Smart Choices

An Overview of the Community Resilience Economic Decision Guide for Buildings and Infrastructure Systems

Community Resilience

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

WHY AN ECONOMIC DECISION GUIDE FOR RESILIENCE PLANNING?

When communities decide to become more resilient, they need an approach that helps them to identify and prioritize options consistent with their overall goals. Ideally, the options will be based on the community's social and economic needs as well as increase the likelihood that critical services will be provided as needed and expected before and after hazard events strike.

The National Institute of Standards and Technology (NIST) ***Community Resilience Planning Guide for Buildings and Physical Infrastructure Systems (Community Resilience Planning Guide)*** helps communities do just that, by focusing on the role of the built environment in enabling the community to rapidly recover from disruption. It provides a process for communities to develop their resilience plans by engaging stakeholders, establishing performance goals for buildings and infrastructure systems, identifying priority gaps and options, and developing an implementation strategy. That kind of planning process creates a proactive approach to ensure critical social and economic functions of the community are supported.

Simply identifying those goals, gaps, and options is a major step forward in resilience planning. But once options are developed, communities need to decide among alternatives. They want options that mitigate the risk of damage levels and speed recovery—while considering their available resources. They must take economic considerations into account.

That can be difficult because buildings and infrastructure systems are themselves part of an interconnected system of systems and support social and economic functions, making standard benefit-cost analysis practices more challenging for community resilience planners and economists.

So NIST developed the ***Community Resilience Economic Decision Guide for Buildings and Infrastructure Systems (EDG)*** as a companion to the NIST ***Community Resilience Planning Guide (CRPG).*** It offers an easy-to-follow approach that captures cost and benefits for the variety of resilience options any community may be considering.

This brochure offers an overview of the ***Economic Decision Guide***, which provides a mechanism to prioritize potential resilience solutions, while supporting the needs of the community.

The ***Economic Decision Guide*** can be used as a standalone tool, but it is most useful as part of a more comprehensive planning process and in combination with the NIST ***Community Resilience Planning Guide. Like the Community Resilience Planning Guide***, it aligns with the National Preparedness System.

HOW THE ***ECONOMIC DECISION GUIDE*** FITS INTO THE ***RESILIENCE PLANNING SIX-STEP PROCESS***

EDG	CRPG
1 SELECT CANDIDATE STRATEGIES	1) Form a Collaborative Planning Team
2 DEFINE INVESTMENT OBJECTIVE & SCOPE	2) Understand the Situation
3 IDENTIFY BENEFITS & COSTS	3) Determine Goals & Objectives
4 IDENTIFY NON-MARKET (NON-ECONOMIC) CONSIDERATIONS	4) Plan Development
5 DEFINE ANALYSIS PARAMETERS	5) Plan Preparation, Review & Approval
6 PERFORM ECONOMIC EVALUATION	6) Plan Implementation & Maintenance
7 RANK STRATEGIES	

SELECT CANDIDATE STRATEGIES

STEP 1

Once a community has identified projects that may improve its resilience to a disruption—perhaps using the NIST CRPG—the ***Economic Decision Guide*** can be used to compare candidate projects for increasing community resilience. The evaluation could be between a single option and the status quo, or it could involve multiple options—including choices across different infrastructure sectors.

For example:

- repair a bridge,
- relocate a water treatment plant,
- fortify a dam,
- upgrade the structural performance of a school's main assembly space,
- …or a combination of options.

Based on existing studies, computer modeling, and expert judgment, the selection of candidate projects by the community's collaborative planning team (see Step 1 of the CRPG) generally should identify those most likely to have the greatest overall benefit.

DEFINE INVESTMENT OBJECTIVES & SCOPE
STEP 2

DEFINE ECONOMIC OBJECTIVES

The ***Economic Decision Guide*** is designed to identify community investment projects with the greatest net benefit, accounting for all factors that can be valued. A community will want to decide what additional factors—like increased access to a quality livelihood, education, and other social welfare resources—are important in choosing between and among alternative strategies. Furthermore, communities may choose a diverse approach to resilience planning that involves specific mitigation actions to ***reduce*** risk and steps to ***transfer*** risk, such as insurance investments.

DETERMINE PLANNING HORIZON

A planning horizon—the period over which alternatives are compared in terms of costs and benefits that occur—needs to be selected for the analysis. Does the community feel comfortable with a 10, 20, or 30 year planning horizon for improving resilience? Longer? There may be benefit in making the planning horizon the same as the time horizon considered in the community's comprehensive plan.

