of the AHJ, the AHJ may perform the review. Alternatively, the AHJ may utilize a third party to perform the review.

4.3.2.2 Detailed Review. When reviewing an FRA, the AHJ should check whether the assumptions, building characteristics, occupant characteristics, and fire characteristics used in the analysis acceptably reflect the actual conditions. The types of items that should be checked are identified in Section 8.3. Additionally, the modeling that was used in the FRA should be reviewed.

4.3.2.3 Final Approval. Final approval of the FRA rests with the AHJ.

4.4 Scope of FRAs.

4.4.1 Defining the Problem.

4.4.1.1 The purpose of conducting the FRA should be identified and documented. The purpose might be to identify the level of risk present in an existing building or facility, to identify methods of lowering the risk in an existing building or facility, or to identify methods of providing a level of risk deemed acceptable in a new or renovated building or facility. The objectives of the FRA might be associated with the risk to life (occupants or fire fighters), the risk to property, the risk to operations (e.g., cost of business interruption), the risk to the environment, or the risk of loss of cultural resources. Fire safety

objectives and appropriate performance, which are generally based on the building's characteristics and functions as well as the owner's fire safety expectation over a specific period of time or throughout the design life of the building, should be clearly stated for new and existing construction.

4.4.1.2 Collateral issues beyond the scope of the FRA or exclusions from the FRA may become the questions of additional FRAs, but should not divert the FRA from its specific objectives.

4.4.2 Elements of Risk. The following elements that affect the fire risk should be characterized.

4.4.2.1 The exposed target at risk should be identified. This may include any or all of the following:

- (1) People (occupants, employees, general public, emergency responders)
- (2) Property (structures, systems, components of the built environment)
- (3) Environment (national parks, monuments, hazardous materials)
- (4) Mission (heritage, business continuity, information/communication)

4.4.2.2* The fire stimuli to which the target is vulnerable should be characterized. These may include any or all of the following:

- (1) Heat (radiant flame, convective gases)
- (2)* Smoke (obscuration, respirable, corrosive/conductive aerosols)
- (3) Gases (toxic, corrosive)
- (4) Explosions (overpressure, projectiles)

4.4.2.3 The transport phenomena, which bring the fire stimuli into contact with the exposed target, should be characterized.

4.4.2.4 The response of the exposed target to the resulting fire stimuli should be assessed to determine whether the defined acceptance criteria have been met.

4.4.3 Acceptance Criteria.

4.4.3.1 Metrics should be established that document the results in a way that facilitates decision making.

4.4.3.2 Results may be either relative (e.g., compared to a baseline or comparing alternative options) or absolute (e.g., deaths per year). Within this context, they may be qualitative or quantitative.

4.4.3.3 The acceptance criteria may be in the form of a quantitative risk value, a comparative value, or other values as agreed to by the stakeholders and the AHJ. The form of the acceptance criteria should be dependent on the risk problem and should influence the selection of appropriate FRA methods.

4.4.3.4* Acceptance criteria should be established during preplanning.

4.4.3.5 Acceptance criteria may be based on one of the following:

- (1) Prescriptive regulations
- (2) Performance regulations
- (3) Other agreed-to criteria
- (4) Standards and guides

4.4.3.6 The FRA should present its conclusions in terms that meet its objectives. For project evaluation, the criteria should

specify all the risks that are to be addressed and how those risks are to be measured. The criteria may be specified in terms of absolute values or comparisons to a benchmark. They may further specify limits on probability, consequence, or risk.

4.4.4 Methods.

4.4.4.1 Choice of Methods. The method that was used should be outlined, and its appropriateness to the objectives of the FRA should be documented. The documentation should include a brief description of method of solution, numerical computations (including identification of units used), and identification of the source or derivation of all equations that are not in common usage.

4.4.4.2 Methods may include a variety of elements based on the problem definition. These elements may be qualitative or quantitative and may involve deterministic or probabilistic models.

4.4.4.3 Each element of the method should be applied properly within its scope and limitations. (*See Chapter 5.*)

4.4.5 Data.

4.4.5.1 Data used with the selected method should be appropriate and of sufficient quality to support decision making for the defined problem (*See Chapter 6.*)

4.4.5.2 The scope and the limitation of input data should be expressly documented.

4.4.5.3 Sources of data should be identified.

4.4.5.4 Any assumption or default values used in the absence of data should be explained clearly.

4.4.5.5 The FRA methods, data, and results should be documented to allow review and to provide for changes in management or conditions that could affect the fire risk. (*See Chapter 6.*)

4.5* Uncertainty and Variability Analysis. The FRA should include an assessment of uncertainties in the models and methods and of the uncertainties and variability in the assumptions and data used. This assessment should provide reasonable assurance that the acceptance criteria have been met.

Chapter 5 Selection and Evaluation: FRA Methods

5.1 General. This chapter presents the different types of FRA methods, including guidance on the appropriate selection and application of the various types of risk methods and models.

5.1.1 FRA Concepts. In evaluating FRA methods, the following FRA concepts should be considered: risk in terms of likelihood and consequences and the scope of the FRA in terms of systems and fire scenarios.

