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Standard Guide for Developing Cost-Effective Community Resilience Strategies[1]

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INTRODUCTION

There is a need for best practices for resilience planning that address the increasing value-at-risk of U.S. infrastructure and communities. Communities, as a system, are particularly vulnerable to the effects of natural, technological, and human-caused disruptive events. There are best practices for community resilience assessment methodologies; however, there are gaps that remain in the characterization of robust, benefit-cost measures of community resilience, especially in the planning process. In many cases, resilience remains in a planning silo and is considered separately by communities from economic growth or disaster risk planning. Efforts to increase resilience capacities are best realized when resilience is considered as an attribute in general community planning efforts, especially in planning and implementing building and infrastructure projects. This guide develops economic decision guidance for evaluation of investment strategies designed to improve community resilience through strengthening the ability to respond, withstand, and recover from disruptive events. It is designed to support the principles and attributes of resilient communities upon which enhanced resilience may be developed, evaluated, and implemented.

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1. Scope

1.1 This guide describes a generic economic methodology for evaluating investment decisions aimed to improve the ability of communities to adapt to, withstand, and quickly recover from, disruptive events. The methodology describes a framework for developing cost-effective community resilience strategies 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 and analysts with an approach for planning and comparing resilience strategies.

1.2 This guide frames the economic decision process by identifying and comparing the relevant present and future streams of costs and benefits to a community—the latter realized through cost savings and damage loss avoidance—associated with new capital investment into resilience to those generated by the status-quo.

1.3 This guide provides a means to increase the capacity of communities to objectively and effectively compare and contrast capital investment projects through consideration of benefits and costs while maintaining an awareness of system resilience. Topics related to non-market values and uncertainty are also explored.

1.4 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

[1] This guide is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.81 on Building Economics.

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1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

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
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
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 Projects, Products, and Processes
E2204 Guide for Summarizing the Economic Impacts of Building-Related Projects
E2506 Guide for Developing a Cost-Effective Risk Mitigation Plan for New and Existing Constructed Facilities

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.

3.1.1 *community resilience, n*—the ability of a community to anticipate, prepare for, and adapt to changing conditions, and withstand, respond to, and recover rapidly from disruptions.

3.2 *Abbreviations:*

3.2.1 *OMB*—Office of Management and Budget

3.2.2 *OMR*—operation, maintenance, and repair

3.2.3 *PVNB*—present value net benefits

4. Summary of Guide

4.1 This guide presents a generic economic methodology for evaluating investment decisions aimed to improve the ability of communities to adapt to, withstand, and quickly recover from disruptive events. The generic framework consists of seven interrelated stages. The stages are: (*1*) select candidate strategies; (*2*) define investment objectives and scope; (*3*) identify benefits and costs; (*4*) identify non-market (non-economic) considerations; (*5*) define analysis parameters; (*6*) perform economic evaluation; and (*7*) rank strategies. The generic framework builds on an approach presented in NIST Special Publications 1190 (**1**) and 1197 (**2**).

4.2 This guide identifies related ASTM standards and describes why measuring uncertainty and risk is critical in the development of cost-effective protective strategies for constructed facilities.

4.3 Appendix X1 provides an example case study to highlight the steps of the standard and demonstrate how they can be used to evaluate the cost-effectiveness of community resilience strategies.

[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.

5. Significance and Use

5.1 Investments in projects supporting community resilience are characterized by uncertainties regarding the frequency and magnitude of natural, technological, and human-caused disruptions. Accounting for these low-probability, high-consequence events challenge traditional economic evaluation methods.

5.2 The traditional approach to evaluating the benefit-cost of investment decisions routinely focus on measures directly tied to loss avoidance.

5.3 Following this guide when performing an economic evaluation assures the user that relevant economic information, including information regarding uncertainties and indirect inputs, is considered for capital project facing possible disruptions from natural, technological, and human-caused hazards.

5.4 Use this guide in the planning phases of community resilience plan development process. Consideration of risk mitigation choices early in the planning process allows both greater flexibility in addressing specific hazards and lower costs associated with their implementation.

5.5 Use this guide to integrate community resilience plans with economic development, zoning, hazard mitigation, and other community planning activities that affect buildings, public works, and infrastructure systems.

5.6 Use this guide to identify all relevant inputs—that is, costs and benefits (savings)—associated with construction, implementation, and use of the capital asset, over the lifetime of the asset. Relevant inputs include direct, indirect and externalities, and non-market values.

