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Standard Guide for Developing a Cost-Effective Risk Mitigation Plan for New and Existing Constructed Facilities[1]

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INTRODUCTION

Protecting constructed facilities from damages from natural and man-made hazards in a cost-effective manner is a challenging task. Several measures of economic performance are available for evaluating building-related investments. These measures include, but are not limited to, life-cycle cost, present value net savings, savings-to-investment ratio, and adjusted internal rate of return. This guide provides a generic framework for assessing the risks associated with natural and man-made hazards, formulating combinations of risk mitigation strategies for constructed facilities exposed to those hazards, and using measures of economic performance to identify the most cost-effective combination of strategies.

1. Scope

1.1 This guide describes a generic framework for developing a cost-effective risk mitigation plan for new and existing constructed facilities—buildings, industrial facilities, and other critical infrastructure. This guide provides owners and managers of constructed facilities, architects, engineers, constructors, other providers of professional services for constructed facilities, and researchers an approach for formulating and evaluating combinations of risk mitigation strategies.

1.2 This guide insures that the combinations of mitigation strategies are formulated so that they can be rigorously analyzed with economic tools. Economic tools include evaluation methods, standards that support and guide the application of those methods, and software for implementing the evaluation methods.

1.3 The generic framework described in this guide helps decision makers assess the likelihood that their facility and its contents will be damaged from natural and man-made hazards; identify engineering, management, and financial strategies for abating the risk of damages; and use standardized economic evaluation methods to select the most cost-effective combination of risk mitigation strategies to protect their facility.

1.4 The purpose of the risk mitigation plan is to provide the most cost-effective reduction in personal injuries, financial losses, and damages to new and existing constructed facilities. Thus, the risk mitigation plan incorporates perspectives from multiple stakeholders—owners and managers, occupants and users, and other affected parties—in addressing natural and man-made hazards.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E631 Terminology of Building Constructions
E833 Terminology of Building Economics
E917 Practice for Measuring Life-Cycle Costs of Buildings and Building Systems
E964 Practice for Measuring Benefit-to-Cost and Savings-to-Investment Ratios for Buildings and Building Systems
E1057 Practice for Measuring Internal Rate of Return and Adjusted Internal Rate of Return for Investments in Buildings and Building Systems
E1074 Practice for Measuring Net Benefits and Net Savings for Investments in Buildings and Building Systems
E1121 Practice for Measuring Payback for Investments in Buildings and Building Systems

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

E1185 Guide for Selecting Economic Methods for Evaluating Investments in Buildings and Building Systems
E1369 Guide for Selecting Techniques for Treating Uncertainty and Risk in the Economic Evaluation of Buildings and Building Systems
E1557 Classification for Building Elements and Related Sitework—UNIFORMAT II
E1699 Practice for Performing Value Engineering (VE)/Value Analysis (VA) of Projects, Products and Processes
E1765 Practice for Applying Analytical Hierarchy Process (AHP) to Multiattribute Decision Analysis of Investments Related to Buildings and Building Systems
E1946 Practice for Measuring Cost Risk of Buildings and Building Systems and Other Constructed Projects
E2103/E2103M Classification for Bridge Elements—UNIFORMAT II
E2166 Practice for Organizing and Managing Building Data
E2204 Guide for Summarizing the Economic Impacts of Building-Related Projects

2.2 *Adjuncts:*

Discount Factor Tables Adjunct to Practices E917, E964, E1057, E1074, and E1121[3]

3. Terminology

3.1 *Definitions*—For definitions of general terms related to building construction used in this guide, refer to Terminology E631; and for general terms related to building economics, refer to Terminology E833.

4. Summary of Guide

4.1 This guide presents a generic framework for developing a cost-effective risk mitigation plan for constructed facilities exposed to natural and man-made hazards. The generic framework consists of three interrelated components. The three components are: *(1)* perform risk assessment; *(2)* specify combinations of risk mitigation strategies; and *(3)* perform economic evaluation. The generic framework builds on an approach presented in Chapman and Leng (**1**).[4]

4.2 This guide identifies related ASTM standards and adjuncts and describes why measuring uncertainty and risk is critical in the development of cost-effective protective strategies for constructed facilities. In addition to ASTM standards and adjuncts, this guide identifies technical documents and software that support the generic framework. These documents and software are summarized in Appendix X1.

