WHAT IS A BENEFIT?

GUIDANCE ON BENEFIT-COST ANALYSIS

OF HAZARD MITIGATION PROJECTS

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There is little doubt that flood-proofing a school, installing hurricane shutters on a beachside home, or seismically retrofitting a heavily-traveled bridge can bring substantial benefits to a community. Reducing the risk of damage from a natural disaster has the potential to save lives, significantly lower cleanup and recovery costs, and minimize the amount of time it takes for a community to return to normal among many other benefits.

While it may seem clear that activities that reduce the damage caused by natural disasters would bring a host of benefits, it is far less obvious how we would actually categorize and quantify these benefits. What kinds of benefits *do* activities like flood-proofing a school or upgrading a drainage channel provide? The purpose of this analysis is to help answer this question by identifying the benefits associated with hazard mitigation projects; demonstrating ways to quantify benefits for use in the benefit-cost analysis (BCA) of hazard mitigation projects; and presenting several applied examples of calculating the benefits of mitigation.

1.1 What is Mitigation?

Mitigation is an action taken specifically to reduce ***future*** damages and losses from natural disasters. Most Hazard Mitigation Grant Program (HMGP) mitigation projects are construction projects that are designed to avoid or reduce damages to buildings or infrastructure in future disasters. In addition to reducing damages to a facility or building structure, many mitigation projects also reduce the broader negative impacts that disasters have on affected communities, such as the economic effects of regional loss of power.

Examples of common mitigation projects include:

- Acquiring flood-prone structures to remove them from the floodplain,
- Elevating flood-prone structures,
- Improving storm water drainage systems,
- Adding hurricane shutters to improve building wind resistance,
- Strengthening buildings or infrastructure to resist earthquakes, and
- Bracing building contents to resist earthquakes.

Mitigation projects may also include education programs, publications or videos, building code enhancements, and mitigation planning activities, but only if such projects demonstrably result in actions which reduce future damages and losses. These types of “soft” mitigation projects are sometimes excluded by FEMA policies or priorities and are generally more difficult to evaluate than the more common types of “hard” mitigation projects listed above.

Mitigation is conceptually distinct from repair of damaged facilities. After disasters, many damaged facilities are simply repaired to their pre-disaster condition. Such repair actions are not mitigation because they do not reduce the potential for future damages and losses. However, after a disaster some projects may include both repair and mitigation. In this case, the costs of repair and mitigation must be separated. The guidance for benefit-cost analysis in this document applies only to mitigation projects, or only to the mitigation portion of projects that include both repair and mitigation elements.

1.2 What are Benefits?

The benefits of a mitigation project are the elimination and/or reduction of future damages and losses. In other words:

Benefits are simply avoided damages and losses.

For every mitigation project, benefits are calculated by estimating future damages and losses under two circumstances: with and without undertaking the mitigation project. As a simple example, consider a mitigation project to elevate a single flood-prone residential structure. Assume that future damages and losses for this home are estimated as $5,000 per year for the as-is situation (without mitigation). After elevation, future damages and losses are estimated as $500 per year. In this example, the benefits of the mitigation project are $4,500 per year. The $4,500 in annual benefits is calculated as the difference in estimated future damages and losses before and after mitigation ($5,000 minus $500).

For benefit-cost analysis, much of the effort is focused on estimating damages and losses. This focus on damages and losses is sometimes confusing to novices. However, as illustrated by the example above, mitigation project benefits can only be calculated by estimating damages and losses both before and after the mitigation project and then taking the difference between the two.

There are two aspects of counting benefits that are particularly important to keep in mind when conducting benefit-cost analyses of mitigation projects. First, mitigation projects reduce future damages and losses, but generally do not completely eliminate future damages and losses. Acquisition is the only type of mitigation project that completely eliminates future damages and losses. All other mitigation projects reduce future damages and losses but do not completely eliminate them. For example, mitigation projects to elevate structures for floods or to strengthen structures for hurricanes or earthquakes may greatly reduce future damages, but some level of damages will still occur, especially in major disasters. Thus, except for acquisition projects, it will always be necessary to estimate damages and losses after mitigation.

Second, for every mitigation project, the greater the damages and losses are before mitigation, the greater are the potential benefits.

For example, if damages before mitigation are estimated as $10,000 per year for one house and only $500 per year for another house, then the maximum possible benefit for the first house is $10,000 per year and only $500 per year for the second house. The maximum level of benefit can be achieved only if the estimated damages and losses are completely eliminated by a mitigation project (i.e., by acquiring and demolishing the house). The relationship between damages and losses before mitigation and the maximum possible benefit achieved after mitigation is very important. The best mitigation projects are often those where the damages and losses are greatest before mitigation is undertaken. In other words, the greater the damage and losses are prior to mitigation project, the greater the potential benefits of mitigation. Conversely, when the damages and losses before mitigation are minor, the maximum possible benefits are limited. This relationship is very important for mitigation planning. Mitigation projects providing the highest level of benefit can be identified simply by finding the structures or facilities with the highest risk for future damages and losses.

1.3 What Benefits Should Be Counted?

The goal of FEMA's hazard mitigation program is to reduce the impacts of natural disasters on affected communities. In this context, it is very important to note:

The benefits considered in benefit-cost analysis are the benefits to the community, not just the benefits to FEMA or the federal government. The Office of Management and Budget (OMB) Advisory Circular A-94 (Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs) provides explicit guidance on what benefits to count:

> *Analyses should include comprehensive estimates of the expected benefits and costs to society based on established definitions and practices for program and policy evaluation. Social net benefits, and not the benefits and costs to the federal government, should be the basis for evaluating Government programs or policies that have effects on private citizens or other levels of Government.*

This OMB guidance means that benefits must always be counted from the perspective of the affected community, not from the perspective of FEMA or the federal government. Thus, for benefit-cost analysis of hazard mitigation projects, a broad range of benefits may legitimately be counted, even if Federal programs do not address actually compensate for the damages when they occur.

Some of the benefits to be counted are covered by government programs. Examples of such benefits include avoided damages to public buildings or infrastructure, and emergency management costs (including debris removal) which may be covered under the Public Assistance Program. Other damages and recovery costs may be partially covered by government programs. Examples include avoided damages to private residences and displacement costs for temporary housing, which may be partially covered under FEMA's Individual and Family Grant Program. Other damages, such as deaths and injuries, do not involve any real exchange of money and are not compensated by any government program. Regardless of whether government agencies actually compensate the damages and losses, the OMB guidance directs Federal agencies such as FEMA to count the full direct benefits of hazard mitigation projects. As an example, consider a city hall building damaged in an earthquake. Federal programs may reimburse the city for damages to the city hall and contents, for cleanup costs, and add something else that FEMA would cover or delete, but the Federal government does not provide life insurance for occupants of public buildings. From a community perspective, however, casualties from the earthquake are obviously a major negative effect of the disaster, and hence it is correct and necessary to count the casualties as damages.

The goal of benefit-cost analysis of hazard mitigation projects is always to count ***all*** of the benefits of each mitigation project whether or not the categories of benefits are covered by FEMA programs or programs of other federal agencies.

The broad categories of benefits to be counted are summarized in Section 1.4 below.

1.4 Categories of Benefits

Mitigation projects may be undertaken to reduce the extent of damage from natural disaster for a wide variety of facilities. Mitigation projects may apply to private residential and commercial buildings as well as many types of public buildings from city halls and schools, hospitals, to more specialized buildings providing medical, police, or fire services. Mitigation projects may also cover utilities providing electric power, water and other services as well as a wide range of infrastructure from drainage systems, to roads and bridges, to dams and other specialized structures.

The specific benefits to be counted for each mitigation project depend on the type of facility covered by the mitigation project. Different benefits may be counted for different types of projects. However, conceptually, most of the benefits to be counted for any mitigation project can be sorted into four main categories, as summarized below in Table 1.1.

Table 1.1 Categories of Avoided Damages

Avoided Physical Damages	▪ Buildings ▪ Contents ▪ Infrastructure ▪ Landscaping ▪ Site Contamination ▪ Vehicles ▪ Equipment
Avoided Loss-of-Function Costs	▪ Displacement costs for temporary quarters ▪ Loss of rental income ▪ Loss of business income ▪ Lost wages ▪ Disruption time for residents ▪ Loss of public services ▪ Economic impact of loss of utility services ▪ Economic impact of road/bridge closures
Avoided Casualties	▪ Deaths ▪ Injuries ▪ Illnesses
Avoided Emergency Management Costs	▪ Emergency operations center costs ▪ Evacuation or rescue costs ▪ Security costs ▪ Temporary protective measure costs ▪ Debris removal and cleanup costs ▪ Other management costs

These categories are briefly described below and are discussed more fully in Section 2 of this report. Examples, case studies and guidance on how to count each type of benefit are provided in Sections 3 and 4.

Physical damages are probably the easiest category of damages and losses and benefits to understand. Buildings, contents, infrastructure, landscaping, vehicles and equipment are damaged by a flood or other disaster event. The monetary damages are simply the cost to repair or replace the damaged property. For physical damages, benefits are simply the avoided damages; that is, the reduction in future damages attributable to a mitigation project.

Loss of function economic impacts are losses and costs that are incurred when facilities are damaged to the point that the normal function of the facility is disrupted. Many loss-of-function economic impacts are extra costs incurred by occupants of damaged buildings. For example, occupants of residential, commercial or public buildings may incur displacement costs for temporary quarters when damage levels render buildings unoccupiable after a disaster. The loss of function of buildings may also result in other direct economic impacts to occupants such as loss of rental income, loss of business income, or lost wages as well as disruption time (time spent in cleanup, repair, and replacement of damaged property and so on).

In addition, loss of function of some types of facilities may have negative impacts on the community as a whole. For public buildings, loss of function also means loss of the public service provided from the building; such loss of public service has a direct impact on the community. Similarly, loss of utility or transportation services may have large direct economic impacts on affected communities as a whole.

Mitigation projects that reduce physical damages to buildings and other facilities also reduce the loss of function of the facilities, so benefits from mitigation projects often include reducing loss-of-function impacts. The types of reduced loss-of-function benefits to be counted vary, depending on the type of facility, but these benefits can be large and important to count in benefit-cost analysis. For some types of mitigation projects, especially for utilities, roads, bridges, and critical facilities such as hospitals, the benefits of avoiding the loss-of-function impacts are *always* important and may be larger than the benefits of avoiding physical damages. Indeed, many mitigation projects for these types of facilities are undertaken primarily to preserve the critical function of the facility, with reduction of physical damages being an important, but secondary consideration.

> **For important community operations, loss of function is often the most severe impact of a hazard event, so it is critically important to correctly count the losses and the benefits of avoiding some or all of them.**

Casualties include deaths, injuries and illnesses. For some types of mitigation projects, such as seismic retrofit of buildings, reducing casualties is often the main reason a project is undertaken. Whenever a specific mitigation project demonstrably reduces the future potential for casualties, it is proper and necessary to count the benefits of reduced casualties.

Emergency management costs include a range of disaster response and recovery costs that may be incurred by communities during and immediately after a disaster. In many disasters, these costs are much smaller than physical damages or loss-of-function economic impacts. Furthermore, many common mitigation projects have little or no significant impact on a community's emergency management costs. However, in circumstances where a project affects a large part of a community and may significantly reduce future emergency management costs; counting the benefits of reduced emergency management costs is proper. For most projects, however, the benefits in this category are negligible or very small. Thus, in most cases it may not be necessary to make the effort to estimate the benefits of reduced emergency management costs. In cases where a project has a benefit-cost ratio very close to 1.0 and has significant potential benefits in reducing future emergency management costs, it may be worthwhile to calculate the damages from this source, and the benefits of reducing or eliminating them.

1.5 What Benefits Cannot Be Counted?

As summarized above, the intent of benefit-cost analysis is to count all benefits for each hazard mitigation project, whether or not FEMA or other Federal government programs cover the benefit category. . However, OMB Circular A-94 does place one important limit on the types of benefits than can be counted. In simple terms, the OMB guidance is to NOT count indirect or secondary benefits. The technical language in Circular A-94 is:

> *Employment or output multipliers that purport to measure the secondary impacts of government expenditures on employment and output should not be included in measured social benefits or costs*

In simpler terms, this means that the possible impact of a mitigation project on local or regional employment or on overall economic output or economic activity should not be counted. Therefore, changes in employment levels, economic growth or development, tourism, or future tax revenues should not be considered in benefit-cost analysis.

The focus of OMB guidance on benefit-cost analysis is thus to count direct benefits; that is, to count the damages and losses that would be incurred in the future if the mitigation project were not completed. Such direct benefits include: avoided physical damages, avoided loss-of-function costs incurred by the affected community, avoided casualties, and avoided emergency management costs. Other, more indirect or secondary impacts should not be counted.

This policy guidance from OMB applies to FEMA and to all other federal agencies that do benefit-cost analysis except for the U.S. Army Corps of Engineers (USACE). USACE benefit-cost analysis of projects for navigable waterways is separately mandated by legislation to include a broader range of long-term regional economic impacts, reflecting the large scale and long-term regional economic impact of many Corps projects. Thus, USACE benefit-cost analysis may include benefits that are not countable for most other Federal benefit-cost analysis.

Detailed guidance on what direct benefits to count for particular types of projects, with examples and case studies are given later in this report.

1.6 What is Benefit-Cost Analysis?

Benefit-cost analysis is a standardized, systematic way to count the benefits of a mitigation project and to compare these benefits to the costs of mitigation. A complete benefit-cost analysis counts ***all*** of the significant direct benefits of a mitigation project.

A benefit-cost analysis always involves looking at damages and losses twice: first, before mitigation (the as-is situation) and second, after mitigation. The benefits of a mitigation project are simply the difference in expected damages and losses before and after the mitigation project are completed.

In more technical detail, a benefit-cost analysis also takes into account:

1. The probabilities of various levels of natural hazard events and damages
2. The useful lifetime of the mitigation project
3. The time value of money (the discount rate)

As a quick review, the underlying principles of benefit-cost analysis are illustrated by one simplified example. Consider a mitigation project to elevate a single flood-prone residential structure. Annualized damages are calculated for each flood depth by estimating each damage category and then taking into account the annual probability of each flood depth. First, annualized damages are estimated before mitigation by combining the probability of each level of flooding with the estimated damages and losses at each flood depth. For a residential structure, the damages considered typically include building damages, damages to contents, and displacement costs for temporary housing (refer to Table 1.2).

Table 1.2
Example Showing Principles of Benefit-Cost Analysis
Damages Before Mitigation

Flood Depth (feet)	Annual Probability of Flooding	Scenario Damages and Losses (per flood event)	Annualized Damages and Losses
0	0.2050	$6,400	$1,312
1	0.1234	$14,300	$1,765
2	0.0867	$24,500	$2,124
3	0.0233	$28,900	$673
4	0.0098	$32,100	$315
5	0.0034	$36,300	$123
Total Annualized Damages and Losses (Before Mitigation)			**$6,312**

In the Table 1.2, the scenario damages (damages per flood event) increase with increasing flood depth in the home, as expected. However, the annualized damages, which also take into account the probability of flooding, are lower at high flood depths because such floods are very infrequent at this site.