5.1.1.1 Likelihood and Consequences. FRAs should evaluate the likelihood and consequences of fire scenarios, as follows:

- (1) The evaluation of likelihood may be based on past experience (e.g., statistics) for well-understood events or on a combination of available knowledge and accepted mathematical treatment (subjective) for less-understood events and where uncertainty and variability are high.
- (2) The evaluation of consequences may be based on expert knowledge (e.g., risk indices), probabilistic modeling (e.g., life safety tree to arrive at safe or unsafe condi-

tions), or deterministic modeling (e.g., fire growth, smoke spread, and occupant evacuation to arrive at safe or unsafe conditions).

5.1.1.1.1 Depending on the FRA objectives, the evaluation of likelihood and/or consequences may focus on relative changes associated with different design alternatives, rather than absolute values.

5.1.1.1.2 Some methods may attempt to assess or compare the change in the likelihood of certain events (i.e., the design alternatives may attempt to alter the probability of the event occurring), others may attempt to assess the impact of different design solutions on the consequences (i.e., they assume the event will happen), and others may attempt to assess both.

5.1.1.1.3 Some methods, such as risk indices, provide a measure of relative risk that only implicitly identifies likelihood and consequences.

5.1.1.2 Scope of an FRA: Concepts and Systems. Depending on the goal, FRAs may involve the assessment of one fire protection concept or system on the overall level of risk, or they may involve the assessment of multiple concepts or systems on the overall level of risk, as follows:

- (1) A single-system FRA involves assessing the impact on risk, given changes to one fire protection system, such as the presence or absence of a sprinkler system or of a fire alarm system.
- (2) A multisystem FRA involves assessing the impact on risk, given changes to a number of fire protection systems, both active and passive, as well as factors such as the egress system, alarm systems, occupant characteristics, training, and education.

5.1.1.2.1 Single-system FRAs may be conducted at various levels. For example, one level of sophistication involves the comparison of one fire protection system to other similar systems, looking at the impact on risk of changing system attributes (e.g., water density or sprinkler head type). Another level of sophistication is needed to compare the effectiveness of one type of automatic fire suppression system to another, based on their ability to extinguish a fire in a certain period of time.

5.1.1.2.2 Multisystem comparisons often require relatively sophisticated methods in which the overall impact on fire risk is assessed based on the availability, reliability, and operation of both passive and active fire protection systems and on other factors that may affect the overall risk.

5.1.1.2.3 The fire safety concepts tree in NFPA 550 provides a comprehensive overview of the concepts or systems that may need to be considered in the FRA.

5.1.1.3 Scope of an FRA: Fire Scenarios. The FRA should address the risk contribution from all potentially significant fire scenarios. When approximations are used (e.g., the risk contribution from a single fire scenario is used as a basis for estimating the risk from a wider range of fire scenarios), the approximations should be justified in the context of the decision problem.

5.1.1.4 Fire Scenario. Depending on the defined problem and the FRA objectives, the FRA method may need to explicitly assess the effect of a design alternative on each event in the fire scenario, in order to assess the risk associated with the alternative. The following are examples for a typical life safety fire scenario:

- (1) *Fire ignition.* Often based on the most probable event in a particular setting, for example, cigarette ignition of a couch in a living room. Prevention education would reduce the probability of occurrence of this event and the consequential risks.
- (2) *Fire growth.* Based on all probable developments of a fire, from smoldering to flashover fires. Fire protection systems such as sprinklers, compartmentation, and door closers may help to contain these fires and to reduce their consequential risks. The reduction in risk depends on the reliability and effectiveness of the fire control systems.
- (3) *Smoke spread.* Based on smoke spread to critical egress routes and other parts in a building. Fire protection systems such as smoke control and stairwell pressurization may help to contain the smoke and to reduce its consequential risks. The reduction in risk depends on the reliability and effectiveness of the smoke control systems.
- (4) *Exposure of occupants.* Based on smoke and fire blocking egress routes. Fire protection systems such as fire alarms, voice communication, clear egress routes, and refuge areas may help to provide early warning to occupants and to direct them either to evacuate the building or to seek refuge in certain areas. The reduction in risk depends on the reliability and effectiveness of the warning and evacuation systems.
- (5) *Failure of fire department to respond.* Based on no response or late response. Proper notification procedure and adequate fire department resources would help to rescue the trapped occupants or to control the fire. The reduction in risk depends on the reliability of the notification procedure and the adequacy of fire department resources.

5.1.1.5* Selecting Fire Scenarios. The objective in selecting the fire scenarios to be analyzed is to find a set of scenarios that are sufficiently diverse and representative such that analyzing the risk for these scenarios captures the overall fire risk for the facility.

5.1.1.5.1 Scenarios can be grouped into scenario clusters.

5.1.1.5.2 A single representative scenario is selected from each scenario cluster for the purposes of consequence analysis.

5.1.1.5.3 If scenario likelihoods are quantified, the frequency of the cluster is the sum of the frequencies of the individual scenarios in that cluster.

5.1.2* FRA Methods: Categories.

5.1.2.1 Table 5.1.2.1 defines five categories of FRA methods. In order of increasing complexity, those methods are as follows:

- (1) Qualitative method
- (2) Semiquantitative likelihood method
- (3) Semiquantitative consequence method
- (4) Quantitative method
- (5) Cost-benefit risk methods

5.1.2.2 The tabulation provides definitions, types of output, and examples for all five categories.

5.1.3 Selection of Methods. The selection of an FRA method for a particular application should consider the following factors: stakeholder objectives and acceptance criteria, scope of the FRA, intended audience and decision makers, regulatory and/or litigation considerations, precedents for similar applications, available resources and data, cost and time constraints,