4.3 Data about the frequency and consequences of natural and man-made hazards are helpful when assessing the risks that a particular facility faces from these hazards. Historical patterns of natural disasters, in particular, indicate which areas are more prone to these specific hazards in the future. Many analysts refer to past incidences of man-made hazards, such as crime, as predictors of future occurrences. Sources of hazards data are presented in Appendix X2.

5. Significance and Use

5.1 Standard practices for measuring the economic performance of investments in buildings and building systems have been published by ASTM. A computer program that produces economic measures consistent with these practices is available.[5] The computer program is described in Appendix X3. Discount Factor Tables has been published by ASTM to facilitate computing measures of economic performance for most of the practices.

5.2 Investments in long-lived projects, such as the erection of new constructed facilities or additions and alterations to existing constructed facilities, are characterized by uncertainties regarding project life, operation and maintenance costs, revenues, and other factors that affect project economics. Since future values of these variable factors are generally unknown, it is difficult to make reliable economic evaluations.

5.3 The traditional approach to uncertainty in project investment analysis is to apply economic methods of project evaluation to best-guess estimates of project input variables, as if they were certain estimates, and then to present results in a single-value, deterministic fashion. When projects are evaluated without regard to uncertainty of inputs to the analysis, decision makers may have insufficient information to measure and evaluate the financial risk of investing in a project having a different outcome from what is expected.

5.4 To make reliable economic evaluations, treatment of uncertainty and risk is particularly important for projects affected by natural and man-made hazards that occur infrequently, but have significant consequences.

5.5 Following this guide when performing an economic evaluation assures the user that relevant economic information, including information regarding uncertain input variables, is considered for projects affected by natural and man-made hazards.

5.6 Use this guide in the project initiation and planning phases of the project delivery process. Consideration of alternative combinations of risk mitigation strategies early in the project delivery process allows both greater flexibility in addressing specific hazards and lower costs associated with their implementation.

5.7 Use this guide for economic evaluations based on Practices E917 (life-cycle costs), E964 (benefit-to-cost and savings-to-investment ratios), E1057 (internal rate of return and adjusted internal rate of return), E1074 (net benefits and net savings), E1121 (payback), E1699 (value engineering), and E1765 (analytical hierarchy process for multiattribute decision analysis).

5.8 Use this guide in conjunction with Guide E2204 to summarize the results of economic evaluations involving natural and man-made hazards.

[3] Available from ASTM International Headquarters. Order Adjunct No. ADJE091703.

[4] The boldface numbers in parentheses refer to a list of references at the end of this standard.

[5] The NIST Cost-Effectiveness Tool for Capital Asset Protection helps users calculate measures of economic performance for buildings and building systems that are consistent with ASTM standards. The program is downloadable from http://www.nist.gov/el/economics/CETSoftware.cfm.

6. Procedures

6.1 The recommended steps in developing a cost-effective risk mitigation plan are as follows:

6.1.1 Establish risk mitigation objectives and constraints.

6.1.2 Conduct assessment and document findings.

6.1.3 Review alternative risk mitigation strategies.

6.1.4 Select candidate combinations of risk mitigation strategies.

6.1.5 Develop cost estimates and sequence of cash flows for each candidate combination.

6.1.6 Select appropriate economic method(s) for evaluating the candidate combinations of risk mitigation strategies (see Guide E1185).

6.1.7 Compute measures of economic performance for each candidate combination.

6.1.8 Recompute measures of economic performance taking into consideration uncertainty and risk (see Guide E1369 and Practice E1946).

6.1.9 Analyze results and recommend the most cost-effective combination of risk mitigation strategies.

6.1.10 Prepare report with documentation supporting recommended risk mitigation plan.

7. Perform Risk Assessment

7.1 *Establish Risk Mitigation Objectives and Constraints:*

7.1.1 Specify the decision-maker's objectives. This is crucial in defining the problem and determining the suitability of the economic evaluation method(s).

7.1.2 Identify the constructed facility or set of facilities to be evaluated. Identify the types of hazards to be evaluated.

7.1.3 Specify the design or system objective that is to be accomplished. Identify any constraints that limit the available options to be considered.

7.2 *Conduct Assessment and Document Findings:*

7.2.1 Form an assessment team composed of individuals familiar with the type of facility or set of facilities to be evaluated, individuals familiar with assessment tools and techniques, and individuals who have breadth and depth of experience and understand other disciplines and system interdependencies. Refer to the risk assessment guidance documents and software tools summarized in Appendix X1 to gain assessment insights on specific hazards or classes of hazards. Supplement your data sources with those described in Appendix X2 to compile information on the likelihood and severity of specific hazards or classes of hazards.