The total annualized damages and losses, $6,312 in the above example, indicates the level of risk faced by the property. The greater the frequency and depth of flooding for a given home, the higher the annualized damages and losses. To the extent that a mitigation project reduces or eliminates these damages and losses, the greater the potential benefits of the mitigation project.

For benefit-cost analysis, a similar calculation is done after mitigation, and then benefits are calculated as the difference between annualized damages with and without undertaking the mitigation project (as shown in Table 1.3).

Table 1. 3
Example Showing Principles of Benefit-Cost Analysis
Summary Calculation

Flood Depth (feet)	Before Mitigation Annualized Damages (from Table 1.2)	After Mitigation Annualized Damages	Annualized Benefits (Avoided Damages) "Before Mitigation" – "After Mitigation"
0	$1,312	$0	$1,312
1	$1,765	$0	$1,765
2	$2,124	$0	$2,124
3	$673	$0	$673
4	$315	$63	$252
5	$123	$49	$74
Totals	**$6,312**	**$112**	**$6,200**
Present Value Coefficient (7% discount rate, 30 year project lifetime)			12.41
Net Present Value of Future Benefits			$76,942
Mitigation Project Costs			$20,000
Benefit-Cost Ratio (Net Present Value of Future Benefits ÷ Project Costs)			**3.85**

In this example, the annualized benefits are calculated as the difference in the annualized damages before and after mitigation. The benefits of this mitigation project are assumed to occur over a 30-year useful lifetime of the mitigation project. To compare this future stream of statistical (probabilistic) benefits to the present cost of the mitigation projects, a present value calculation is done. The present value calculation depends on the project useful lifetime and on the discount rate that accounts for the time value of money. For FEMA projects, the discount rate is specified by OMB Circular A-94 as 7%. The present value coefficient, which depends on the project useful lifetime and the discount rate, is a multiplier that converts the annualized benefits to net present value.

In this example, the annual benefit of $6,200 corresponds to a net present value of benefits of $76,942. The benefit-cost ratio of 3.85 indicates that the benefits are 3.85 times the costs. In other words, for each dollar spent on mitigation there is an expected return of $3.85 in reduced damages and losses.

1.7 Why Does FEMA Do Benefit-Cost Analysis?

There are four primary reasons why FEMA does benefit-cost analysis of hazard mitigation projects:

1. To meet the statutory and regulatory requirement eligibility requirement, as specified in the Stafford Act and in 44 CFR. To be eligible for FEMA funding under the HMGP or Flood Mitigation Assistance (FMA) program, each mitigation project must be shown to be cost-effective. As defined in the regulations, cost-effective means that the benefits of each project must exceed the costs (i.e., that the benefit-cost ratio exceeds 1.0).
2. To determine whether or not a mitigation project is worth doing.
3. To provide a common basis with which to compare and prioritize mitigation projects and to help ensure that limited mitigation funds result in the greatest possible reduction in future damages and losses.
4. To demonstrate that mitigation works. Benefit-cost analysis can be a powerful tool to help sell the concept of mitigation and to convince individuals and communities that mitigation investments are in their own self interest. For the HMGP and FMA program overall, benefit-cost analysis helps to demonstrate that the programs and their actions are fiscally sound.

The statutory and regulatory basis of FEMA's benefit-cost analyses is outlined in the Stafford Act and in the program regulations in the Code of Federal Regulations.

1.7.1 The Stafford Act

FEMA's disaster assistance activities, including the HMGP, are enabled by the Robert T. Stafford Disaster Relief and Emergency Assistance Act. The intent and purpose of the Stafford Act is spelled out in Section 102 (2):

> *to supplement the efforts and available resources of States, local governments and disaster relief organizations in alleviating the damage, loss, hardship, or suffering caused by major disasters.*

Hazard mitigation activities, which by their nature are designed to alleviate the damage, loss, hardship, and suffering caused by natural disasters, are addressed in Section 404 of the Stafford Act:

> *The President may contribute up to 50 percent of the cost of hazard mitigation measures which the President has determined are cost-effective and which substantially reduce the risk of future damage, hardship, loss, or suffering in any area affected by a major disaster.*

1.7.2 44 CFR, Emergency Management and Assistance

The requirement that each mitigation project must be cost-effective is described in Section 44 206.434 Eligibility (Code of Federal Regulations, 44 Emergency Management and Assistance, Revised as of October 1, 1998). Section 206.434 specifies the eligibility requirements for Hazard Mitigation Program Grants:

> *"(b) Minimum project criteria. To be eligible for the Hazard Mitigation Grant Program a project must:*
>
> *(5) Be cost effective and substantially reduce the risk of future damage, hardship, loss, or suffering resulting from a major disaster. The grantee must demonstrate this by documenting that the project;*
>
> > *(i)Addresses a problem that has been repetitive or a problem that poses a significant risk to public health and safety if left unsolved,*
> >
> > *(ii) Will not cost more than the anticipated value of the reduction in both direct damages and subsequent negative impacts to the area if future disasters were to occur. Both costs and benefits will be computed on a net present value basis,*
> >
> > *(iii) Has been determined to be the most practical, effective and environmentally sound alternative after consideration of a range of options,*
> >
> > *(iv) Contributes, to the extent practicable, to a long-term solution to the problem it is intended to address,*
> >
> > *(v) Considers long-term changes to the areas and entities it protects, and has manageable future maintenance and modification requirements.*

The goal of benefit-cost analysis of hazard mitigation projects is always to count the benefits of each mitigation project whether or not the categories of benefits are covered by FEMA programs or programs of other federal agencies.

The OMB Guidance to count the social net benefits, not only the benefits to the federal government, also applies on the cost side of benefit-cost analysis. Thus, it is always the total cost of the project that is included in the analysis, not the FEMA share of the cost. For example, consider a mitigation project with a total cost of $500,000 and calculated benefits of $300,000 (i.e., a benefit-cost ratio of 0.60). This project fails the cost-effectiveness criterion. From the perspective of the community as a whole, the benefits are less than the cost of the project. This conclusion does not depend on what fraction of the project is FEMA funded, even if FEMA funds less than $300,000 of the project cost, because the OMB guidance for benefit-cost analysis requires the entire project be cost-effective in order to be eligible for funding.

As discussed in Section 1, the benefits of mitigation projects are future damages and losses avoided by undertaking the mitigation project. Damages and losses become benefits when they are avoided by a mitigation project. This section describes the major categories of damages and losses estimated before and after mitigation; the estimates of damages and losses are then used to calculate the benefits of avoided such damages and losses.

In most cases, FEMA's goal is to count fully all of the benefits of each mitigation project. There are four major categories of benefits:

1. Avoided physical damages
2. Avoided loss-of-function impacts
3. Avoided casualties,
4. Avoided emergency management costs

A brief summary of how to count each of these four categories is provided in this section.

2.1 Avoided Physical Damages

Physical damages are the most direct kind of damages and usually are the easiest to count. Physical damages are simply the costs to repair or replace damaged facilities, including buildings, building contents, and infrastructure. Physical damages may also include repair or replacement costs for landscaping, site contamination restoration, vehicles, and equipment. The most common sub-categories of avoided physical damages are:

Buildings

Contents

Infrastructure

Landscaping

Outbuildings

Site Contamination

Vehicles

Equipment

Physical damage estimates (before and after mitigation) are expressed in dollars. For benefit-cost analysis of hazard mitigation projects, damages are often expressed as a percentage of the replacement value of the damaged element (e.g., a building, the contents of a building, a utility component or a bridge). Damage functions are used to express the percentage damage expected as a function of flood depth for floods, wind speed for hurricanes or level of ground shaking for earthquakes.

For buildings and infrastructure, facilities are generally deemed a complete loss and replaced rather than repaired whenever the damage percentage exceeds a value known as the demolition threshold. For buildings, a 50% demolition threshold is often assumed. For outdated or marginal buildings, much lower demolition thresholds are sometimes appropriate. Similar concepts apply to infrastructure damages.

Guidance for evaluating physical damages is summarized below in Table 2.1. FEMA has developed typical or default damage functions that express the expected percentage damage for buildings and contents. These damage functions are most useful for ordinary residential, commercial or public buildings and may have to be modified for more specialized buildings, using historical damage data, professional judgment, or both.

There are no typical or default damage functions available for estimating the other sub-categories of physical damages. For these categories, historical data and professional judgment are used to make damage estimates.

Table 2.1
Summary Guidance for Physical Damage Estimates

Type of Facility	Level of Technical Expertise Required	Typical Data Sources
Residential buildings	Low	Historical damage data Professional judgment
Commercial buildings	Low	Historical damage data Professional judgment
Public buildings	Low	Historical damage data Professional judgment DSRs if available
Specialized buildings for police, fire, and medical facilities	Moderate	Historical damage data Professional judgment Default damage functions may need to be adjusted
Contents, ordinary or specialized buildings	Low to moderate	Historical damage data Professional judgment

Type of Facility	Level of Technical Expertise Required	Typical Data Sources
Infrastructure (including utility and transportation elements)	Moderate to high	Historical damage data Specialized engineering experience with these type of facilities is essential
Landscaping damages and yard cleanup	Low to moderate	Historical data Professional judgment
Site contamination restoration	Moderate to high	Historical data Specialized engineering experience helpful
Vehicles and equipment	Moderate to high	Historical data Professional judgment

2.2 Loss-of-Function Impacts

The negative impacts of a disaster on a community often go far beyond the physical damages alone. Loss-of-function impacts are the losses, costs and direct economic impacts that occur when physical damages are severe enough to interrupt the function of a building or other facility. For a building, loss-of-function impacts may include the costs for temporary quarters while repairs are made, as well as losses in rental income, business income, or public services provided from the building. For utilities, loss of function means a loss of service or a reduction in the level of service. For a road or bridge, loss of function means closures of a road or bridge, or delays arising from a reduction in traffic capacity of a damaged road or bridge.

Loss-of-function impacts are sometimes as important as or even more important than the direct physical damages. For example, the loss of function of a hospital or fire station or other facility critical to the emergency response and recovery during and immediately after a disaster may have a much greater economic impact on the community than simply the repair costs for the physical damages. Similarly, loss of electric power or potable water service has a much larger economic impact on a community than simply the costs to repair damage to the electric power or water systems. Thus, to fully count the benefits of each hazard mitigation project it is very important to count all of the benefits of avoiding loss-of-function impacts.

The type of loss-of-function impacts to be counted varies depending on the type of facility under evaluation. Some of the sub-categories of loss-of-function impacts are somewhat more difficult to understand and to calculate than the more self-evident physical damage sub-categories. As a result, loss-of-function impacts have often been only partially counted or not counted at all when conducting benefit-cost analyses of hazard mitigation projects. Undercounting loss-of-function impacts is a serious error that may result in highly meritorious and highly cost-effective mitigation projects being improperly rejected. The most common sub-categories of loss-of-function impacts are:

- Displacement costs for temporary quarters
- Loss of rental income
- Loss of business income
- Lost wages
- Disruption time for residents
- Loss of public services
- Economic impact of loss of utility services
- Economic impact of road/bridge closures

2.2.1 Displacement Time and Functional Downtime

Estimating loss-of-function economic impacts for a building or other facility always requires two steps. First, the time duration of the interruption of function must be estimated, and second, the economic value per unit time of interruption of service must be estimated.

For purposes of benefit-cost analysis, displacement time and functional downtime must be considered. **Displacement time** is the time period during which occupants are displaced from a building so repairs can be made. For low levels of damage, displacement time is generally zero; that is, minor repairs can be made without displacing occupants. **Functional downtime** is the time period during which services are lost.

Functional downtime may be much shorter than displacement time. For example, consider a city hall building that is badly damaged in a disaster. The occupants of the building may be displaced to temporary quarters for six months - this is the displacement time. Displacement costs are estimated from the displacement time and the daily or monthly cost of displacement. However, in this simple example, the functional downtime is much less than six months. If the services are re-established in the temporary quarters in two weeks, then the functional downtime is only two weeks, not six months.

Functional downtime can also be fractional. One day of functional downtime can be one day of complete loss of service, or two days of 50% loss of service, or 10 days of 10% loss of service, and so on.

For utility and transportation systems, there are generally no displacement costs because such service generally can't simply be moved to temporary quarters. Thus for these systems the loss-of-function economic impacts are calculated from the estimated functional downtime and the value of the service per day.

2.2.2 Loss-of-Function Impacts for Buildings

For buildings, loss-of-function impacts may include the following categories: displacement costs, loss of rental income, loss of business income, loss of wages, loss of public services, and disruption time.

Displacement costs are the extra costs incurred when occupants of a building are displaced to temporary quarters. Displacement costs may be incurred for residential, commercial, or public buildings. Displacement occurs only when damages to a building are sufficiently severe that the building cannot be repaired with occupants in place. At lower levels of damage, repairs are commonly made with occupants remaining in the building during the repair process.

Displacement costs include the following sub-categories of costs:

1. Rental costs for temporary quarters
2. Other monthly costs of displacement such as furniture rental, other costs of being in temporary space, extra commuting costs, etc.
3. One-time costs such as utility hookup fees, round-trip moving costs, etc.

Displacement costs are the most commonly counted loss-of-function impact. The necessary data is straightforward and relatively easy to obtain. Rental costs for temporary quarters can be obtained from local officials or real estate firms. Estimates for other monthly costs and one-time moving costs can be provided by applicants or estimated using common sense.

Rental income losses are incurred by owners when tenants vacate premises because of damages, resulting in a loss of rental income for the owner. Rental income losses may apply to any building that is rented (residential, commercial, or public).

Analysts should be aware of the potential for double-counting rental income losses. Consider an example where two homes are damaged by floods and the occupants are displaced to temporary quarters for several months while repairs are made. If one home is owner-occupied, the owner is still responsible for mortgage and tax payments on the home in addition to paying rent and other expenses for temporary quarters. In this case, the full displacement costs for temporary quarters are additional expenses and should be counted. However, for a rented home, the economics are different. If a renter is displaced to temporary quarters, then he/she no longer pays rent for the damaged facility. This loss of rental income is a loss to the owner and may be counted as part of the loss-of-function impacts for the building. However, in this case, the displacement costs for the renter must be adjusted to consider only the possible increase in rent above the previous rent, rather than the total cost of rent at the temporary quarters. Counting the displacement costs for the renter and the full loss of rental income for the owner is double-counting and must be avoided.

The simplest way to avoid potential double-counting is to not count rental income losses. If this is done, then the full displacement costs should be counted for both owners and renters. Counting the full displacement costs for renters, does, in effect, count the lost rental income. This approach has the additional advantage that it is no longer necessary to determine whether occupants of buildings are owners or renters.

Loss of business income may occur for commercial buildings when damage is severe enough to result in temporary loss of function of a building. For benefit-cost analysis, the proper measure of loss of business income is the net income, not the gross income since expenses as well as receipts are lower when a business is closed.