IDENTIFY CONSTRAINTS

Political, legal, financial, and other considerations will influence which resilience projects a community can undertake, and can be hard to quantify. Nevertheless, it is vital to factor them into planning. Planners also often will need to consider ways to reformulate or present activities over time.

IDENTIFY BENEFITS AND COSTS
STEP 3

DETERMINE BENEFITS

Benefits are determined primarily on the basis of the improvement in performance over the status quo for a hazard event. That includes reductions in the magnitude of damages (e.g., to property and livelihoods) from a disaster as well as lower costs during the response and recovery phases. Benefits also include the positive effects, or non-disaster-related benefits, from a resilience strategy that improves community function and value.

DETERMINE COSTS

Costs to implement a mitigation strategy may occur once or multiple times over a project's life. In addition to initial costs, estimates should include all costs associated with owning, operating, maintaining, and disposing of goods and services related to the project. Non-economic costs, like environmental degradation due to construction, and social disruption due to displacement of a neighborhood/vulnerable population, also should be considered. (See Step 4)

VALUES CAN BE GROUPED IN SEVERAL WAYS

Benefits (including avoided losses and costs) and costs can be classified by their cause and to whom in the community it accrues, including: direct, indirect, and non-economic.

- Direct values are those that accrue to stakeholders without intervening factors or channeled through intermediaries. Examples include mitigation costs and avoided damages.
- Indirect values are those that accrue to stakeholders in a cascading manner. Examples include business interruption costs and the cost of unemployment payments due to disturbance-related job losses.
- Non-economic values are those with no "market price." (These can be direct or indirect.) Examples include fatalities and injuries.

CONSIDER ALL THE VALUES

Importantly, resilience strategies may produce benefits whether or not hazard events occur. These can be analyzed using the same categories: direct benefits, indirect benefits, and non-economic benefits. They should take into account the benefits and costs that accrue during all phases associated with a hazard event, as well as under business-as-usual circumstances.

- An infrastructure project (e.g., a replacement sewage treatment plant or bridge) that reduces operation and maintenance costs would be a ***direct non-hazard-related benefit***.
- A reduction in traffic delays due to highway improvements intended to improve its resilience to earthquakes or flooding would be an ***indirect non-hazard-related benefit***.

Positive and negative externalities also should be taken into account. For example, improvements in a bridge's durability also could cut the amount of greenhouse gas emissions due to reduced maintenance needs.

Externalities are costs or benefits that impact a third party that are not part of the direct decision to implement a given strategy.

DON'T DOUBLE-COUNT!

Care needs to be taken to ensure that costs and benefits are not double-counted. For example, if savings on insurance premiums are tallied as part of the resilience strategy benefits (or deducted from the costs of a strategy), then the benefits need to be considered as payouts minus premiums paid.

In some cases, potential resilience projects may have overlapping costs or benefits. As is the case with many decisions, adopting one resilience measure may completely eliminate the possibility of, or the need for, other options.

ADJUST TIME HORIZON

Moreover, if a proposed action that is part of the strategy ends before the planning horizon is reached, the projected benefits need to be adjusted accordingly. For example, a community's overall resilience planning horizon may extend 50 years out, but a structure built as part of those plans may only have a service life of 30 years. Likewise, if the strategy includes an element that extends beyond the end of the planning horizon, then its residual value needs to be determined. Of course, it is possible that the residual value may be negative. An example: a structure may have served its purpose after 30 years; the community then may incur a cost if it needs to be demolished and hauled away.

Enhancing resilience on a community scale creates value, including co-benefits, even if a hazard event does not strike.

THE RESILIENCE DIVIDEND AND CO-BENEFITS

Just the prospect of a hazardous event can make life difficult. For planners charged with helping communities to make wise decisions about investing in resilience, the uncertainties about how often a particular type of event might strike, its magnitude, and its timing can make conducting a benefit-cost analysis challenging. And it is not surprising that communities generally prefer capital investments based on first-cost considerations expected to produce certain outcomes in the immediate- or short-term. That is the business-as-usual case, and it reflects the reality of limited resources that all communities face.

Nevertheless, there is a growing recognition that enhancing resilience on a community scale creates value, including co-benefits, even if a hazard event does not strike. Focusing on resilience investments can:

- Enable individuals, communities, and organizations to better withstand and recover from a disruption more quickly and effectively.

IDENTIFY NON-MARKET CONSIDERATIONS

STEP 4

Externalities and other impacts may or may not be quantifiable. Some externalities carry more obvious dollar values than others. Residents of homes near a transportation project that is part of a resilience plan may suffer from noise, dust, degraded air quality or traffic restrictions during or after construction.