7.2.2 Use information from the documents and software summarized in Appendix X1 to produce an assessment plan. Provide the assessment team with the tools, such as laptop computers and electronic forms/data collection sheets, needed to implement the assessment plan.

7.2.3 Make assignments and deploy the assessment team. Collect and compile information on specific hazard types, their likelihood, and consequences.

7.2.4 Use an agreed upon format, such as Classifications E1557 or E2103/E2103M or Practice E2166, to create a compiled set of information collected from the assessment team that documents the findings of the risk assessment. Transmit the compiled set of information to a central repository to insure that access to sensitive information can be limited to those with a legitimate need to know.

8. Specify Combinations of Risk Mitigation Strategies for Evaluation

8.1 *Review Alternative Risk Mitigation Strategies*—This section describes three risk mitigation strategies—engineering, management, and financial. Each strategy is composed of multiple approaches for addressing hazards identified in the risk assessment. These approaches focus on hazard mitigation for a specific system or collection of systems and components, as well as facility and site-related elements. Strategies may be used either singly or in combination. Past research indicates that combinations of risk mitigation strategies offer flexibility in dealing with both a single hazard and multiple hazards.

8.1.1 *Engineering:*

8.1.1.1 Engineering strategies are technical options in the construction or renovation of constructed facilities, their systems, or their subsystems designed to reduce the likelihood or consequences of disasters. Engineering strategies provide protection against both natural and man-made hazards. Engineering strategies also help defend against man-made hazards, where their ability to detect or deter may reduce the likelihood or consequences of such hazards.

8.1.1.2 Protective engineering strategies are intended to reduce harm to occupants, damage to the structure, and disruption of business if a disaster occurs. Protective engineering strategies may improve the structural integrity of a building, facilitate evacuation of occupants, or circumvent compromised systems.

8.1.1.3 There is some overlap among engineering strategies that deter, detect, and protect against terrorist attacks and other criminal acts. Detection and protective engineering strategies that are observable to potential terrorists may deter them from attacking. Closed-circuit television (CCTV), for example, is designed to detect unauthorized activities, but its visibility may deter these activities.

8.1.1.4 Risk mitigation strategies may also be hazard-specific. Reinforced building shell, shatter-resistant glass, and use of barriers and bollards to achieve increased setback distances for existing buildings are examples of engineering strategies that protect against blast.

8.1.2 *Management:*

8.1.2.1 Management strategies can be procedural or technical. Some management strategies relate to security, training, and communications. Others relate to decisions on where to locate the building and who should have access to its systems and subsystems. Some management strategies complement engineering strategies, while others substitute for them.

8.1.2.2 Security practices are the use of security personnel and procedures to prevent terrorist or criminal breaches from happening by detection or deterrence. They may be used to perform identification checks at building entrances, conduct background checks on individuals with access to sensitive areas and information, patrol facilities, and monitor CCTVs. Security personnel may also be used to capture attackers or facilitate recovery if a breach occurs.

8.1.2.3 Training practices are used primarily to prepare responses to disaster. Building owners and managers may institute periodic emergency response drills for building occupants. These drills may include information about evacuation routes or sheltering procedures to improve survival during emergencies. Security and facility management personnel may receive training about proper techniques for responding to breaches and containing damage. Training may also be used for prevention: building security personnel and occupants may be trained in detection of suspicious activities and notification procedures.

8.1.2.4 Building owners and managers may also use communications practices to coordinate responses with emergency personnel and to relay information and instructions to occupants during emergencies. Communications practices include setting up emergency phone numbers or instituting building-wide audio or e-mail broadcast mechanisms. Coordinated communications can play a key role in occupant safety. Building owners and managers can develop communications procedures to coordinate with first responders, security staff, and other emergency personnel responding to the incident. Finally, communications practices can be used by firms occupying the building to facilitate recovery, assess consequences, and minimize disruptions to the organization's mission or business.