Estimates of net business income losses can generally be obtained from applicants, the owners, or local officials. In making estimates of net business income losses, it is important to remember that some lost business income can be made up. For example, a business that is closed for two weeks because of hurricane damage does not necessarily lose two weeks of net business income. In many cases, some of the lost sales or income will be made up after the business reopens.

FEMA considers relatively few mitigation projects for commercial buildings. In most cases, the loss of business income constitutes only a very small fraction of total damages and losses. Thus, the benefits of avoiding or reducing loss of business income are generally only a small fraction of total damages and losses. For projects that are clearly cost-effective, it may not be necessary to consider business income losses to demonstrate cost-effectiveness. However, to count fully the benefits of hazard mitigation projects for commercial buildings, it is necessary to consider loss of business income.

Loss of wage income may also occur for commercial buildings, when damage is severe enough to result in temporary loss of function of a building. When a business closes temporarily due to damages, loss of wages for employees is analogous to the loss of business income for the owner. Historically, loss of wage income has not been considered in FEMA's benefit-cost analysis. In economic theory, wages are considered fungible, that is, movable or transferable, and it is commonly assumed that wage earners who lose one job find another. However, since loss of wages due to disaster damage is short-term and not predictable, the assumption of fundability does not appear to apply.

The intent of the Stafford Act is to alleviate the "damage, loss, hardship, and suffering" caused by major disasters. In this context and for consistency with regard to counting losses in net business income, counting loss of wage income is appropriate for benefit-cost analysis of hazard mitigation projects. For purposes of benefit-cost analysis, wage income losses to be counted are only short-term losses due to temporary business closes. The wage losses to be counted are primarily those for hourly workers. Wage losses for salaried workers should not be counted unless these workers are also laid off without pay. Wage losses should be counted as business income losses only to the extent that they are not likely to be made up later after the business reopens.

Situations where a business may leave town with permanent loss of wages (if, for example, some flood protection improvements are not made) should not be counted because such impacts fall under the type of secondary impacts on employment or output that are excluded from consideration under OMB guidance.

Loss of wages for public employees should not be counted for two reasons: 1) most public employees are likely to continue to receive wages during and after disasters, and 2) the value of public sector wages is already included in evaluating the loss of public services.

Loss of hourly wages due to temporary business closures due to disaster damage should include the full value to employees, wages plus benefits. Local data on wages and benefits are generally available from local officials. If not, national average data may be used. As discussed in Section 7 of this report (Roads and Bridges), the current national average for wages and benefits is $21.16 per hour.

Economic value of disruption time for residents is the value of lost time incurred by residents for pre-disaster preventative measures, evacuation time, cleanup and repair of flood damages, replacement of damaged property, dealing with insurance claims and other disaster-related matters. The key economic concept is that personal time has value, whether or not the time is formally compensated by employment. Outlined below is an approach closely analogous to that adopted by the U.S. Department of Transportation (DOT) in calculating the benefits of reducing travel time delays. The simplest assumption consistent with economic theory is that each hour of time is worth the same amount, whether such time is personal or business, compensated or not. In other words, the last hour of work time and the first hour of leisure time are assumed to have equal value. This is the assumption suggested in Section 7 (Roads and Bridges) for placing a value on delay or detour times due to closures of roads and bridges. The same economic principles apply to personal time lost due to disaster damages to residential structures. Placing an economic value on personal disruption time is consistent with the DOT's approach and with the intent of the Stafford Act to alleviate the "damage, loss, hardship, and suffering" caused by major disasters.

The economic value of disruption time for residents is estimated at $21.16 per hour, the national average value for wages and benefits.

Loss of Public Services may occur for public buildings when damage is severe enough to result in temporary loss of function of the building. For purposes of benefit-cost analysis, private non-profit organizations providing what are essentially public services (e.g., the Red Cross, schools, and hospitals) are evaluated in exactly the same manner as public buildings. For commercial buildings, the loss of net business income is a measure of the economic impact of loss of function of the building. For public buildings, the measure of the economic impact of loss of function is the value of the services provided to the community by the agencies operating in the building.

To value public services, FEMA makes the very simple and direct assumption that public services are worth what it costs to provide the services to the public. For example, if a public service costs $1,000 per day to provide, then the value is assumed to be $1,000 per day. If the service is lost because of damage to the building, the loss is assumed to be $1,000 per day. If the loss of service is avoided because of a hazard mitigation project, then the benefit is assumed to be $1,000 per day.

The daily cost of services is estimated from the annual operating budget for the agencies occupying a building. The annual operating budget includes all of the direct costs necessary to provide the public services, including salaries and benefits, materials, supplies, utilities, equipment costs, and rent or the annual cost of owning the building. The only exclusion is for transfer payments. For example, if a public office distributes pension checks, the value of the service is not the value of the checks distributed, but rather the cost of providing the service.

This method for valuing the loss of public services applies to all public services, including administrative functions, schools, as well as more specialized services such as public works, police, fire and medical services. For ordinary (non-disaster related) public services, the annual operating budget is used directly as a proxy to determine the daily value of services to the community. For services which are essential to immediate disaster response and recovery, a continuity premium is added to reflect the greater impact of losing services when they are most in demand and most critical to the community.

The continuity premium is a multiplier on the normal daily cost of service that is applied only to services, such as police, fire and medical that are directly related to emergency response and recovery. The continuity premium reflects the greater demand for such services during disasters and, in effect, is an estimate of how much more than the normal cost a community would be willing to pay to maintain these services during disasters. Determining an appropriate continuity premium for public services that are critical to disaster response and recovery is difficult and requires a great deal of judgment and experience. Guidance on appropriate continuity premiums for police, fire, and hospital services is given in Section 4 of this report. Guidance on appropriate continuity premiums for emergency operations centers and emergency shelters is given in Section 5 of this report.

2.2.3 Economic Impact of Loss of Utility Services

Utility services such as electric power, potable water, and wastewater are often referred to as "lifelines" because these utility services are so critical to the functioning of modern cities. Mitigation projects for utilities are often motivated primarily by the desire to maintain function of these critical services. The economic impacts of loss of utility services are generally many times larger than the physical damages alone. For example, loss of electric power affects not only the utility itself but impacts economic activity in the entire community.

Since the loss-of-function impacts (economic impact of loss of utility services) for utility systems are almost always much larger than physical damages alone, benefit-cost analysis for utility systems must always include loss-of-function impacts. Because of the complex, technical nature of most utility systems, evaluating mitigation projects for these systems usually requires specialized expertise.

Detailed technical guidance on how to evaluate mitigation projects for electric power, potable water, and wastewater utility systems is given in Section 6 of this report. The economic impacts of loss of utility services are calculated by first estimating the functional downtime (i.e., the time period for which utility service is lost), then the per capita economic impacts per day of lost service are estimated by the summing the impact of lost service on local economic activity and the economic impacts on residents, and finally, the economic impact of loss of utility services is calculated as the product of the functional downtime and the economic impact per day of lost service.

2.2.4 Economic Impact of Road and Bridge Closures

Roads and bridges, like utilities, are commonly considered lifelines for communities because they are so critical to the functioning of modern cities. Mitigation projects for roads and bridges are often motivated primarily by the desire to maintain function of these critical transportation system links. The economic impacts of road and bridge closures are often many times larger than the physical damages alone.

Since the loss-of-function impacts for roads and bridges (economic impact of road and bridge closures) are often larger than physical damages alone, benefit-cost analysis for hazard mitigation projects must always include the loss-of-function impacts.

Detailed technical guidance on how to evaluate mitigation projects for roads and bridges is given in Section 7 of this report. The economic impacts of road and bridge closures are calculated by first estimating the functional downtime (i.e., the duration of road or bridge closures), then, calculating the number of person hours of delay or detour time from the daily traffic volume and the expected duration of delays or detours, and finally, calculating the economic impact using the number of person hours of delay or detour times the average value of wages and benefits.

This section has reviewed the major types of loss-of-function impacts and how to calculate each one. A summary of loss-of-function impacts is given below in Table 2.2.

Table 2.2
Loss-of-Function Impacts

Type of Facility	Loss-of-Function Impact	Data Inputs
Building (residential, commercial, public)	Displacement costs	▪ Displacement time ▪ Rent for temporary quarters ▪ Other monthly costs ▪ One-time costs
Building (residential, commercial)	Rental income losses	▪ Displacement time ▪ Monthly rent
Building (commercial)	Business income losses Wage income losses	▪ Functional downtime ▪ Net business income per month ▪ Wages and benefits per month
Building (residential)	Disruption costs	▪ Disruption time ▪ Economic value per person per hour
Building (public, ordinary services))	Loss of public services	▪ Functional downtime ▪ Operating budget
Building (public, critical services))	Economic Impact of Loss of public services	▪ Functional downtime ▪ Operating budget ▪ Continuity premium (sometimes)
Utilities	Economic Impact of Loss of public services	▪ Functional downtime ▪ Economic impact per capita per day
Roads and Bridges	Economic impact of road and bridge closures	▪ Functional downtime ▪ Delay or detour time ▪ Daily traffic load ▪ Economic value per person per hour

2.3 Casualties

Natural disasters commonly result in casualties, including deaths, injuries, and illnesses. Casualties are the most devastating impact of disasters. Some mitigation projects are designed to reduce casualties in future disasters. Almost all earthquake projects are designed to reduce casualties, as are some hurricanes, wind, and flood mitigation projects.

For some mitigation projects, the benefits of reduced casualties can be a large fraction of the total benefits, or even the largest category of benefits. Thus, for some mitigation projects, it is very important to count the benefits of reduced casualties.

Like other benefits, the benefits of avoided casualties are calculated as the difference in casualties occurring before mitigation and after mitigation. FEMA uses statistical values to place a monetary value on the benefits of avoided casualties. In the most recent FEMA benefit-cost analysis software, statistical values of $1,250, $12,500 and $2,200,000 are assigned to minor injuries, major injuries and deaths, respectively. Minor injuries are defined as those requiring medical treatment, excluding minor bruises or scrapes. Major injuries are defined as those requiring hospitalization for treatment. Minor and major illnesses can be defined similarly, using the same statistical values.

When adjusted to year 2001, these statistical values for casualties are approximately $1,560, $15,600, and $2,710,000 for minor injuries, major injuries, and deaths, respectively. For economic correctness, these adjusted values are suggested for benefit-cost analysis of FEMA hazard mitigation projects.

As reviewed in Section 1.3, OMB guidance for benefit-cost analysis mandates that the benefits to be considered in FEMA's benefit-cost analyses are social net benefits, not the benefits to FEMA or to the federal government. Even though neither FEMA nor any other Federal Agency provides compensation for disaster casualties, the perspective of benefit-cost analysis is always that of the affected community. Thus, it is proper and indeed necessary to count the benefits of avoided casualties, whenever a mitigation project directly and demonstrably will reduce future casualties.

Counting the benefits of avoided casualties is necessary for nearly all earthquake mitigation projects. Reducing casualties is often the primary motivation for earthquake mitigation projects.

For many common types of mitigation projects, life safety benefits are non-existent or negligible. For example, except for situations with flash flooding or dam failures, most flood hazard mitigation projects do not significantly reduce casualties. Similarly, except for shelter projects, most hurricane mitigation projects do not significantly reduce casualties. Assuming that a mitigation project for floods or hurricanes will increase life safety may actually increase casualties by given a potentially false sense of safety and reducing people's motivation to evacuate when necessary.

For some mitigation projects life safety benefits are very important and must be included. Calculation of life safety benefits must always be done carefully, by experienced analysts. Including spurious life safety benefits has the potential to greatly distort benefit-cost results and lead to erroneous decisions about mitigation projects.

2.4 Emergency Management Costs

Disasters commonly result in a range of emergency management costs for affected communities. Emergency management costs include emergency operations center costs, evacuation or rescue costs, security costs, temporary protective measure costs, debris removal, pumping costs and other cleanup costs, and other costs for disaster response and recovery.

If a mitigation project under evaluation significantly reduces these emergency management costs, then the benefits of reduced emergency management costs should be counted. However, many FEMA hazard mitigation projects deal with single structures or a few scattered structures in a larger community. In this case, the reduction in emergency management cost is non-existent or negligible and should not be counted.

For example, elevating or acquiring a single structure or a few scattered structures in a community does not significantly impact a community's overall emergency management costs. However, acquisition of an entire flood prone neighborhood of homes might significantly reduce emergency management costs.

Determining whether or not a specific mitigation project significantly reduces a community's emergency management costs requires considerable judgment and experience. Calculation of such benefits must be done carefully, with full documentation of data and assumptions.

The most common subcategories of emergency management costs are:

Emergency operations center costs

Evacuation or rescue costs

Security costs

Temporary protective measure costs

Debris removal and cleanup costs

- Other management costs

2.5 Summary

The above sections provide summary guidance for four main categories of benefits, including avoided physical damages, avoided loss-of-function costs, avoided casualties, and avoided emergency management costs. For every type of benefit to be counted the procedure is the same: damages and losses are estimated both before and after undertaking a mitigation project. Then, benefits are calculated as the difference between damages and losses before and after mitigation, taking into account the time value of money (mitigation project useful lifetime and discount rate).

Within these four major categories of benefits, more than 20 subcategories of benefits were described briefly. However, once the basic procedure for calculating benefits for the major categories is mastered, calculating additional benefits for the subcategories is relatively straightforward.

Counting some of the less commonly used subcategories of benefits requires a little more ingenuity. In some cases, it may be convenient to do a side calculation and then add these benefits to those calculated in the module. For example, the modules for hurricane and flood projects to do not include spaces for calculating the benefits of reduced casualties. If counting the benefits of avoided casualties is necessary for a particular mitigation project (e.g., a hurricane shelter, or acquisition of properties subject to flash flooding), then a side calculation is probably the easiest way to include these benefits in the module.

As a caveat, it is important to do note that evaluating some types of projects, for example mitigation projects for utility systems, requires a moderate- to high-level of technical understanding of utility systems and thus should not be attempted by analysts lacking this expertise. Similarly, performing estimates of avoided casualty benefits and estimates of some of the other less commonly calculated benefits requires a considerable amount of experience and expertise and should not be attempted by novice analysts. Throughout the process of counting applicable benefits, care must also be taken to avoid double-counting benefits in more than one place or more than one subcategory.

This section provides examples of how to count benefits for "ordinary" buildings. In the present context, "ordinary" buildings are those that are not critical facilities for emergency response and recovery. Ordinary buildings include residential and commercial buildings, and public buildings used for non-critical functions, such as schools and administrative buildings. Public buildings used to provide services that are critical to disaster response and recovery, such as police, fire and medical facilities, emergency operations centers, and emergency shelters are addressed separately in Section 4.

Mitigation projects for ordinary buildings are the most common type of FEMA mitigation project. Most of the guidance below is applicable to mitigation projects for all types of hazards and for all types of mitigation projects. However, some categories of benefits may be applicable only to certain types of mitigation projects and/or only for some types of hazards. For example, counting the benefits of avoided casualties is almost always very important for seismic hazard mitigation projects, but generally not applicable to most other types of projects.