Economists have several methods for determining and placing a value on this category of costs. They can be determined and considered as "contingent values," based on a survey of homeowners and prospective homeowners in the area, for example. While contingent valuation is based on direct or stated preferences, "hedonic valuation" is an indirect or revealed preference approach to non-market valuation. The ***Economic Decision Guide*** offers more options and details.

Regardless of the method selected, it is important that communities put their ***own*** values on these non-market/non-economic considerations, which may or may not be captured as part of Step 3. For example, the value of tourism lost due to a hazard event may differ from one community to another; if tourism is a vital part of one community's economy, a much greater value should be placed on potential benefits or losses related to its resilience planning.

- Lessen impact of chronic stresses—like crime, poverty, and unemployment—and improve a community's ability to maintain essential functions.
- Improve the community's attractiveness to residents and businesses by adding features and facilities and/or increasing the likelihood of continuity in the face of a hazard event.

This "resilience dividend," as it has been dubbed, means that investment in financing and resources for ***future*** resilience yields ***current*** economic benefits. Those may include co-benefits like increased jobs and enhanced reliability of an infrastructure system, improving the community even in the absence of a hazard event. Taking less obvious benefits into account as part of the economic analysis will help to answer the question: "If the adverse event doesn't happen, was the investment still worthwhile?"

Moving elements of the resilience dividend into upfront benefit-cost assessments of capital investments for resilience projects will likely bolster the case for mainstreaming resilience and help create less vulnerable communities.

DEFINE ANALYSIS PARAMETERS

STEP 5

SELECT DISCOUNT RATE

Generally, communities and individuals consider one dollar to be worth more today than one year from now. Communities considering resilience options that require significant funding need to select a "discount rate." This decision is crucial in selecting candidate resilience strategies; the discount rate will affect affordability at a particular point in time.

There are several sources for information on typical ranges for discount rates, including the U.S. Government Accountability Office (GAO), which recommends a 7% rate for cost-benefit studies. For life-cycle cost analyses, GAO recommends a rate tied to the U.S. Treasury's borrowing rate. The federal Office of Management and Budget (OMB) also provides voluntary guidance on discount rates to be used in economic analyses, as do other agencies. Private companies tend to use higher discount rates. For most jurisdictions, the cost of obtaining capital is the most reasonable choice for discount rate. It also is important to keep in mind that different types of infrastructure projects may require different discount rates in any analysis.

DEFINE PROBABILITY DISTRIBUTIONS

The ***Economic Decision Guide*** treats extreme hazard events as discrete, relatively rare events with significant long-term consequences. Still, the

HAZARD LEVELS FOR PLANNING

The ***CRPG*** encourages communities to define three hazard levels for planning purposes: routine, design, and extreme.

- ***Routine hazard:*** A high-frequency/low-consequence event. It is expected to occur more often than the design hazard, but result in a stress on the built environment below the design level causing little/no damage or disruptions.
- ***Design hazard:*** The level designed for in the codes and standards for buildings, bridges, and similar infrastructure systems. Some disruption can be tolerated at this level.
- ***Extreme hazard:*** Low-frequency/high-consequence event. It is expected to occur far less often than the design hazard, but produce shocks on the built environment far exceeding their designed capability.

frequency and hazard level of multiple disruptive events clearly matter and should be factored into economic analysis.

In addition, while the economic analysis should consider all possible consequences of an event, the ***Economic Decision Guide*** recommends using three hazard levels—routine, design, and extreme—to provide key points on the hazard probability distribution. The ***Economic Decision Guide*** provides guidance on the actual probability distribution communities may employ based on codes and standards, as well as the scenarios the community may have developed for resilience planning purposes.

Since analysts need to estimate expected costs and benefits associated with competing investment scenarios, assumptions about benefits (for example, the expected reduction in losses) must take into account the uncertainties of disaster occurrences and outcomes. Of course, typical uncertainties related to estimating cost also must be factored in. Some of those uncertainties will depend on the timing and severity of the disaster itself, like response and recovery costs. The ***Economic Decision Guide*** offers specific guidance about performing probability analyses, including sensitivity considerations.

DEFINE RISK PREFERENCE

For a community that is risk neutral, a 10% chance of a $1 million disaster is equally distasteful as a 1% chance of a $10 million disaster. But most jurisdictions are likely to be more averse to the consequences of a few, large disruptive events than to many small events.