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 multi-attribute decision analysis), and Guide E1369 (treatment of uncertainty).

5.8 Use this guide in conjunction with Guide E2204 to summarize the results of economic evaluations involving natural, technological, and human-caused hazards.

5.9 This guide generalizes Guide E2506 (cost-effective risk mitigation plan for new and existing constructed facilities) by evaluating investments into capital assets for a community.

6. Procedures

6.1 The recommended steps for economically evaluating strategies for community resilience are as follows:

6.1.1 Select Candidate Strategies,

6.1.2 Define Investment Objectives and Scope,

6.1.3 Identify Benefits and Costs,

6.1.4 Identify Non-Market Considerations,

6.1.5 Define Analysis Parameters,

6.1.6 Perform Economic Evaluation, and

6.1.7 Rank Strategies.

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7. Select Candidate Strategies

7.1 *Form a Collaborative Planning Team:*

7.1.1 Identify resilience leadership and team members. This should include representatives from local government; private owners and operators of buildings and infrastructure systems; developers, builders, and contractors; local business and industry leaders; representatives of social organizations and any other significant community groups.

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7.2 *Understand the Situation:*

7.2.1 Characterize the existing built environment. Identify key attributes and dependencies for buildings and infrastructure systems within the community. Characteristics that will help determine the current condition of the built environment include the owner, location(s), current use, age, construction types, zoning, maintenance and upgrades, and applicable codes, standards, and regulations, both at the time of design and for current performance.

7.2.2 Characterize the social dimensions. Identify social needs and functions, including those that are supported by the built environment.

7.2.3 Identify dependencies between the built environment and the social dimensions.

7.3 *Determine Community Goals and Objectives:*

7.3.1 Establish long-term community goals and objectives for the built environment based on the input from all stakeholders, including local government offices for community development, emergency response, social needs, public works, and buildings; private owners and operators of buildings and infrastructure systems; developers, builders, and contractors; local business and industry representatives; and social and economic organizations.

7.3.2 Determine performance goals. Establish criteria for the desired performance of the built environment, and identify gaps between desired and anticipated performance levels.

7.3.3 Identify community hazards. Each community has a set of prevalent hazards that should be considered in resilience planning. Determine the likelihood and consequence of those hazards.

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7.4 *Plan Development:*

7.4.1 Match performance goals for the built environment with the social needs of the community and consider the functions that buildings and infrastructure systems need to provide, as well as any dependencies between systems or cascading effects caused by failures.

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7.4.2 Identify strategies, or combinations of strategies, for a comparison of desired and anticipated performance based on identifying gaps in performance that will impact community resilience and therefore need to be integrated into the alternative community resilience investment strategies. A strategy is an approach or method to enhance community resilience. A strategy may be evaluated individually or, jointly, in combinations with other strategies (as a portfolio). A candidate strategy (or a combination of strategies) can be evaluated against the status quo (do nothing), against others, or both. Note, however, rank reversals may occur when strategies are evaluated jointly (combined).

7.4.3 Consider combinations of mitigation, disaster preparedness, design and construction, emergency response, and pre-event recovery planning strategies. Inclusion of desired performance goals versus anticipated (actual) performance of the built environment to hazard events, and expected recovery sequences, time, and costs provides a complete basis for communities to understand gaps in performance, prioritize improvements through the use of economic evaluation techniques, and allocate resources.

8. Define Investment Objectives and Scope

8.1 *Define Economic Objective Function:*

8.1.1 Establish those factors that are important to consider when selecting between strategies, and take those factors into account when determining what candidate strategies to evaluate and in deciding on strategies for implementation.

8.2 *Define Planning Horizon:*

8.2.1 Select the period over which strategies are to be compared in terms of costs and benefits. The combination of the length of the planning horizon and the discount rate dictate the relative importance of future benefits and costs.

8.3 *Identify Constraints:*

8.3.1 Identify those political, legal, financial, and other considerations that might serve as important limits on what a community can implement. There are numerous factors that influence decisions that have an impact on the well-being of a community, and some may be difficult to quantify.