3.1 Single Residential Buildings

This section describes benefits to be counted for mitigation projects for single residential buildings, small groups of residential buildings, or a group of residential buildings at scattered locations. The benefits to be counted for mitigation projects for an entire neighborhood of residential buildings, which are somewhat different than for single buildings, are addressed in Section 3.2.

The categories of benefits to be counted for mitigation projects for single residential buildings are summarized below in Table 3.1.

For mitigation projects for residential buildings, the suggested benefit-cost analysis strategy is to first count the largest and most easily counted benefits. For this type of project, these benefits include building damages, contents damages, and displacement costs. For seismic projects, casualties should also be counted. If the project is cost-effective, it may not be necessary to count other benefits. If the project is not cost-effective, the categories of other physical damages and disruption costs are generally the most significant additional benefits to count. The other benefit categories generally contribute only minor benefits or aren't applicable.

Table 3.1
Categories of Benefits to be Counted
Single Residential Buildings[1]

Type of Benefits to Consider	When to Count
1. Physical Damages	
Building damages	Always counted
Contents damages	Always counted
Other physical damages[2] - Landscaping - Outbuildings - vehicles, equipment - site contamination	Applicable to acquisition or flood control infrastructure projects only[3]. Consider counting if significant, especially for projects that are close to being cost-effective without counting these categories.
2. Loss-of-Function Impacts	
Displacement costs	Always counted
Rental income losses	Can count if appropriate, but easier to include in displacement costs[4]
Business income losses	For home business, consider counting, but generally constitutes only a very small fraction of benefits
Disruption time costs[5]	Consider counting, especially for projects that are close to being cost-effective, can add significantly to benefits
3. Casualties	Always counted for seismic projects, rarely applicable to other projects[6]
4. Emergency Management Costs	Not applicable to single residential structures[7]

Notes:

[1] Guidance in table applies to single residential structures, small groups of residential structures, and groups of structures at scattered locations.

[2] Other physical damages can be counted by adding appropriate damage percentages to the damage function for building or contents. These damages may be significant and thus counting them may add significantly to the total benefits. This type of mitigation project does not reduce damages to off-site utilities or transportation systems and no benefits should be counted for such other physical damages.

[3] Other physical damages are applicable only to acquisition projects or flood control

infrastructure projects because mitigation projects to elevate or retrofit the primary structure have no impact on these other categories of damages - thus, there are no additional benefits.

[4] Rental income losses are not necessary to count if the full costs of temporary quarters are included in displacement costs for both owners and renters. Double-counting must be avoided.

[5] Disruption costs may be significant and thus counting them may add significantly to the total benefits.

[6] Casualties may be important for seismic hazard mitigation projects. Counting the benefits of avoided casualties may be a substantial fraction of total benefits and thus they should always be counted. For most other mitigation projects, benefits of casualties avoided are non-existent or negligible and thus should be counted only in special circumstances.

[7] Acquisition, elevation or retrofit of single residential structures, small groups of structures, or groups at scattered locations does not significantly reduce a community's emergency management costs because the area affected by a disaster is not decreased, and the total population affected by disaster is not decreased or not decreased significantly.

Counting Other Physical Damage. This simplified example is for floods, but the same principles apply for other hazards as well. Consider a one-story home without basement, with a replacement value of $100,000. Building damage estimates, before and after mitigation, are calculated as percentages of building replacement value. If other physical damages are to be added to building damages, these damages must also be expressed as percentages of building replacement value (not as percentages of their replacement value). For example, if landscaping damages at -2 feet flood depth are estimated as $500, then this damage is entered as 0.5% of the building replacement value (refer to Table 3.2).

Table 3.2
Example Showing How to Count Other Physical Damages

Flood Depth (feet)	Building Damage %	Landscaping and Outbuilding Damage %	Vehicle and Equipment Damage %	Adjusted Total Damage %
-2	0.0%	0.5%	0.0%	0.5%
-1	0.0%	1.0%	1.0%	2.0%
0	9.0%	1.5%	2.0%	12.5%
1	14.0%	2.0%	3.0%	19.0%
2	22.0%	2.5%	4.0%	28.5%
3	27.0%	3.0%	5.0%	35.0%

In this example, the building damage percentages are the typical or default values for a one-story structure without basement. Dollar damage estimates were made, using common sense and professional judgment, for the two other categories of physical damages. The dollar estimates were then converted to percentages of building replacement value. The sum of these damage percentages then represents the total damage estimates for the building, for landscaping and outbuildings, vehicles and equipment.

In making estimates of expected dollar damages for landscaping, outbuildings, vehicles, and equipment, historical damage data can be used, along with common sense. Structures with different types of landscaping may have different levels of damage. Not all homes have outbuildings and not all vehicles and equipment will be damaged in floods, because many owners will move such items to higher ground before floods. Whenever adjustments are made as shown above in the simplified example, full documentation of data sources and assumptions are essential.

If adjustments for other physical damages are made, it is very important to make appropriate, consistent adjustments in damage estimates both before and after mitigation. For example, damages to landscaping, outbuildings, vehicles and equipment are eliminated by acquisition. However, elevation or retrofit of the primary structure does not reduce these other types of damages. Thus, estimating these types of damages makes sense only for acquisition projects.

Counting Reduced Disruption Costs. To count the benefits of disruption, disruption time estimates must be made for each damage level (e.g., flood depth or wind speed bin). Then the dollar value of disruption time is calculated by multiplying the number of adults per house by the national average value of wages and benefits ($21.16) to get a dollar value of disruption time. This dollar value for disruption time can be converted to a percentage of building replacement value and added to the building damage percentage in the same manner as discussed above for other physical damages. This approach is mathematically correct, and reasonably straightforward, albeit perhaps confusing to the novice. As always, whenever such adjustments are made, full documentation of data sources and assumptions is essential.

3.2 Groups of Residential Buildings

Counting benefits for groups of residential buildings is very similar to counting benefits for single residential buildings. All of the categories of benefits discussed above in Section 3.1 for single residential buildings apply to groups of residential buildings. For groups of buildings, these benefits can be calculated for each building and then summed.

In some cases, groups of very similar buildings can be combined for purposes of benefit-cost analysis. However, this type of aggregation has to be done carefully. Groups of buildings can be combined if and only if they are the same structure type and have very similar frequencies and severities of disaster events. For flood mitigation projects this means that the structures must have very closely similar first floor elevations, and be close enough geographically so that they have very closely similar flood hazard data. For hurricane, wind, or earthquake projects, this means that the structures must be geographically close.

In addition to the benefits countable for single residential structures, mitigation projects for groups of residential may have two additional categories of benefits in some cases: avoided infrastructure damages and avoided emergency management costs. These additional benefits are generally only applicable to certain types of flood hazard mitigation projects.

If a mitigation project, such as improvements in flood control infrastructure, affects an entire town or an entire neighborhood, the damages to infrastructure will generally be reduced along with damages to the structures themselves. For example, there will be reduced damages to roads and utilities as well as to buildings. Similarly, if an acquisition project removes <u>all</u> of the homes from a neighborhood, then much of the infrastructure supporting the homes can be “retired” and is no longer subject to damage.

Likewise, if improvements in flood control infrastructure or acquisition of all homes in a neighborhood significantly reduces the level of flood risk for a community, then there is expected to be a proportional reduction in future emergency management costs.

All of the categories of benefits discussed above in Section 3.1 for single residential structures also apply to groups of residential structures. The additional categories of benefits that may be applicable for some flood hazard mitigation projects for groups of residential structures are summarized below in Table 3.3.

Table 3.3
Additional Categories of Benefits to be Counted for Groups of Residential Buildings[1,2]

Additional Types of Benefits to Consider	When to Count
1. Physical Damages	
Other physical damages: - infrastructure	Applicable only to some flood mitigation projects
2. Emergency Management Costs	
Emergency operations center costs Evacuation or rescue costs Security costs Temporary protective measure costs Debris removal and cleanup costs Other emergency management costs	Applicable only to some flood mitigation projects

Notes:

[1] These possible additional categories of benefits apply only when a mitigation project such as improvements in flood control infrastructure affects an entire town or entire neighborhood or when an acquisition project affects an entire neighborhood.

[2] These possible additional categories of benefits generally apply only to flood hazard mitigation projects. Mitigation projects for hurricanes and earthquakes generally affect only individual structures and do not reduce a community's infrastructure damages or emergency management costs.

3.3 Commercial Buildings

Most of the benefit categories counted for commercial buildings are the same as for residential buildings discussed above. One exception is that disruption costs, which may be counted for residential buildings, are not applicable to commercial buildings. The equivalent of disruption time for commercial businesses is already implicitly included in estimates of functional downtime and lost business income. To count disruption time for commercial structures would be double-counting.

For mitigation projects for commercial buildings, the suggested benefit-cost analysis strategy is to count first the largest and most easily counted benefits. For this type of project, these benefits include building damages, contents damages, and displacement costs. In addition, for seismic projects, casualties should always be counted. If the project is cost-effective, it may not be necessary to count additional benefits. If not, the categories of other physical damages, business income losses and wage losses are generally the most significant additional benefits to count. The other categories are likely to contribute only minor benefits or to not be applicable.

The categories of benefits to be counted for mitigation projects for single commercial buildings (or small groups of commercial buildings or a group of commercial buildings at scattered locations) are summarized below in Table 3.4.

Table 3.4
Categories of Benefits to be Counted for
Commercial Buildings[1]

Type of Benefits to Consider	When to Count
1. Physical Damages	
Building damages	Always counted
Contents damages	Always counted
Other physical damages[2] - landscaping - outbuildings - vehicles, equipment - site contamination	Applicable to acquisition or flood control infrastructure projects only[3]. Consider counting if significant, especially for projects that are close to being cost-effective without counting these categories
2. Loss-of-Function Impacts	
Displacement costs	Always counted
Rental income losses	Can count if appropriate, but easier to include in displacement costs[4]
Business income losses[5]	Consider counting, but generally constitutes only a small fraction of benefits
Wage income losses[5]	Consider counting, especially for projects that are close to being cost-effective, can add significantly to benefits

Type of Benefits to Consider	When to Count
3. Casualties	Always counted for seismic projects, rarely applicable to other projects[6]
4. Emergency Management Costs	Not applicable to single commercial structures[7]

Notes:

[1] Guidance in table applies to single commercial structures, small groups of commercial structures, and groups of structures at scattered locations.

[2] Other physical damages can be counted by adding appropriate damage percentages to the damage function for building or contents. These damages may be significant and thus counting them may add significantly to the total benefits. This type of mitigation project does not reduce damages to off-site utilities or transportation systems and no benefits should be counted for such other physical damages.

[3] Other physical damages are applicable only to acquisition or flood control infrastructure projects because mitigation projects to elevate or retrofit the primary structure have no impact on these other categories of damages - thus, there are no additional benefits.

[4] Rental income losses are not necessary to count if the full costs of temporary quarters are included in displacement costs for both owners and renters. Double-counting must be avoided.

[5] Business income losses and especially wage losses may be significant for commercial structures and thus counting them may add significantly to the total benefits.

[6] Casualties may be important for seismic hazard mitigation projects. Counting the benefits of avoided casualties may be a substantial fraction of total benefits and thus they should always be counted. For most other mitigation projects, benefits of casualties avoided are non-existent or negligible and thus should be counted only in special circumstances.

[7] Acquisition, elevation or retrofit of single commercial structures, small groups of structures, or groups at scattered locations does not significantly reduce a community's emergency management costs because the area affected by a disaster is not decreased, and the total population affected by disaster is not decreased or not decreased significantly.

For commercial businesses, the appropriate measure of business income losses is net business income not gross business income because loss of function of a commercial building (i.e., functional downtime) generally reduces costs as well as receipts.

Loss of wage income generally applies only to hourly employees, since most salaried employees are likely to continue to be paid during relatively short post-disaster business interruptions. Estimates of lost wages should include wages and benefits. If local data are not available, the national average value of $21.16 for hourly wages and benefits may be used for benefit-cost analysis.

Only in rare circumstances are FEMA hazard mitigation projects likely to include an entire neighborhood of commercial structures. If, however, a flood infrastructure improvement project or flood acquisition project does affect an entire neighborhood of commercial structures (or a mix of residential and commercial structures), then the additional benefits discussed above for groups of residential structures also apply to groups of commercial structures. These possible additional benefits, which include avoided infrastructure damages and avoided emergency management costs, are subject to the same caveats and the same calculation methods as for residential structures.

3.4 Public Buildings

Most of the categories of benefits to be counted for public buildings are the same as for commercial buildings discussed above. Two exceptions are that business income losses and wage income losses are generally not applicable to public buildings. For public buildings, the measure of the economic impact of loss of function of a building is the loss of public services.

For ordinary public buildings that do not provide critical services for disaster response and recovery, the measure of the value of loss of service is the cost of providing the public service. To value public services, FEMA makes the very simple and direct assumption that public services are worth what it costs to provide the services to the public. For example, if a public service costs $1,000 per day to provide, then the value is assumed to be $1,000 per day. If the service is lost because of damage to the building, the loss is assumed to be $1,000 per day. If the loss of service is avoided because of a hazard mitigation project, then the benefit is assumed to be $1,000 per day. This method for valuing the loss of public services applies to all public services.

The daily cost of services is estimated from the annual operating budget for the agencies occupying a building. The annual operating budget includes all of the direct costs necessary to provide the public services, including salaries and benefits, materials, supplies, utilities, equipment costs, and rent or the annual cost of owning the building. The only exclusion is for transfer payments. For example, if a public office distributes pension checks, the value of the service is not the value of the checks distributed, but rather the cost of providing the service.

The equivalent of wage income losses is already explicitly included in estimates of functional downtime and loss of public services, because wages and benefits are a large portion of the costs of providing public services. Thus, to count wage income losses separately for public structures would be double counting.

For ordinary public buildings, a continuity premium is <u>not</u> added to the normal cost of service. A continuity premium is added <u>only</u> for services such as police, fire and medical, that is critical to emergency response and recovery. However, if some fraction of the staff of an ordinary public building does provide emergency services, an appropriate continuity premium could be added to that proportionate fraction of the cost of services.

For mitigation projects for public buildings, the suggested benefit-cost analysis strategy is to count first the most easily identifiable and quantifiable benefits. For this type of project, these benefits include building damages, contents damages, displacement costs, and loss of public services. In addition, casualties should always be counted for seismic projects. If the project is cost-effective, it may not be necessary to count additional benefits. If the project is not cost-effective, the category of other physical damages may add the most significant additional benefits to count. The other benefit categories generally contribute only minor benefits or aren't applicable.

The categories of benefits to be counted for mitigation projects for public buildings are summarized below in Table 3.5.