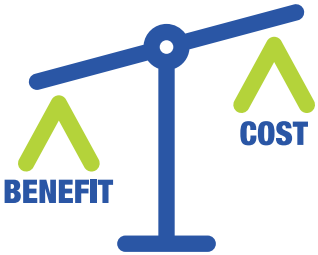
Risk aversion may change over time in response to experience and exposure to actual hazard events, and when insurance is taken into account. Still, some measure of the degree of risk aversion is needed—that is, the level of uncertainty the community is willing to accept in expected outcomes, or returns to investments made against hazard events. Risk aversion is sensitive to risk attitudes, but also to budget constraints and competing investment options. Once quantified, incorporating risk aversion is straightforward using standard economic methods. The basic approach is to employ "utility"—the usefulness or satisfaction that people get out of a certain level of consumption rather than value. The ***Economic Decision Guide*** provides additional detail about options for determining risk.

PERFORM ECONOMIC EVALUATION

STEP 6

The "meat and potatoes" of the economic analysis of community resilience options involves performing the economic evaluation. The ***Economic Decision Guide*** offers several approaches:

- ***Compute Present Expected Value***. This part of the analysis will answer the key question, "How do you value resilience strategies?"
- ***Alternative Formulations***. "Expected utility" is a popular economic strategy for choosing between alternative approaches when there is uncertainty in the potential outcomes. The ***Economic Decision Guide*** presents commonly used techniques that are especially relevant to the NIST ***Community Resilience Planning Guide***.
- ***Evaluate Impact of Uncertainty***. There are many uncertainties in estimating the present expected net benefits for a mitigation strategy, including:



  - The timing and likelihood of future hazards.
  - The amount of damage a future hazard will cause.
  - Future costs of mitigation strategies.
  - The discount rate preferred by the community.
  - The degree of risk-aversion held by the community.
  - Uncertainty about the validity of models used to estimate present expected net benefits.

RANK STRATEGIES
STEP 7

The final step is to rank strategies for implementation—after accounting for relative net benefits and considering constraints and non-market considerations.

The optimal choice is the combination of actions whose total cost is affordable and offers the greatest net benefit. If five resilience planning options have been assessed, perhaps three will be possible to implement given a community's constraints. These three resilience options may have planning elements in common – these duplications should be removed before implementing the resilience plans. In some cases there are interactions between resilience options. For example, if one plan calls for building a seawall then other parts of resilience options to be implemented, such as beach nourishment or breakwaters, are no longer needed.

With the baseline benefit-cost analysis and sensitivity analyses completed, the remaining portions of Step 7 can begin.

PLAN PREPARATION, REVIEW, AND APPROVAL

Each alternative community resilience strategy consists of actions likely to be staged over time so they can be worked into the community's capital budgeting process. It is vital that the economic analyses are integrated into the community's resilience and other planning documents to promote an understanding of its merits by decision makers and stakeholders. That includes:

- Recommending a cost-effective resilience investment strategy.
- Providing a rationale for the recommendation considering the baseline and sensitivity analyses.
- Explaining why an alternative still ranks high if it did not have the best measure of economic performance.

PLAN IMPLEMENTATION AND MAINTENANCE

The plan must be a living document. New information on costs and benefits—including unforeseen spillover benefits and unintended consequences—will emerge and should be integrated into the resilience plan as well as the community's economic development and other long-range plans.

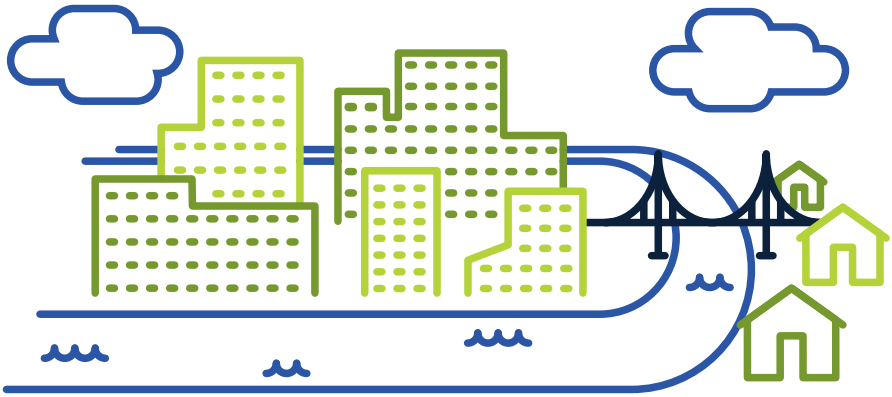
THE ECONOMIC DECISION GUIDE IN ACTION

The NIST ***Community Resilience Planning Guide*** uses a fictional community, Riverbend, USA, to illustrate the planning process. The ***Economic Decision Guide*** selects two candidate strategies under consideration by Riverbend to address an issue with its transportation and water infrastructure: a four-lane interstate bridge between Riverbend and a neighboring community. That bridge is the only crossing that carries traffic, including emergency vehicles, and clean water into the city. It is vulnerable to flood and earthquake events. The Riverbend planning team's options address concerns about the bridge and aim to improve overall community resilience.