8.1.2.5 Another management practice available to building owners and managers relates to the building's location and ease of access. Decisions concerning location come into play for new construction and for acquisitions of existing buildings. Setback distances, which have effects that are interdependent with some engineering strategies, are a component of the management decision about location. For new construction, managers may choose a site within a lot that satisfies a minimum setback distance. When acquiring existing property, managers may make a choice based on the physical characteristics of the available properties. Other structure-related management decisions concern access to the building itself and its sensitive areas. These access areas include attached garages, mailrooms, loading docks, side entrances, connected buildings, driveways, and rooftops. Sensitive areas include rooms housing HVAC equipment and controls; servers, network connections, and other information technology (IT) assets; and CCTV monitoring equipment.

8.1.3 *Financial:*

8.1.3.1 Building owners and managers can explore financial strategies to reduce their pecuniary risks from natural and man-made hazards. There are two types of financial strategies to address risk mitigation: insurance and financial incentives. Both topics are explored in detail in Grossi and Kunreuther (**2**) and in Kunreuther, Meyer, and Van den Bulte (**3**).

8.1.3.2 Building owners and managers may reduce their risk exposure to disasters by purchasing insurance for worker's compensation, property damage, business interruptions, event cancellation, and liability.

8.1.3.3 Financial incentives fall into two categories: government incentives and private incentives. Government incentives are explicitly designed public policy instruments that encourage decision makers to make certain choices over others. Private incentives reward decision makers for making some choices over others through private transactions. In the case of risk mitigation, government and private incentives are policies, measures, or characteristics that motivate building owners and managers to implement risk mitigation measures in their buildings.

8.1.3.4 Federal, state, and local governments can institute direct incentives that reduce the price that building owners and managers pay to protect their buildings. These incentives include subsidies or tax write-offs for investments in protective measures. Other examples of government-initiated financial incentives are formal cost sharing of the protective investments and loan guarantees to ease the short-term financial burdens of structural upgrades.

8.1.3.5 Financial incentives for risk mitigation in constructed facilities may also be offered by the private sector. Building owners have commercial relationships with insurers, tenants, employees, potential buyers, and lenders. These parties may each benefit from a building's reduced vulnerability.

8.1.3.6 Insurance companies benefit from the adoption of either engineering or management strategies through smaller claims if a disaster occurs. To encourage owners to adopt risk mitigation, insurers may reduce insurance premiums for buildings that have protective measures. Building owners may also be able to obtain more favorable insurance policies, such as those that are longer term, have lower deductibles, or have fewer exclusions.

8.1.3.7 Building owners who lease commercial space may find that tenants value a building's safety features and are willing to pay a leasing premium. For owner-occupied buildings, employees may also value the added safety of a less vulnerable building. The perception of danger may affect employees' willingness to work in a particular location.

8.1.3.8 Potential buyers are another party from which a building owner can extract rewards for the building's risk mitigation measures. The installation of protective measures in a building is an improvement that increases the value of the asset. The building owner may realize the benefit of increased property value when the property is sold.

8.1.3.9 Building owners may also receive incentives from their lenders to protect their assets. Lenders would suffer direct financial losses if the destruction of a building led to the building owner's insolvency. To encourage owners to make choices that reduce the likelihood of such destruction, lenders may offer preferential financing terms on the building loan. Another way building owners are potentially rewarded in their relationships with financial institutions for their risk mitigation efforts is through the increased collateral value of their buildings.

8.2 *Select Candidate Combinations of Risk Mitigation Strategies:*

8.2.1 Form a project team empowered to select combinations of risk mitigation strategies. The project team will include some of the individuals from the assessment team as well as additional individuals with specific knowledge about the facility or subject matter expertise. Provide the project team with access to the compiled set of information produced by the risk assessment team (see 7.2).

8.2.2 Review the findings of the assessment team on how individual building elements are affected by each hazard type. Use Practice E1699 for guidance on how to employ value engineering concepts to help identify and specify mitigation strategies. Use information from the documents and software summarized in Appendix X1 to identify mitigation strategies for building elements and hazard types. Employ a combination of mitigation strategies rather than focusing only on engineering-based approaches.

8.2.3 Form each combination of risk mitigation strategies into a well-defined alternative, which addresses one of more of the hazards identified in the risk assessment. Prepare a brief narrative statement for each alternative in the set, describing what it does and how it accomplishes it.

8.3 *Develop Cost Estimates and Sequence of Cash Flows for Each Candidate Combination:*

8.3.1 Consult with senior management to establish a first cost budget constraint for the project. Compile information on the amount and timing of investment costs, operating costs, and maintenance and repair costs for each alternative combination of risk mitigation strategies. Eliminate from further consideration those alternatives whose initial investment costs exceed the first cost budget constraint for the project.