Table 3.5
Categories of Benefits to be Counted for Public Buildings

Types of Benefits to Consider	When to Count
1. Physical Damages	
Building damages	Always counted
Contents damages	Always counted
Other physical damages[1] - landscaping - outbuildings - vehicles, equipment - site contamination	Applicable to acquisition or flood control infrastructure projects only[2]. Consider counting if significant, especially for projects that are close to being cost-effective without counting these categories
2. Loss-of-Function Impacts	
Displacement costs	Always counted
Loss of public services	Always counted No continuity premium for ordinary services
3. Casualties	Always counted for seismic projects, rarely applicable to other projects[3]
4. Emergency Management Costs	Not applicable to single public structures[4]

Notes:

[1] Other physical damages can be counted by adding appropriate damage percentages to the damage function for building or contents. These damages may be significant and thus counting them may add significantly to the total benefits. This type of mitigation project does not reduce damages to off-site utilities or transportation systems and no benefits should be counted for such other physical damages.

[2] Other physical damages are applicable only to acquisition or flood control infrastructure projects because mitigation projects to elevate or retrofit the primary structure have no impact on these other categories of damages - thus, there are no additional benefits.

[3] Casualties may be important for seismic hazard mitigation projects. Counting the benefits of avoided casualties may be a substantial fraction of total benefits and thus they should always be counted. For most other mitigation projects, benefits of casualties avoided are non-existent or negligible and thus should be counted only in special circumstances.

[4] Acquisition, elevation or retrofit of single public structures, does not significantly reduce a community's emergency management costs because the area affected by a disaster is not decreased, and the total population affected by disaster is not decreased or not decreased significantly.

3.5 Summary

Benefit-cost analysis of ordinary residential, commercial, or public buildings is straightforward. Many of the same benefits are counted, regardless of the function of the building. For ordinary buildings, the following benefits are always counted and are usually the largest categories of benefits: 1) building damages, 2) contents damages, and 3) displacement costs. In addition, for public buildings, the value of lost public services should always be counted. For seismic hazard mitigation projects, the benefits of avoided casualties are often very important, sometimes the largest single category of benefits, and should always be counted. The most important benefits to count are summarized in Table 3.6 below.

Table 3.6
The Most Important Benefits for Hazard Mitigation Projects for Ordinary Buildings

Types of Benefits to Consider	When to Count
▪ Building damages	Always counted
▪ Contents damages	Always counted
▪ Displacement costs	Always counted
▪ Loss of public services	Always counted for public buildings
▪ Casualties	Always counted for seismic projects

In addition, there are several other categories of benefits that apply in more limited cases or are generally significantly smaller than those identified in Table 3.6. Possible additional benefits to count are summarized below in Table 3.7.

Table 3.7
Possible Additional Benefits to Count
(if project is not cost-effective after counting benefits in Table 3.6)

Types of Benefits to Consider	When to Count
▪ Other physical damages	Applicable for all building types, but only for acquisition or flood control infrastructure mitigation projects; may add significantly to total benefits.
▪ Rental income losses	Applicable to all building types, but not necessary to count; instead, it is easier to include in displacement costs.
▪ Business income losses	Applicable to commercial buildings and to home businesses; this category of benefits is generally small.
▪ Wage income losses	Applicable only to commercial buildings; may add significantly to total benefits.
▪ Disruption costs	Applicable to residential buildings; may add significantly to total benefits.

Types of Benefits to Consider	When to Count
▪ Emergency management costs	Applicable only to flood control infrastructure projects or acquisition projects that protect entire neighborhoods; this category of benefits is generally small.

This section provides guidance and examples of how to count benefits for mitigation projects for buildings providing police, fire, and medical services. Such buildings are considered critical facilities because the services they provide are critical to disaster response and recovery.

Benefit-cost analysis for critical facilities is generally similar to that for ordinary public buildings. The same categories of benefits are typically counted, as summarized below in Table 4.1

Table 4.1
Categories of Benefits to be Counted for
Critical Facilities: Police, Fire and Medical Buildings

Types of Benefits to Consider	When to Count
1. Physical Damages	
▪ Building damages	▪ Always counted ▪ Building replacement values may differ from those for ordinary buildings ▪ Specialized damage functions may be needed
▪ Contents damages	▪ Always counted ▪ Contents replacement values may differ from those for ordinary buildings ▪ Specialized damage functions may be needed
▪ Other physical damages1 - landscaping - outbuildings - vehicles, equipment - site contamination	Applicable to acquisition or flood control infrastructure projects only[2]. Consider counting if significant, especially for projects that are close to being cost-effective without counting these categories
2. Loss-of-Function Impacts	
▪ Displacement costs	▪ Generally counted ▪ May not be applicable for some facilities
▪ Loss of public services	▪ Always counted ▪ A continuity premium must be added to the normal cost of providing service ▪ In many cases, the continuity premium has a large impact on the benefit-cost analysis
3. Casualties	Always counted for seismic projects, rarely applicable to other projects[3]
4. Emergency Management Costs	Not applicable to single public structures[4]

Notes:

[1] Other physical damages can be counted by adding appropriate damage percentages to the damage function for building or contents. These damages may be significant and thus counting them may add significantly to the total benefits. This type of mitigation project does not reduce damages to off-site utilities or transportation systems and no benefits should be counted for such other physical damages.

[2] Other physical damages are applicable only to acquisition or flood control infrastructure projects because mitigation projects to elevate or retrofit the primary structure have no impact on these other categories of damages - thus, there are no additional benefits.

[3] Casualties may be important for seismic hazard mitigation projects. Counting the benefits of avoided casualties may be a substantial fraction of total benefits and thus they should always be counted. For most other mitigation projects, benefits of casualties avoided are non-existent or negligible and thus should be counted only in special circumstances.

[4] Acquisition, elevation or retrofit of single public structures, does not significantly reduce a community's emergency management costs because the area affected by a disaster is not decreased, and the total population affected by disaster is not decreased or not decreased significantly.

There are, however, important differences in benefit-cost analysis of mitigation projects for critical facilities as compared to analysis for ordinary buildings.

4.1 Physical Damage Estimates for Police, Fire and Medical Buildings

Physical damage patterns for these types of buildings are generally similar to those for ordinary buildings. However, in some cases critical facilities are designed to higher codes and standards than ordinary buildings and thus may be somewhat less vulnerable to damages. Building replacement values may also differ because of the specialized nature of these buildings. For example, building replacement values for hospitals can be has high as $300 per square foot. On the other hand, building replacement values for fire stations can be quite low, because of the simple nature of most fire stations, with much of the space being garage space for fire apparatus. Building replacement values for police, fire, or medical facilities are generally available from the agencies providing such services, from local building officials, or from local building engineers.

Contents damage patterns for these types of buildings are generally similar to those for ordinary buildings. In some cases, professional judgment is necessary to adjust typical or default contents damage functions to reflect the specialized communications or medical equipment in these types of facilities. For hospitals and other medical facilities, the contents replacement value may be very high, in some cases similar to or exceeding the building replacement value. Appropriate contents replacement values for police, fire, or medical facilities are generally available from the agencies providing such services, from local building officials, or from local building engineers.

For acquisition or flood control infrastructure mitigation projects, one of the benefits may be reductions in other physical damages. As for ordinary buildings discussed in Section 3, other physical damages for critical service buildings include damages to landscaping, outbuildings, vehicles, and equipment and possible site contamination. Such damages can be estimated, but are generally small compared to the other categories of benefits for critical service facilities. Thus, such benefits can generally be ignored except for projects that are very close to being cost-effective without counting this category. For mitigation projects other than acquisition or flood control infrastructure, there are no benefits in this category because elevation, retrofit or strengthening of a building itself does not reduce this category of damages.

4.2 Displacement Costs

When facilities housing police and fire services are damaged to an extent such that the buildings cannot be occupied during repairs, the services are moved to temporary quarters. The displacement costs for such temporary quarters are part of the damages and losses attributed to a disaster and these displacement costs become part of the benefits to the extent that they are avoided or reduced by a mitigation project.

Displacement costs for police and fire facilities are counted in the same manner as for ordinary buildings. Displacement costs include:

Monthly costs of rent for temporary space

Other monthly costs such as furniture rental

One-time costs such as round-trip moving costs, utility connection fees and other such costs

For police and fire facilities, the one-time costs may be higher than for ordinary buildings because of the critical communications equipment that would have to be moved and reinstalled. Other monthly costs could also include extra transportation time and costs if the temporary facility is not as well located as the permanent facility.

For police facilities that include jails, the concept of displacement costs is somewhat more complicated. For security reasons, inmates probably cannot be housed in ordinary temporary quarters. Rather, displacement of jail inmates probably requires moving inmates to another correctional facility. In such cases, displacement costs would include the transportation or moving costs, any extra daily transportation time and costs, plus the monthly cost of housing inmates in the alternative facility.

For hospitals, the concept of displacement to temporary quarters is also somewhat more complicated. Some hospital facilities such as office space, storage space, residential quarter for staff and other ordinary functions can be relocated to temporary quarters. For such space, displacement costs are calculated as summarized above for police and fire services.

Some hospital services, including most patient care facilities cannot readily be located to temporary quarters. For such services, displacement probably requires moving patients and services to another medical facility. In this case, displacement costs would include the transportation or moving costs, any extra daily transportation time and costs, plus the extra monthly cost of housing patients in the alternative facility.

The typical values for displacement time assume that building damages of less than 10% of the building replacement value can be repaired without requiring displacement of occupants. For damages above 10%, a minimum displacement of 30 days is assumed, with the displacement time increasing linearly with damage percentage up to a cap of 365 days (one year) for displacement time. That is, regardless of the level of damages, it is assumed that public services will be back in the original (repaired) building or in a new permanent building within one year of the disaster. Professional judgment, experience, and many years of use confirm that these estimates appear reasonable in most cases, especially for small- to medium-sized facilities.

For major, complex or specialized facilities that suffer major damage or that require replacement with new facilities, or for large, monumental historical buildings, longer displacement times of up to two or three years are sometimes experienced. While such long displacement times are uncommon, they do occur and in such cases it is important to make realistic estimates of displacement time. Displacement time estimates for major complex projects can be based on construction duration estimates, construction bids, or on the professional judgment of the design and construction details of the repairs or of the replacement facility. Longer displacement time estimates are appropriate if and only if there is sound documentation of longer repair or replacement times for a specific facility under evaluation.

4.3 Loss of Public Services

For critical facilities, the first step in evaluating the benefits of reducing the loss of public service is exactly the same as that for ordinary buildings, as discussed in Section 3.4. The base value of public services, including police, fire and medical services, is estimated from the annual operating budget of the facility providing the service. The annual operating budget includes all of the direct costs necessary to provide the public services, including salaries and benefits, materials, supplies, utilities, equipment costs, and rent or the annual cost of owning the building. The only exclusion is for transfer payments. For example, if a public office distributes pension checks, the value of the service is not the value of the checks distributed, but rather the cost of providing the service.

The equivalent of wage income losses is already explicitly included in estimates of functional downtime and loss of public services, because wages and benefits are a large portion of the costs of providing public services. Thus, to count wage income losses separately for public structures would be double-counting.

4.3.1 Continuity Premiums for Police, Fire and Medical Services

A continuity premium is a measure of the extra importance that some public services have during disasters. In simple terms, a continuity premium is a measure of how much extra a community would be willing to pay to continue to have critical services during a disaster.

In benefit-cost analysis, the effect of a continuity premium is to count more highly those services that are essential for disaster response and recovery, compared to ordinary services that are not more important to a community during disasters. A high continuity premium increases the benefits of a mitigation project by increasing the benefits of avoiding loss of public services.

In assigning continuity premiums for police, fire and hospital services, the following question must be answered:

> **In a disaster, how much more important are police, fire and hospital services compared to their value to the community in non-disaster circumstances?**

Answering the above question and thereby determining an appropriate continuity premium for these services profoundly affects the determination of which hazard mitigation projects are or are not cost-effective.

For police and fire services, the maximum possible continuity premium is limited by the capacity of police and fire departments to respond to emergency calls. For example, police and fire departments cannot respond to 1,000 times more calls than normal during a disaster because of limited staff and apparatus. A more detailed analysis of continuity premiums for police and fire services is given in Chapter 1 of the Supporting Documentation (Technical Appendix: Guidance for Benefit-Cost Analysis of Mitigation Projects for Police, Fire, and Medical Service Facilities). In general, a continuity premium of ten times the normal cost of service is appropriate for police and fire services.

For medical services, similar concepts apply as discussed above for police and fire services, although appropriate continuity premiums for medical services vary with the disaster type as follows:

For earthquakes, the potential for mass casualties means that an appropriate continuity premium will be governed by the capacity to provide emergency medical services. A continuity premium of 10 times the normal cost of service is suggested for medical facilities providing direct patient care.

For floods, there is very little likelihood of significantly more than normal demand for emergency medical services and therefore no continuity premium should be applied.

For hurricanes, the typical number of casualties is low because of the widespread evacuations that are commonly ordered in advance of a hurricane. Thus, there is very little likelihood of significantly more than normal demand for emergency medical services and no continuity premium should be applied.

For tornadoes and fires, some casualties are likely. However, such events typically impact only very small segments of a hospital service area and thus, there is very little likelihood of significantly more than normal demand for emergency medical services and no continuity premium should be applied

Thus, for hospitals and other patient care medical facilities, a continuity premium is suggested only for seismic hazard mitigation projects. For seismic hazard mitigation projects for hospitals, a continuity premium of 10 is suggested only for facilities providing direct patient care. For a hospital complex as a whole, many facilities are support facilities not directly related to immediate patient care; therefore for hospital complexes as a whole, a continuity premium of 5 is suggested. For non-patient care buildings within a hospital complex, continuity premiums from none to perhaps 5 are suggested, depending on the strength of the linkage between the building's services and patient care. A more detailed analysis of continuity premiums for hospitals and other medical care services is given in Chapter 1 of the Supporting Documentation (Technical Appendix: Guidance for Benefit-Cost Analysis of Mitigation Projects for Police, Fire, and Medical Service Facilities).

Suggested continuity premiums for police, fire and medical services are summarized below in Table 4.2.

Table 4.2
Continuity Premiums
Police, Fire, and Medical Services

Type of Facility	Continuity Premium
Police Services	10
Fire Services	10
Medical Services	▪ 0 for non-seismic mitigation projects ▪ 10 for seismic mitigation projects for patient care facilities ▪ 5 for seismic mitigation projects for whole hospital complex ▪ 0 to 5 for seismic mitigation projects for non-patient care buildings, depending on linkage between services provided and patient care

4.3.2 Functional Downtime Estimates for Police, Fire and Medical Services

Functional downtime is the number of days that a public service is not available because of disaster damage. Functional downtime days may be fractional. For example, one day of functional downtime may be one day with 100% loss of service or two days with 50% loss of service or 10 days with 10% loss of service.

Functional downtime is not the same as displacement time. For example, a building providing a public service is damaged in a flood and occupants are displaced to temporary quarters for 3 months while repairs are made. The public service, however, is restored in two weeks from the temporary quarters. In this simple example, the functional downtime is two weeks, while the displacement time is three months.

Estimates of functional downtime are substantially different for critical services than for ordinary services. For example, if a library suffers damage in a flood or an earthquake, the library may close for several weeks or several months. Loss of library service may be tolerable to a community for an extended period of time. However, if a police or fire station suffers a similar level of damage, the police or fire services cannot be closed down for an extended period of time because these services are simply too important to the community. Thus, in the case of damage to a police or fire station, the essential police or fire services are generally reestablished quickly in temporary quarters. Essential services will be reestablished much more quickly than would less important services.