8.3.2 Discard from consideration alternative strategies that violate the identified constraints.

9. Identify Benefits and Costs

9.1 *Identify Costs and Losses:*

9.1.1 Identify costs of implementing a mitigation strategy that may occur one time or over the life-cycle of the project. Account for all costs, including negative effects, of implementing a resilience action. This specifically includes the initial costs, operation and maintenance costs, end-of-life costs, and replacement costs. Use Practice E1699 for guidance on how to employ value engineering concepts to help identify and estimate the costs of implementing a mitigation strategy.

9.2 *Identify Savings and Benefits:*

9.2.1 Identify benefits, including those primarily determined to improve the performance during a disruptive event compared to the status quo, that is, those obtained directly or indirectly by the implementation of the new resilience strategy. This includes benefits related to the reductions in the (*1*) magnitude of damages from a disaster and (*2*) the costs of the response and recovery phases. Other benefits to be considered include positive effects from a resilience strategy that improve non-risk related community function and value.

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9.3 *Identify Externalities:*

9.3.1 Identify those costs or benefits that impact a third party that is not part of the direct decision to implement a given strategy. Externalities may be positive or negative; they also may be *non-market* in nature, meaning they are not bought or sold in the market, so their price is not observable.

9.4 *Identify Non-Market Considerations:*

9.4.1 It can be challenging to estimate economic values for some costs and benefits. For example, damages are non-economic if they exclude physical infrastructure or do not directly affect the economy. Most prominent among the non-economic losses are deaths and injuries. Others include social, cultural, and environmental impacts.

9.4.2 The value of a statistical life can be used to convert *fatalities averted* into economic value.

9.4.3 The value of a statistical injury can be used to convert *injuries averted* into economic value.

10. Define Analysis Parameters

10.1 *Select Discount Rate:*

10.1.1 The discount rate embodies a time preference of money. In general, it is commonly accepted that people tend to prefer consumption at present over future consumption. Discounting future consumption allows comparison between current and future consumption in equivalent terms. In this case, that means discounting future costs and benefits for the proposed mitigation strategies.

10.1.2 The discount rate is a key variable in the valuation process. It encapsulates the time preferences of the community. There are standard discount rates used by federal agencies, but an individual jurisdiction may choose its own discount rate, as appropriate to the project being assessed and consistent with its identified priorities. Information on the setting of the federal discount rates is contained in the ~~Office of Management and Budget (OMB)~~ OMB Circular A-94 (**3**). The selected discount rate should be appropriate to the source or sources of funding for investments in resilience. A different discount rate should apply to strategies funded through public investments versus those funded through private investments. Additional information on the selection of the discount rate for a risk analysis of engineered systems is contained in Chapter 6 of Ayyub (**4**).

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10.2 *Define Probability Distributions:*

10.2.1 Link the frequency of hazard events with their potential outcomes. Distributional assumptions are required to estimate expected costs and benefits associated with competing investment scenarios. Distributional assumptions for benefits—the expected reduction in losses—are required given the uncertainties related to disaster occurrence and outcome, while the assumptions needed for costs are due to typical uncertainties related to cost estimation, and with some stemming from the dependence on the timing and severity of the disaster itself (for example, response and recovery costs).

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10.2.2 Information from the probability distributions is used in two ways: (*1*) in a baseline analysis where all parameters are fixed equal to their expected value and (*2*) in a sensitivity analysis where the baseline values are allowed to vary. First, the expected value for each input variable—the annual value for each cost, loss, and benefit—is used in the baseline analysis of each alternative resilience strategy. This corresponds to the traditional approach to project investment analysis, which applies economic methods of project evaluation to best-guess estimates of project input variables as if they were certain estimates and then presents the results in single-value, deterministic terms. Second, data points from each probability distribution for each alternative resilience strategy are used as inputs in a sensitivity analysis to measure how "sensitive" the value of net benefits for the given resilience strategy is to changes in input variables (see 11.3).

10.3 *Define Risk Preference:*

10.3.1 Determine the degree of risk aversion or risk acceptance. See Guide E1369 and Chapter 7 of Ayyub (**4**).

11. Perform Economic Evaluation

11.1 *Select Appropriate Economic Method(s) for Evaluating the Candidate Community Resilience Strategies:*

11.1.1 Several economic methods are available for evaluating investment decisions aimed to improve the ability of communities to adapt to, withstand, and quickly recover from disruptive events. Use Guide E1185 to identify types of decisions that require economic evaluation and to match the technically appropriate economic methods with the decisions.

11.1.2 Four economic evaluation methods addressed in Guide E1185 apply to the development of a cost-effective community