8.3.2 Compile information on the likelihood and consequences of each hazard type (see Section 7) for each alternative. Develop estimated costs for each consequence.

8.3.3 Identify areas where information is impacted by uncertainty.

8.3.4 Identify any significant effects that remain unquantified.

9. Perform Economic Evaluation

9.1 *Select Appropriate Economic Method(s) for Evaluating the Candidate Combinations of Risk Mitigation Strategies:*

9.1.1 Numerous methods are available for measuring the economic performance of investments in buildings and building systems. Use Guide E1185 to identify types of building design and system decisions that require economic evaluation and to match the technically appropriate economic methods with the decisions.

9.1.2 Four economic evaluation methods addressed in Guide E1185 apply to the development of a cost-effective risk mitigation plan for dealing with natural and man-made hazards: *(1)* life-cycle costs (Practice E917); *(2)* present value net savings (Practice E1074); *(3)* savings-to-investment ratio (Practice E964); and *(4)* adjusted internal rate of return (Practice E1057). The computer program described in Appendix X3 produces calculated values for each of the four economic evaluation methods.

9.1.3 More than one method can be technically appropriate for many design and system decisions. If more than one method is technically appropriate, use all that apply, since many decision makers need information on measures of magnitude (life-cycle costs and present value net savings) and of return (savings-to-investment ratio and adjusted internal rate of return) to assess economic performance.

9.2 *Compute Measures of Economic Performance for Each Candidate Combination:*

9.2.1 Follow the instructions given in the selected evaluation method(s) for computing the measure(s) of economic performance (see 9.1). Perform these computations with fixed parameter values. Cases where parameter values are allowed to vary are treated in 9.3.

9.2.2 Use the computed values of the measure(s) of economic performance (outcomes) to rank order the alternatives (combinations of risk mitigation strategies). Refer to the selected evaluation method(s) to determine the criterion for ranking alternatives.

9.2.3 Designate the alternative with the best outcome (measure of economic performance) as the most cost-effective risk mitigation plan. For example, if the life-cycle cost method is used, the alternative with the lowest life-cycle cost has the best outcome. Consequently, it qualifies as the most cost-effective risk mitigation plan.

9.2.4 Examine any significant effects that remain unquantified. Note how these effects differ across alternatives.

9.3 *Recompute Measures of Economic Performance Taking into Consideration Uncertainty and Risk*—Decision makers typically experience uncertainty about the correct values to use in establishing basic assumptions and in estimating future costs. Guide E1369 recommends techniques for treating uncertainty in parameter values in an economic evaluation. It also recommends techniques for evaluating the risk that a project will have a less favorable economic outcome than what is desired or expected. Practice E1946 establishes a procedure for measuring cost risk for buildings and building systems, using the Monte Carlo simulation technique as described in Guide E1369. The computer program described in Appendix X3 incorporates the treatment of risk and uncertainty to produce a set of calculated values for each of the four economic evaluation methods referenced in 9.1.2 that are consistent with Guide E1369.

9.3.1 *Perform Sensitivity Analysis* (see Guide E1369):

9.3.1.1 Sensitivity analysis is a test of the outcome of an economic evaluation to changing values of one or more parameters about which there is uncertainty. It shows decision makers how the economic viability of a project changes as the discount rate, key unit costs, escalation rates, and other critical parameters vary.

9.3.1.2 A sensitivity analysis might use as inputs a pessimistic value, a value based on a measure of central tendency (mean or median), and an optimistic value for the parameter of interest. Then an analysis could be performed to see how each outcome (for example, savings-to-investment ratio) changes as each of the three chosen values for the selected input is considered in turn, while all other parameters are held constant. A sensitivity analysis can also be performed on different combinations of parameters. That is, several parameters are altered at once and then an outcome measure is computed.

9.3.1.3 The key advantage of sensitivity analyses is that they are easily constructed and computed and the results are easy to explain and understand. Their disadvantage is that they do not produce results that can be tied to probabilistic levels of significance (for example, the probability that the savings-to-investment ratio is less than 1.0).

9.3.2 *Perform Monte Carlo Simulation* (see Guide E1369 and Practices E917 and E1946):

9.3.2.1 Monte Carlo simulation varies a small set of key parameters either singly or in combination according to an experimental design. Associated with each key parameter is a probability distribution function from which values are randomly sampled. The major advantage of the Monte Carlo simulation technique is that it permits the effects of uncertainty to be rigorously analyzed through reference to a derived distribution of project outcome values. Their disadvantage is that they require a computer program to implement.