> **A general rule of thumb is that the more important a public service is to a community, the shorter the functional downtime will be.**

Police and fire services are in large part provided away from the facility housing the staff and apparatus. This aspect of such services is very important because it means that, to a considerable degree, service can be continued even when the facility housing the service has considerable damage. In an emergency, many operations can be run from a parking lot with manual dispatch or cell phone dispatch in the event that a station is heavily damaged in a disaster.

For the reasons cited above, loss of police and fire services is almost always partial. It would be very rare for a police or fire department to provide no service for any significant period of time. Rather, damage to facilities or disruption of communication links commonly result in delays or disruption of normal service. For any given disaster event, days of loss of service are not likely to be complete days with 100% loss of service. More likely there might be, for example, one day with 50% service, several days with 80% service and several days with 90% service. When historical data on service disruption are available, the functional downtime can be calculated by summing up the fractional days of lost service over the service restoration time period after the disaster.

The concepts discussed above and the analysis of functional downtime for police and fire services suggests that functional downtimes for these services are expected to be significantly shorter than for ordinary (non-critical) public services. A common sense rule of thumb, based on professional judgment and experience, is that functional downtimes might average a factor of three less than for ordinary public services.

Functional downtime estimates for hospitals are, in some regards, similar to those for police and fire services. Because hospital services, like police and fire services, are obviously important to a community in a disaster situation, functional downtimes are likely to be shorter for hospitals than for ordinary facilities. That is, repair and restoration of damaged hospital facilities almost always has a very high priority.

However, the shorter functional downtimes expected for hospitals because of their importance to the community is counterbalanced by the fact that many critical hospital services require special, sterile medical conditions and complex modern medical equipment. Thus, while police and fire staff and apparatus can be dispatched from a parking lot, if necessary, few major medical, surgical, or diagnostic procedures requiring specialized equipment and/or sterile conditions can be performed in a parking lot.

Similarly, a few inches of water or even a foot or two of water in a police or fire station will disrupt service, but will not result in complete loss of service. However, a few inches of water in an operating room, a diagnostic room with specialized medical equipment, or a patient care room, would almost certainly result in complete loss of service.

Combining the importance of hospital services to a community and the medical requirements for sterile conditions and other operating constraints for medical facilities suggests that functional downtimes for hospitals are likely to be shorter than those for ordinary buildings but longer than those for police and fire services. A common sense rule of thumb, based on professional judgment and experience, is that functional downtimes for hospitals might average a factor of two less than for ordinary public services.

4.4 Casualties

In some disaster events, occupants of facilities housing police and fire services and hospitals and other medical facilities are at risk of injury or death. Casualty estimates for such facilities are made in exactly the same manner as for ordinary buildings. Casualties are estimated from the average occupancy (24 hours per day, 365 days per year) of a facility and the estimated casualty rate as a function of severity of disaster.

For these critical facilities, casualty estimates are most important for earthquakes. Major earthquakes may pose a significant life safety risk for occupants of buildings with seismic vulnerabilities. For seismic hazard mitigation projects, the benefits of reduced or avoided casualties may be a major component of total benefits for any of these critical facilities, which usually have 24-hour occupancy. However, the benefits of avoided casualties are particularly important for hospitals because of their typically very high occupancy levels (patients, staff, and visitors). In some cases, especially for hospitals, the benefits of reduced casualties may be the largest single benefit of a mitigation project. For seismic mitigation projects, the benefits of reduced casualties are important and these benefits should always be counted.

For floods and hurricanes, casualties are generally low and many casualties that do occur are a result of individuals ignoring evacuation warnings (in the case of hurricanes) or ignoring road or bridge closures (in the case of floods). For most flood and hurricane hazard mitigation projects the benefits of reduced casualties are generally not significant and are not considered in the benefit-cost analysis. However, critical facilities such as those for police and fire services and hospitals are probably less likely to be evacuated in hurricanes than are ordinary facilities. Especially for mitigation projects that are designed to harden such facilities to withstand hurricane winds or tornadoes, the benefits of reduced casualties may be significant and should be considered in the analysis. In these circumstances, casualty rate estimates should always be made in close consultation with an engineer knowledgeable about the wind design characteristics of the existing building and the capacity of the post-mitigation building.

For benefit-cost analyses where reductions in casualties are included, the benefits of casualties avoided are often a large component of total benefits and thus estimates of casualty rates before and after mitigation become a very important determinant of the overall benefit-cost analysis and results. Making realistic estimates of casualty rates is difficult and requires a substantial understanding of the failure modes of buildings and the likely casualty rates that would result. Estimates of casualty rates should always be made by an engineer or analyst very knowledgeable about such issues, with a considerable amount of experience.

For seismic mitigation projects, the casualty rate estimates in the FEMA-sponsored HAZUS program (HAZUS, Earthquake Loss Estimation Methodology, National Institute of Building Science and Federal Emergency Management Agency, 1997) provide the best available consensus estimates of casualty rates for different structural types of buildings designed to varying seismic design levels. However, using these estimates is possible if and only if a building's seismic vulnerability is expressed as a fragility curve. A fragility curve is a mathematical representation that states the probability that a building will sustain a given level of damage as a function of the level of ground motion. Fragility curve-based estimates of casualty rates are the best available, but the necessary calculations are mathematically complicated and should not be attempted by analysts not thoroughly familiar with this mathematics.

Damage to critical facilities may also result in a loss of function that may pose a life safety threat to the community served by the facility. This potential casualty risk is separate from casualty risk faced by the occupants of the building. Police, fire and medical services are directly related to life safety in the community as a whole. The high operating budgets of such facilities reflect, in large part, the life safety aspects of these services. However, the life safety impacts of losing service from such facilities are already included in the value of public services calculation discussed above in Section 4.3. The high normal daily cost of service and the high continuity premiums for these critical services include the importance of these facilities in preserving life safety in the community. Thus, separate casualty estimates for the community as a whole should not be done for benefit-cost analysis and to do so would be to incorrectly double-count life safety benefits.

4.5 Summary Guidance

The major categories of benefits to be counted for mitigation projects for public buildings providing police, fire, and medical services are summarized below in Table 4.3.

Table 4.3
Summary Guidance
Benefit-Cost Analysis of Mitigation Projects for Police, Fire, and Medical Facilities

Damages/Benefits Categories	Data Sources and Guidance
1. Physical Damages	
▪ Building replacement value and contents value	Values from local officials.
▪ Building and contents damage functions	Historical data and professional judgment, as necessary.
▪ Other physical damages	For acquisition and flood control infrastructure projects only, generally of minor importance, estimates based on historical data and professional judgment.
2a. Economic Impact of Loss of Function (i.e., Displacement Costs)	
▪ Displacement time	Historical data and professional judgment, as necessary.
▪ Displacement costs	Estimates of monthly rent, other costs, and one-time costs from local officials. Costs may differ for critical service facilities.
2b. Economic Impact of Loss of Function (i.e., Loss of Public Services)	
▪ Normal cost of service	Annual operating budgets from local officials
▪ Functional downtime	▪ Police services: 1/3 of typical values ▪ Fire services: 1/3 of typical values ▪ Medical services: 1/2 of typical values
▪ Continuity Premiums - police and fire services	10x cost of normal service
▪ Continuity Premiums - medical services, seismic projects	▪ Patient care facilities: 10x cost of normal services ▪ Whole medical complex: 5x cost of normal services ▪ Non-patient care bldgs: 0 to 5x cost of normal services
▪ Continuity Premiums - medical services, other projects	None, demand for services is typically not significantly greater than normal

Damages/Benefits Categories	Data Sources and Guidance
3. Casualties	
▪ Average Facility occupancy	Local officials or applicant
▪ Casualty rates	HAZUS casualty rates for earthquakes, professional judgement for other hazards
▪ Statistical values of deaths, injuries, and illnesses	FEMA values, updated to 2001 values, see Section 2.3 - deaths: $2,710,000 - major injuries/illnesses: $15,600 - minor injuries/illnesses: $1,560

Mitigation projects for critical facilities are, by definition, important projects to communities. The guidance for benefit-cost analysis presented above makes it more likely that mitigation projects are cost-effective, compared to similar mitigation projects for ordinary facilities. Most importantly, the continuity premium places a greater value on avoiding loss of service, thus substantially increasing benefits. Furthermore, especially for hospitals, the greater building values, contents values, and high occupancy all result in higher benefits when mitigation projects will reduce damages and casualties. Benefit-cost analysis properly and fully recognizes and counts the importance of these critical facilities to a community.

However, regardless of how important these facilities may be to a community, not every mitigation project for a critical facility will be cost-effective. For example, consider a mitigation project for a seismic upgrade or replacement of a fire station built below the current building codes. If the building is located in a high seismic hazard area and is constructed of unreinforced masonry, subject to collapse during an earthquake with resulting casualties and substantial loss of the important services, then the benefits of retrofit or replacement will be very high. In many such cases, even a complete replacement of the building with a new building may be cost-effective. On the other hand, if the existing fire station has only minor seismic deficiencies, with little potential for casualties, and only limited potential for loss of service, then a very expensive seismic retrofit (e.g., $100 or $150 per square foot) to bring the entire building up to current code requirements will almost certainly not be cost-effective. In these circumstances a more modest seismic retrofit to address the specific deficiencies has a higher likelihood of being cost-effective.

Mitigation projects for critical facilities, which are reasonable in cost and address specific deficiencies in high hazard areas, have a high likelihood of being cost-effective. On the other hand, expensive mitigation projects that correct only minor deficiencies or located in areas with only minor exposure to hazards are unlikely to be cost-effective, even for critical facilities. It is important to understand that a benefit-cost analysis indicating that a mitigation project for a critical facility is not cost-effective does not mean that the benefit-cost analysis is flawed but may instead indicate that the mitigation project is poorly conceived and, indeed, not worth doing.

In many regards, benefit-cost analysis of mitigation projects for emergency operations centers (EOCs) and emergency shelters is similar to that for other critical facilities. For EOCs and emergency shelters, however, there are two very important differences: 1) such facilities often occupy only part of a building, and 2) such facilities are in function only immediately before, during or immediately after disaster events. Both of these differences affect benefit-cost analysis of mitigation projects for EOCs and emergency shelters.

Many mitigation projects for EOCs and emergency shelters address only the portion of a building used for the EOC or shelter. In this case, the benefit-cost analysis should consider only the portion of the building used for the EOC or shelter, because such a mitigation project has no effect on the remainder of the building. Estimates of building damages, contents damages, displacement costs, casualties, loss of public services and any other categories of benefits should consider only the portion of the building used as an EOC or shelter.

If a mitigation project affects the entire building housing an EOC or shelter and other non-critical public functions, then the easiest way to approach the benefit-cost analysis is to consider separately the parts of the building providing ordinary services and critical services and then add the benefits together. For benefit-cost analysis, the part of the building providing ordinary services is evaluated in exactly the same manner as "ordinary" public buildings, with guidance as outlined in Section 3.

For benefit-cost analysis, the portion of a building providing EOC or shelter services is treated conceptually as a separate building.

The guidance in this section focuses only on portions of a facility providing EOC or shelter services, or the whole building if the whole building provides EOC or shelter services.

Benefit-cost analysis for these buildings or parts of buildings providing EOC or emergency shelter services is generally similar to that for ordinary public buildings. The same categories of benefits are typically counted, as summarized below in Table 5.1

Table 5.1
Categories of Benefits to be Counted
Critical Facilities: EOCs and Emergency Shelters

Types of Benefits to Consider	When to Count
1. Physical Damages	
▪ Building damages	▪ Always counted ▪ Building replacement values may differ from those for ordinary buildings ▪ Specialized damage functions may be needed
▪ Contents damages	▪ Always counted ▪ Contents replacement values may differ from those for ordinary buildings ▪ Specialized damage functions may be needed
▪ Other physical damages[1] - landscaping - outbuildings - vehicles, equipment - site contamination	▪ Applicable to acquisition or flood control infrastructure projects only2 ▪ Consider counting if significant, especially for projects that are close to being cost-effective without counting these categories
2. Loss-of-Function Impacts	
▪ Displacement costs	▪ May be applicable for some facilities, ▪ Displacement time estimates are different than for ordinary buildings: limited to normal duration of use during disasters
▪ Loss of public services	▪ Always counted ▪ A continuity premium must be added to the normal cost of providing service ▪ In many cases, the continuity premium has a large impact on the benefit-cost analysis ▪ Functional downtime estimates are different than for ordinary buildings: limited to normal duration of use during disasters
3. Casualties	Always counted for seismic projects, may be applicable for hurricane and tornado projects as well[3]
4. Emergency Management Costs	Not applicable to single public structures[4]

Notes:

[1] Other physical damages can be counted by adding appropriate damage percentages to the damage function for building or contents. These damages may be significant and thus counting them may add significantly to the total benefits. This type of mitigation project does not reduce damages to off-site utilities or transportation systems and no benefits should be counted for such other physical damages.

[2] Other physical damages are applicable only to acquisition or flood control infrastructure projects because mitigation projects to elevate or retrofit the primary structure have no impact on these other categories of damages - thus, there are no additional benefits.

[3] Casualties may be important for seismic hazard mitigation projects. Counting the benefits of avoided casualties may be a substantial fraction of total benefits and thus they should always be counted. Benefits of avoided casualties may also be important for hurricane and tornado mitigation projects because EOCs and emergency shelters are intended to be occupied during disaster events.

[4] Acquisition, elevation or retrofit of single public structures, does not significantly reduce a community's emergency management costs because the area affected by a disaster is not decreased, and the total population affected by disaster is not decreased or not decreased significantly.

5.1 Physical Damage Estimates for EOC and Emergency Shelter Buildings

Physical damage estimates for EOCs and emergency shelters are generally similar to those for ordinary buildings. If the EOC or shelter is designed to higher than normal building code standards, then professional judgement must be used to make appropriate estimates of damages, before and after mitigation.

Contents damage estimates for EOCs and emergency shelters are also generally similar to those for ordinary buildings. For EOCs, the extra value of communications and other EOC equipment must be considered in the analysis.

Acquisition projects are uncommon for EOC or shelters. However, if a mitigation project is acquisition or is a flood control infrastructure project that provides better flood protection for an EOC or shelter, other physical damages (landscaping, outbuildings, etc.) can also be counted. However, for typical mitigation projects for EOCs and shelters, that involve hardening of the building itself, there are no additional benefits in this category and they should not be counted.

5.2 Displacement Costs

In principle, the public services provided by EOCs and emergency shelters are subject to being displaced to temporary quarters due to disaster damages, just like any other public service. In practice, however, the operation of EOCs or emergency shelters is typically only for short periods of time immediately before, during, or after disaster events. Furthermore, because of the specialized, temporary function of EOCs and shelters, displacement to temporary quarters may not be physical possible, during the brief periods that EOCs and shelters would normally operate in a single disaster event. Typically, there is ample time between disasters to allow for repairs between uses of EOCs or shelters.