The first option: Upgrade the bridge, which is scheduled and budgeted for a deck replacement in 10 years. Upgrading the bridge included completing a seismic update, elevating the bridge deck, and mitigating against scour at the piers. Replacing the deck requires closing the bridge, which will force a longer route for emergency services and regular traffic. The costs that users will incur from a detour and the deterioration of alternate route roads are classified as indirect costs.

The second option: Add a bridge designed to the most current codes and intended to last 125 years. This second crossing would relieve congestion during high traffic periods and also provide additional water supply, which will be a co-benefit to Riverbend's long-term development plans. The new bridge would allow traffic to be shifted when the existing bridge is replaced, reducing the detour and its associated costs, and providing better performance in case of an earthquake. This option also would introduce multiple benefits associated with providing a path for pedestrians and bicyclists.

The chart to the right summarizes the economic evaluation of these two options, using the ***Economic Decision Guide's*** process.



Economic Evaluation for Resiliency of Bridge Options in Riverbend, USA

STEP	CONSIDERATIONS
Select Candidate Strategies	Option 1: Retrofit Option 2: New Construction
Define Investment Objectives & Scope	
Define Economic Objective Function	Maximum Net Benefits
Define Planning Horizon	50 year
Identify Constraints	None
Identify Benefits & Costs	
Identify Costs & Losses	Option 1: Construction costs; business interruption costs Option 2: Construction costs; business interruption costs; maintenance costs
Identify Savings & Benefits	Option 1: Reduced (direct) bridge damage; reduced response costs; reduced recovery costs; reduced (indirect) business interruption Option 2: Reduced response costs; reduced recovery costs; reduced (indirect) business interruption; shortened commute time
Identify Non-Market Considerations	Value of a Statistical Life: $7.5 million (M)
Define Analysis Parameters	
Select Discount Rate	5%
Define Probability Distribution	Disaster Reoccurrence: 25 years (4% annual probability) Disaster Magnitude: Direct damage ~ 1/16 replacement cost Option 1 Costs: $3M direct; $0.5M indirect Option 2 Costs: $4.25M direct; $0.05M indirect; $0.025M maintenance Option 1 Benefits: $0.26M direct loss reduction; $2M indirect loss reduction; $0.6M response & recovery cost reduction; 0.1 fatalities averted Option 2 Benefits: $3.5M indirect loss reduction; $1M response and recovery cost reduction; 0.2 fatalities averted; $0.1M non-disaster related benefits
Define Risk Preference	Risk neutral

WHAT TO EXPECT

The National Institute of Standards and Technology is committed to its investment in community resilience planning, ensuring that its Guides are relevant and used to achieve impact. To meet this goal:

- The Guide and companion documents and tools can be downloaded at ***www.nist.gov/el/resilience***.
- NIST has released the EDGe$ (Economic Decision Guide Software) Tool based on the methodology in the EDG. The EDGe$ Tool is a powerful software-based technique for electing cost-effective, infrastructure-based community resilience projects. EDGe$ helps to identify and compare relevant present and future resilience costs and benefits associated with identified investment alternatives versus maintaining a community's status quo. More information about the software can be found at: ***https://www.nist.gov/services-resources/software/edge-economic-decision-guide-software-tool.***
- Multiple communities—of different jurisdictional type and sizes—across the country are now using the Guide to plan for improved resilience as they address a variety of potential hazard events. See the Success Stories capturing the highlights of their experiences, including lessons learned at ***www.nist.gov/el/resilience***.

OTHER ASSISTANCE

Improving community resilience must take economic considerations into account, and analyzing those factors isn't easy. The NIST ***Community Resilience Economic Decision Guide for Buildings and Infrastructure Systems*** is likely to help. Get it at ***www.nist.gov/el/resilience***. This brochure offers a quick overview of that process. For more information, answers to your questions, and to receive regular updates, contact resilience@nist.gov. Have a suggestion? Please forward your observations and ideas to ***resilience@nist.gov***.

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