9.3.2.2 In a Monte Carlo simulation, not only the expected value of the outcome can be computed but also the variability of that value. In addition, probabilistic levels of significance can be attached to the computed outcome value for each alternative under consideration.

9.3.2.3 Key elements of Guide E1369 and Practice E1946 have been incorporated into the calculation of life-cycle costs (Practice E917). Practice E917 provides direction on how to apply Monte Carlo simulation when performing economic evaluations of alternatives designed to mitigate the effects of natural and man-made hazards that occur infrequently but have significant consequences. Practice E917 contains a comprehensive example on the application of Monte Carlo simulation in evaluating the merits of alternative risk mitigation strategies for a prototypical data center.

9.4 *Analyze Results and Recommend the Most Cost-Effective Combination of Risk Mitigation Strategies*—Choosing among alternatives designed to reduce the impacts of natural and man-made hazards is more complicated than most building investment decisions. Consequently, guidance is provided to help identify key characteristics and the level of effort that will promote a better-informed decision. This guidance draws on information presented in 9.2 and 9.3.

9.4.1 Review the calculated values of each alternative's measures of performance. Include the outcomes computed for each of the three types of analysis: *(1)* fixed parameter values (see 9.2); *(2)* sensitivity analyses (see 9.3.1); and *(3)* Monte Carlo simulations (see 9.3.2).

9.4.2 Use the performance criterion from each selected evaluation method to rank order alternatives for each type of analysis (fixed parameter values, sensitivity analyses, and Monte Carlo simulations). Document differences in alternative rankings among the three types of analysis. Focus on circumstances under which the most cost-effective risk mitigation plan identified in the fixed parameter values analysis is replaced by (an)other alternative(s) when the effects of uncertainty are considered. Use the results of the Monte Carlo simulations to identify the characteristics associated with ranking changes for those alternatives under consideration.

9.4.3 Recommend an alternative as the most cost-effective risk mitigation plan. Provide a rationale for the recommendation. Include as part of the rationale, findings from each of the three types of analysis. Include a discussion of circumstances under which the recommended alternative did not have the best measure of economic performance.

9.4.4 Describe any significant effects that remain unquantified. Explain how these effects impact the recommended alternative. Refer to Practice E1765 and its adjunct for guidance on how to present unquantified effects along with the computed values of the measures of economic performance.

10. Prepare Report with Documentation Supporting Recommended Risk Mitigation Plan

10.1 In a report of an economic evaluation, state the objective, the constraints, the alternatives considered, the key assumptions and data, and the computed value for each outcome (measure of economic performance) of each alternative. Make explicit the discount rate; the study period; the main categories of cost data, including initial costs, recurring and nonrecurring costs, and resale values; and grants and incentives if integral to the decision-making process. State the method of treating inflation. Specify the assumptions or costs that have a high degree of uncertainty and are likely to have a significant impact on the results of the evaluation. Document the sensitivity of the results to these assumptions or data. Describe any significant effects that remain unquantified in the report.

10.2 Use the generic format for reporting the results of an economic evaluation described in Guide E2204. It provides technical persons, analysts, and researchers a tool for communicating results in a condensed format to management and non-technical persons. The generic format calls for a description of the significance of the project, the analysis strategy, a listing of data and assumptions, and a presentation of the computed values of any measures of economic performance. Guide E2204 contains a comprehensive example evaluating the merits of alternative risk mitigation strategies for a prototypical data center summarized using the generic format.

10.3 To complete the report, include as supporting documentation information compiled from the risk assessment and a description of the process by which combinations of risk mitigation strategies were assembled.

10.4 Appendix X4 provides a comprehensive, illustrative application of the three-step protocol in the development of a risk mitigation plan against intentionally-set fires in at-risk Michigan communities.

11. Keywords

11.1 adjusted internal rate of return; analytical hierarchy process; building condition assessment; building economics; building systems; cost analysis; economic evaluation methods; economic impacts; engineering economics; homeland security; impact assessment; life-cycle costs; man-made hazards; measures of economic performance; Monte Carlo simulation; multiattribute decision analysis; natural hazards; net savings; present-value analysis; project management; risk assessment; risk mitigation strategies; savings-to-investment ratio; sensitivity analysis; value engineering