Because of the operating characteristics of EOCs and emergency shelters, the possible benefits of reduced displacement time are likely to be substantially less than for ordinary buildings. For ordinary buildings, the benefits of reduced displacement time generally constitute only a small fraction of total benefits. Thus, for EOC or emergency shelter mitigation projects the benefits of reduced displacement time are likely to be very minor. Except for mitigation projects that are very close to being cost-effective without counting the benefits of reduced displacement time, it may not be necessary to count displacement benefits for most mitigation projects for EOCs and emergency shelters.

5.3 Loss of Public Services for EOCs

In principle, the benefits of avoiding loss of public services provided by EOCs and emergency shelters are calculated from the daily cost of public services, just like any other public service. In addition, since EOCs and emergency shelters are critical facilities, an appropriate continuity premium must be added to reflect properly the greater importance of EOCs and emergency shelters during disasters.

5.3.1 Functional Downtime Estimates for EOCs and Shelters

Functional downtime estimates for EOCs and shelters are different from those for ordinary buildings because EOCs and shelters are typically used only for short periods of time before, during and/or after disaster events. Functional downtimes for EOCs and shelters cannot be longer than the typical duration of use.

5.3.2 Value of Services

As with any public building, the base value of the service provided by an EOC or shelter is estimated from the daily cost of providing the service. However, unlike other public services, EOCs and shelters are used only for brief periods of time before, during or after disaster events. For ordinary public buildings, the daily cost of service is estimated by dividing the annual operating budget of a facility by 365 days per year.

> **For EOCs the daily cost of service is estimated by dividing the annual operating budget by the typical or average number of days of use per year.**

For example, if an EOC has an annual operating cost of $36,500 per year and operates an average of only 2 days per year, based on historical data, then the average daily cost of service is $17,500 per day (when used). In this case, the average value of the EOC services is estimated at $17,500 per day. As with any public services, the annual operating budget for an EOC includes annual costs for equipment, supplies, utilities, administrative and training costs and other operating costs, as well as the salary and benefit-costs of personnel when the EOC is activated.

Rather than trying to estimate an annual operating budget for emergency shelters, a different approach is suggested for estimating the base value of emergency shelter. For Federal travel, the GSA establishes standard rates for lodging and meals. For the continental U.S., the base CONUS daily rates are $55 or lodging and $30 for meals and incidentals. Higher rates are published for counties with higher than these typical values (i.e., many medium- to large- urban areas). The simplest measure of the value of temporary lodging and meals provided by an emergency shelter would be $85 per day (the base CONUS rate). A more accurate measure could be obtained by using the GSA rate appropriate for the county in which the emergency shelter is located. Current GSA lodging and meals rates are available at several websites, including a DOD site (*www.dtic.mil/perdiem*).

> **For emergency shelters, the base daily value of the public service is estimated by multiplying the average number of people given shelter by the $85 per day CONUS value (or the appropriate local value of lodging and meals from the GSA data).**

5.3.4 Continuity Premiums for EOCs and Shelters

Determining an appropriate continuity premium for an EOC is difficult. In many ways, evaluating a mitigation project for an EOC is similar to evaluating a mitigation planning project. An EOC does not, by itself, directly reduce damages, losses, or casualties in a disaster. Rather, by coordinating response efforts, an EOC makes a community's disaster response more efficient and thus is beneficial to the community. Indirectly, an EOC may reduce damages by targeting and implementing preventative measures more efficiently or reduce casualties by focusing search and rescue operations more efficiently.

Clearly, an EOC is important to a community during disasters. However, because of the indirect connection between and EOC and reductions in damages, losses, and casualties, it is difficult to estimate a suitable continuity premium. For consistency, we suggest assuming that a functioning EOC has the same continuity premium, relative to the cost of service, as police and fire services. This assumption then assigns a common continuity factor of 10 times the daily cost of services to each of the primary emergency response functions: police, fire and EOCs.

In a disaster, there are several reasons why emergency shelter is clearly worth more to residents and to the community than during ordinary times. First, hotels and motels are likely to be filled to capacity, or unavailable due to closures and/or damage. Second, emergency shelter is more important than discretionary temporary shelter. Discretionary travel and shelter can be postponed, but the need for emergency shelter is immediate and cannot be postponed. Third, there is a life safety impact of emergency shelter. Availability of safe emergency shelters in tornadoes and hurricanes reduces casualties because people move from less safe structures to safer emergency shelters. In hurricanes, the availability of shelters undoubtedly reduces the number of people who are at risk because they ignore evacuation warnings. That is, the availability of emergency shelter makes it more likely that people will evacuate when so ordered by local officials.

Estimating the value of emergency shelter to a community and determining an appropriate continuity premium depends primarily on common sense and professional judgement. Clearly, people displaced from their homes or evacuated would be willing to pay more than the normal cost of shelter and food - perhaps twice normal costs, or several times normal costs or even ten times normal costs, but not 100 or 1000 times normal costs. At 100 or 1000 times normal costs, the value per day of temporary shelter would be $8,500 or $85,000 per person per day, respectively, and clearly such numbers exceed the bounds of common sense for the typical or average value of emergency shelter in disasters.

For emergency shelters, a continuity premium similar to, but not larger than, those assigned to police and fire services and EOCs appears reasonable. Thus, a continuity premium of 10 times the normal cost of service for emergency shelters should be used.

5.4 Casualties

In some disaster events, occupants of EOCs and shelters may be at risk of injury or death. In estimating casualties, the occupancy characteristics of EOCs and shelters must be carefully considered. Methods for estimating casualties depend on whether or not the facility has alternative uses during non-disaster times and whether or not the expected types of disasters occur with or without warnings.

For seismic hazard mitigation projects for EOCs and shelters, the appropriate occupancy value is the typical year-round occupancy for the normal function of the facility. In other words, casualty estimates are made in exactly the same manner as for any other building. For seismic mitigation projects, the best available casualty rate estimates are those in the FEMA-sponsored HAZUS program (HAZUS, Earthquake Loss Estimation Methodology, National Institute of Building Sciences and FEMA, 1997). HAZUS has consensus estimates of casualty rates for different structural types of buildings designed to several seismic design levels. However, using these estimates is possible if and only if a building's seismic vulnerability is expressed as a fragility curve. A fragility curve is a mathematical representation of a damage function expressed as the probabilities that a building will sustain a given level of damage as a function of the level of ground motion. Fragility curve-based estimates of casualty rates are the best available, but the necessary calculations are mathematically complex and should not be attempted by analysts not thoroughly familiar with this specialized mathematics and methodology.

For hurricane or tornado mitigation projects for EOCs and shelters, the appropriate occupancy value would be the occupancy during hurricane or tornado warnings, which may differ significantly from the normal occupancy of the facility. For hurricane winds and tornadoes, there are no currently available resources such as the earthquake HAZUS model to assist in casualty rate estimates. Rather, casualty rate estimates must be made for each building, based on the capacity of the specific building to withstand wind forces. In these circumstances, casualty rate estimates should always be made only in close consultation with an engineer very knowledgeable about the wind design characteristics of the existing building and the ability of the post-mitigation building to withstand wind forces.

For flood hazard mitigation projects for EOCs and shelters, life safety is generally not an issue and thus it is not necessary to make casualty estimates.

5.5 Summary Guidance

The major categories of benefits to be counted for mitigation projects for EOCs and emergency shelters are the same as those addressed for ordinary public buildings (Section 3) and for police, fire and medical facilities (Section 4). However, because of the function and occupancy characteristics of EOCs and shelters, there are several significant differences in benefit-cost analysis. These special considerations for EOC and shelter mitigation projects are highlighted in the summary Table 5.2 below.

Table 5.2
Special Considerations for Benefit-Cost Analysis of Mitigation Projects for EOCs and Emergency Shelters

Types of Benefits to Consider	Data Sources and Guidance
1. Economic Impact of Loss of Function (i.e., Displacement Costs)	May not be applicable for EOCs and shelters, because of short period of use of these services.
▪ Displacement time	Maximum possible displacement times are limited by the typical duration of use of EOCs or shelters.
▪ Displacement costs	If appropriate, the extra costs of providing service from temporary locations.
2. Economic Impact of Loss of Function (i.e., Loss of Public Services)	
▪ Normal cost of service	▪ EOCs: daily base cost of service is annual operating budget divided by average number of days of use, plus daily costs during operation. ▪ Shelters: $85 per day CONUS cost of temporary lodging and meals or local GSA values.
▪ Functional downtime	Maximum possible displacement times are limited by the typical duration of use of EOCs or shelters
▪ Continuity Premiums	10 x cost of normal service, calculated as above, differently than for other public services
3. Casualties	
▪ Facility occupancy	▪ Earthquakes: normal occupancy for all functions ▪ Hurricanes and tornadoes: occupancy during warnings ▪ Floods: not necessary to estimate, minimal life safety benefits
▪ Casualty rates	HAZUS casualty rates for earthquakes, professional judgement for other hazards
▪ Statistical values of deaths, injuries, and illnesses	FEMA values, updated to 2001 values, see Section 2.3 - deaths: $2,710,000 - major injuries/illnesses: $15,600 - minor injuries/illnesses: $1,560

6.1 Overview

In the context of emergency planning, disaster response, and disaster recovery, utilities are often characterized as lifelines. This characterization reflects the great importance that such systems have on the functioning of modern society. For example, loss of electric power greatly reduces economic activity in a community, as well as having a direct and major impact on affected residents. Similarly, loss of function of water or wastewater systems generally has direct economic impacts on a community that are far larger than the cost of repairs of the physical damages alone

Electric power, potable water and wastewater systems are subject to physical damages from natural disasters such as earthquakes, hurricanes and floods. More importantly, however, such systems are subject to loss of function; that is, loss of utility service. Such loss-of-function disruptions often have major negative impacts on affected communities.

Hazard mitigation projects for utility systems may eliminate or reduce physical damages in future disasters. However, in many cases, an important motivation or even the primary motivation in undertaking hazard mitigation projects for utility systems is not to reduce the physical damages alone, but rather to reduce the tremendous impacts that the loss of function of such systems may have on the affected communities.

The basic concepts of benefit-cost analysis of mitigation projects for utilities are the same as those for buildings. The general principles and categories of benefits outlined in Section 2 apply to utilities as well as to ordinary buildings (Section 3) and critical facilities (Sections 4 and 5).

Mitigation projects for utility administration buildings are evaluated in the same manner as for an ordinary commercial or public building, as discussed in Section 3. Mitigation projects for utility control or command centers are evaluated in the same manner, except that a continuity premium should be added to reflect the importance of such centers in providing utility services. By analogy to the continuity premiums assigned to EOCs, a continuity premium of 10 times the normal cost of operations appears reasonable for utility control or command centers.

, Most mitigation projects for utilities, however, deal with the complex infrastructure of the utility systems and not with buildings.

> **The guidance in this section focuses specifically on mitigation projects for utility infrastructure (not on mitigation projects for utility buildings).**

Some of the details of benefit-cost analysis differ between mitigation projects for electric power systems, potable water systems, and wastewater systems. These details are discussed below. Benefit-cost analysis for all three of these utilities considers four primary categories of possible benefits, as summarized below in Table 6.1. These are the same primary categories of benefits that were defined and discussed in Section 2.

Table 6.1
Primary Categories of Benefits
Mitigation Projects for Utilities.

Types of Benefits to Consider	Notes for Utility Mitigation Projects
1. Physical damages	Damage estimates made using professional judgement in consultation with those knowledgeable about utility system components and their vulnerability.
2a. Loss-of-Function Impacts (i.e., Displacement costs)	Not applicable to utility infrastructure mitigation projects; utility system components cannot be displaced to temporary quarters.
2b. Loss-of-Function Impacts (i.e., Economic impacts of loss of service)	▪ Economic impacts of loss of service are generally the largest category of benefits. ▪ See detailed guidance for each of the three utility systems evaluated.
3. Casualties	▪ May be significant for some types of projects, for some utility systems, for some hazards. ▪ See detailed guidance for each of the three utility systems evaluated.
4. Emergency Management Costs	▪ Not generally considered. ▪ Most utility mitigation projects have a negligible impact on a community's overall emergency management costs.

6.2 Physical Damage Estimates

Utility systems contain a wide range of highly specialized components. Electric power systems have generating plants, transmission and distribution lines, high voltage substations and a host of specialized ancillary equipment. Potable water systems have storage reservoirs, storage tanks, wells, treatment plants, aqueducts and transmission pipes, distribution pipes, pumping plants, valves and a host of specialized ancillary equipment. Wastewater systems have treatment plants, systems of collection pipes, pumping plants (lift stations) and a host of specialized ancillary equipment.

Because of the complex, technical, and specialized nature of the components of utility infrastructure systems, damage estimates should always be made in close consultation with qualified individuals familiar with the specific systems under evaluation.

6.3 Functional Downtime Estimates

Functional downtime estimates for utility systems differ fundamentally from functional downtime estimates for buildings because of the network characteristics of utility systems. In order for an electric power or potable water or wastewater system to deliver service and to function as intended, a myriad of interconnected components has to work together as designed. Utility system networks are generally described in terms of links and nodes. Links are the lines or pipes that connect the other elements of the system, defined as nodes. Nodes include generating plants, treatment plants, substations, pumping plants and other facilities that are necessary to provide utility service.

In complex, networked utility systems, some components may be redundant; that is, there is an alternative, functionally equivalent component that can serve the same function if the first component fails. Other components are unique; that is, alternative components are not available if the first component fails. Therefore, the extent of loss of utility service that results from specific levels of damage depends on the detailed network operating characteristics of each specific utility system. For example, damage to one substation or pumping plant might result in little or no loss of function if the component is redundant. However, the same level of damage to another substation or pumping plant might result in loss of service to an entire neighborhood or city.

Because of the networked nature of utility systems, estimating functional downtime requires a thorough understanding of the network operating characteristics of the specific utility system under evaluation. Functional downtime estimates for utility systems should always be made in conjunction with qualified individuals knowledgeable about the specific utility system under evaluation and in close cooperation with local utility staff.

For utility systems, functional downtimes are best expressed as “system days” of lost service. A “system day” of lost service is defined as one day in which the entire system is without service. However, system days are usually fractional. For example, one system day may be one day of complete loss of service, or two days with 50% loss of service, or 10 days with 10% loss of service, and so on. Loss of service is generally defined as the percentage of customers without service. For example, if 20% of a utility’s customers have no service for 2 days, with 5% having no service for a third day, then the functional downtime is 0.45 system days. In this example the system days are calculated as 20% (0.20) times two days plus 5% (0.05) times one day or 0.45 days.

6.4 Economic Impact of Loss of Utility Services

The economic impact of loss of utility services is analogous to estimating the impact on a community of loss of public services provided from a building. The estimated economic impacts of loss of utility services differ for electric power systems, potable water systems, and wastewater systems. Thus, guidance for each of these types of utility systems is presented separately.

6.4.1 Economic Impacts of Loss of Electric Power

The base economic value of electric power is the cost of service. Recent data from the U.S. Department of Energy show a national average price of electricity of 6.74 cents per kilowatt-hour. However, electric power is extremely important for the functioning of a modern community. The economic impacts of loss of electric power are far greater than the simple cost of electric power. The primary motivation for most mitigation projects for electric power is to minimize the loss of electric power service to the community. Reductions in damage to the electric power system are an important objective, but generally secondary to preserving the delivery of electric power to the community.

The direct economic impact of loss of electric power is estimated from nationwide data on economic activity by sector of the economy (1997 Economic Census, North American Industry Classification System, and NAICS). These data were combined with electric power importance factors for each major economic sector. These importance factors reflect the reality that different sectors of the economy have varying degrees of dependence on electric power. Importance factors were taken from the FEMA-sponsored publication ATC-25 (Applied Technology Council, Seismic Vulnerability and Impact of Disruption of Lifelines in the Conterminous United States, 1991). These estimated economic impacts include both wage and business income losses.

For purposes of benefit-cost analysis, the economic impacts calculated as described in the previous paragraph were updated to 2000 values and then adjusted downwards. The downwards adjustments were made because: 1) some facilities have on-site generation or back-up power sources, 2) some lost economic production can and will be made up after restoration of electric power, and 3) there is a high potential for double-counting of reasons for the loss of economic production. With these corrections, the direct economic impact of loss of electric power is estimated to be $87 per capita per day. Following this approach, the direct regional economic impact of one system day of complete loss of electric service for a community of 100,000 people would be estimated at $8,700,000 (100,000 times $87).

In addition to these regional economic impacts, loss of electric power service also has direct economic impacts on residents, separate from the regional economic impacts estimated above. Examples of these impacts include food spoilage during prolonged outages, extra costs for meals or temporary lodging for some people, water damages due to frozen pipes and so on. Rough, common sense estimates outlined in the Supporting Documentation Volume Chapter 3 (to be available in late 2001) suggest that these impacts may total about $30 to $35 per capita per day, on average.

In addition, there is an economic value to the major disruption of normal activities that result from loss of electric power. The key point is that people's time has economic value, whether such time is devoted to remunerative work or to personal leisure and recreation.

The estimated economic value per person per hour of disruption from loss of electric power is estimated using an approach similar to that used by the U.S. Department of Transportation (DOT) for highway planning purposes. Technical details of this approach are given in the DOT memo: The Value of Travel Time: Departmental Guidance for Conducting Economic Evaluations (U.S. Department of Transportation, memo from Frank E. Kruesi, Assistant Secretary for Transportation Policy, April 9, 1997).

The simplest assumption consistent with economic theory is that each hour of people's time is worth the same amount, whether such time is personal or business time. In other words, the last hour of work time and the first hour of leisure or recreation time are assumed to have equal value. This is the assumption that should be used when valuing the direct economic impact of the disruption time for residents subjected to electric power outages.

Following the DOT approach, the average hourly compensation rate (wages and benefits) is the best available measure of the economic value of people's time. The latest available data, for March 2000, of average employer cost for employee compensation for civilian workers (private industry and state and local government) is $21.16 per hour (U.S. Department of Labor, Bureau of Labor Statistics News, USDL: 00-186, June 29, 2000). A value of $21.16 per person per hour should be used as the value for the economic impact of disruption time for customers subject to loss of electric power service.

Loss of electric power has a major disruptive impact on residential customers. The impacts include loss of lighting and in many cases loss of cooking capability, hot water and heating. Almost all normal daily activities, including preparing food, cleaning, reading, watching television, listening to music, and using computers, are disrupted. As a conservative estimate, such disruptions total at least 3 to 4 hours per person per system day of electric power outage. At slightly more than $21 per hour, such disruption of normal activities would add $63 to $85 per capita per day to the estimated direct economic impacts of $30 to $35 for residential customers estimated above. The resulting total estimated economic impacts for residential customers are approximately $93 to $110 per capita per day. The midpoint of this range of estimates is $101 per day per person.

Combining the estimated impact of losing electric power on regional economic activity and the estimated impact on residential customers yields a total estimated impact of $187 per person per day of lost service. These estimates are summarized below in Table 6.2.

Table 6.2
Economic Impacts of Loss of Electric Power
Per Capita Per Day

Category	Estimated Economic Impact
Reduced regional economic activity[1]	$87
Impacts on Residential Customers	
▪ Direct economic losses	$30 to $35
▪ Disruption economic impact	$63 to 85
▪ Total Best estimate	$101
Total economic impacts	**$188**

[1] This value of reduced regional economic activity is based on national economic data. If desired, more detailed estimates could be made for specific metropolitan areas using NAICS data in the economic census referenced above.

As an example, consider a community of 40,000 people that suffers a partial loss of electric power due to flood damage at one substation. If 50% of the customers have no power for 1 day, 15% have no power for an additional day, and 5% have no power for two additional days, then the number of system days of loss of power is calculated as 0.50 times 1 plus 0.15 times 1 plus 0.05 times 2 or 0.75 system days. With 0.75 system days of lost service, total economic impacts of $188 per person per day and 40,000 customers, the total economic impacts are calculated as 0.75 times 40,000 times $188 or $5,640,000.

6.4.2 Economic Impacts of Loss of Potable Water

The economic impacts of loss of potable water service are estimated in the same manner as for electric power service above. For potable water systems, two levels of loss of service are evaluated: 1) complete loss of water service, and 2) water unsafe for drinking.

The impact of loss of water service on regional economic activity is estimated using nationwide economic data by economic sector and water importance factors from the same sources as referenced in Section 6.4.1. The economic impact of loss of water service is large, but smaller than that for electric power. For complete loss of water service, and water unsafe for drinking, the regional economic impacts are estimated at $35 and $8.75 per person per day, respectively.

In addition to these regional economic impacts, loss of potable water service also has direct economic impacts on residents, separate from the regional economic impacts estimated above. Examples of these impacts include costs of bottled water for drinking, cleaning and sanitation purposes, increased meal costs for restaurant meals, temporary lodging for some people, increased transportation costs to obtain water, meals, and sanitation facilities and so on. Prolonged outages could also cause landscaping damage in climates where irrigation is necessary. Rough, common sense estimates outlined in the Supporting Documentation Volume (Chapter 4) (to be available in late 2001) suggest that these impacts may total about $15 per capita per day, on average.

In addition, there is an economic value to the major disruption of normal activities that result from loss of potable water service. As described in Section 6.4.1, people's time has economic value, whether such time is devoted to remunerative work or to personal leisure and recreation. As a conservative (lower bound) estimate, we suggest that such disruptions would total about 2 to 3 hours per person per system day of complete loss of water service. At about $21 per hour (the average hourly wage, as described in Section 6.4.1), the economic impact of such disruption would add $42 to $63 per day to the estimated direct economic impacts of $15 per day. The resulting total estimated economic impacts of complete loss of water service for residential customers are approximately $57 to $78 per day. The midpoint of this range is about $68 per person per day.

For loss of water quality, such that water is unsafe for drinking, the estimated economic impacts on residential customers are about 50% of the estimates for complete loss of service, or about $34 per person per day.

The above estimates of the economic impact of loss of potable water service apply to all types of natural hazard events. For earthquakes, there are additional potential losses arising from fire following the earthquake event. Earthquakes commonly cause fire ignitions, due to building damage, downed power lines, and gas line breaks. For earthquake-induced fires, loss of water service reduces fire suppression capability and leads to a statistical expectation of higher fire losses. The extent of fire following earthquake losses arising from loss of water service is possible to model mathematically, with inputs on building stock, building density, climate and wind conditions, and fire suppression capability. As a first level estimate, fires following earthquake losses due to loss of water service are estimated at $35, $17.50, and $8.75 per person for dry, moderate and wet climates, respectively.

Fire following earthquakes occurs predominantly during the first few hours or first day after a major earthquake, although some ignitions may occur later. For example, reconnecting gas lines may lead to fires if leaks are present in the distribution lines.

Loss of water service also reduces fire suppression capability for normal fires, but such fires are relatively infrequent. Thus, the effective number of days of functional downtime to be considered for fire following earthquake should logically be capped at a smaller number than the total system restoration time.

> **For purposes of benefit-cost analysis, a maximum of one system day should be used for estimating fire following earthquake losses.**

Table 6.3
Economic Impacts of Loss of Potable Water Service
Per Capita Per Day

Category	Complete Loss of Water Service	Water Unsafe for Drinking
Reduced regional economic activity[1]	$35	$8.75
Impacts on Residential Customers		
▪ Direct economic losses	$15	$7.50
▪ Disruption economic impact	<u>$42 to 63</u>	<u>$21 to 42</u>
▪ Total Best estimate	$68	$34
Total economic impacts (all hazards)	$103	$43
Fire following earthquake losses		
▪ Dry climates	$35	None
▪ Moderate climates	$17.50	None
▪ Wet climates	$8.75	None

[1] This value of reduced regional economic activity is based on national economic data. If desired, more detailed estimates could be made for specific metropolitan areas using NAICS data in the economic census referenced above.

The estimated economic impacts of loss of water service, as summarized above in Table 6.3 are large, but somewhat lower than those for loss of electric power.

As an example, consider a community of 500,000 people that has a partial loss of potable water service in an earthquake. The loss of service is primarily because of pipe breaks in the distribution system, coupled with minor damage at pumping plants. If 20% of the customers have no power for 1 day and 5% have no power for an average of three additional days, then the number of system days of loss of potable water service is calculated as 0.20 times 1 plus 0.05 times 3 or 0.35 system days. With 0.35 system days of lost service, total economic impacts of $103 per person per day and 50,000 people affected, the total economic impacts are calculated as 0.35 times 500,000 times $103 or $18,025,000.

In this example, there are also earthquake-induced fires resulting from the loss of water service. The community is a moderate climate. The fire losses only occur on the first day (0.20 system day of lost service); therefore the estimated fire losses are 0.20 times 500,000 times $17.50 or $1,750,000. In this example, fire losses are slightly less than 10% of the total estimated economic impacts of loss of water service.

6.4.3 Economic Impacts of Loss of Wastewater Service

The economic impacts of loss of wastewater service are estimated in the same manner as for electric power and potable water service above. A detailed examination of the economic impacts of loss of wastewater service is given in the Supporting Documentation Volume (Chapter 5) (to be available in late 2001). A brief summary is presented below.

The impact of loss of wastewater service on regional economic activity is estimated using nationwide economic data by economic sector and water importance factors from the same sources as referenced sections 6.4.1 and 6.4.2. The economic impact of loss of wastewater service is large, similar to that for potable water, but smaller than that for electric power. The regional economic impacts of loss of wastewater service are estimated at $33.50 and $8.50 per person per day for complete loss of treatment and partial loss of treatment, respectively.

As discussed above in Sections 6.4.1 and 6.4.2, loss of electric power and potable water services has direct impacts on residential customers, separate from the impacts on regional economic activity. For wastewater services, however, impacts on residential customers are generally non-existent or negligible. Temporary loss of wastewater treatment capability (complete or partial loss of treatment) does not generally interrupt residential customer's ability to dispose of sewage or other wastewater.

The above estimates of the economic impact of loss of potable water service apply to all types of natural hazard events. These estimates are summarized below in Table 6.4

Table 6.4
Economic Impacts of Loss of Wastewater Service
Per Capita Per Day

Category	Complete Loss of Treatment	Partial Loss of Treatment
Reduced regional economic activity[1]	$33.50	$8.50
Impacts on Residential Customers		
▪ Direct economic losses	None	None
▪ Disruption economic impact	None	None
▪ Total Best estimate	None	None
Total economic impacts (all hazards)	**$33.50**	**$8.50**

[1] This value of reduced regional economic activity is based on national economic data. If desired, more detailed estimates could be made for specific metropolitan areas using NAICS data in the economic census referenced above.

The estimated total economic impacts of loss of wastewater service, as summarized above in Table 6.4are large, but significantly smaller than those for loss of potable water or electric power service.

As an example, consider a community of 27,000 people with flood damage to a wastewater treatment plant. There is complete loss of service for 2.5 days and then partial loss of treatment capability for an additional 5 days. These losses of service affect the entire community. The estimated economic impact of complete loss of service for 2.5 days is 2.5 times 27,000 times $33.50 or $2,261,250. The estimated economic impact of partial loss of service for 5 additional days is 5.0 times 27,000 times $8.50 or $1,147,500. The total estimated economic impact of loss of wastewater services is $3,408,750.

The above analysis does not explicitly consider environmental impacts of loss of wastewater treatment services. Discharge of untreated or partially treated wastewater has potential negative environmental impacts. Flooding of wastewater treatment plants is the most common reason for loss of wastewater treatment services. Discharges of untreated or partially treated wastewater most commonly occur during periods of high water flows, when dilution of wastes is maximized and potential environmental impacts (are minimized.

The scope of the present guidance does not include evaluating environmental damages or the benefits of reducing or avoiding such damages. However, in effect, such environmental impacts are partially considered in the present analysis of the economic impacts of loss of function of wastewater treatment facilities, as described below.

The analysis of the regional economic impacts of loss of wastewater services implicitly assumes that business activity will be curtailed during periods of loss of wastewater service. When wastewater services are lost, communities sometimes impose operating restrictions on industrial and large commercial facilities to reduce the inflow of waste. More commonly, however, communities simply discharge partially treated or completely untreated waste.

In making a public policy decision to discharge partially treated or completely untreated waste, rather than to impose drastic restrictions to curb waste inflows, communities are implicitly deciding that possible environmental impacts are less than the economic losses that would arise from imposing more drastic reductions to curb waste inflows. To the extent that communities choose to release completely untreated or partially treated waste instead of curbing economic activity to reduce waste inflow, the estimated regional economic impacts of loss of wastewater service, as outlined above, will be over-estimated.

Following the above analysis, the estimated regional economic impacts of loss of wastewater treatment services probably overestimate the actual economic impacts. However, the estimated regional economic impacts implicitly are deemed equal to or greater than possible environmental damages. In effect, possible environmental impacts are counted indirectly (at least roughly) in the proposed methodology for estimating regional economic impacts.

6.5 Casualties

Loss of function of utilities - electric power, potable water and wastewater - has potential life safety impacts on affected communities. In some cases there may be deaths, injuries or illnesses arising from loss of utility services.

Loss of electric power may result in casualties. However, facilities for which electric power is a critical life safety issue (such as acute care in hospitals) always have redundant backup power supplies (e.g., battery back-ups and emergency generators). An upper bound analysis of potential casualties due to loss of electric power in Chapter 3 of the Supporting Documentation Volume (to be available in late 2001), suggests that the economic value of casualties is likely to be well below $2.50 per person per day of lost service. This upper bound value is very low compared to the estimated economic impacts of loss of electric power, $188 per person per day, and thus may be ignored as negligible for benefit-cost analysis. Actual casualties are likely to be less than these upper bound estimates.

Loss of potable water service may also result in casualties, most commonly illness from drinking contaminated water. Deaths from contaminated water are possible, but extremely rare. A rather extreme upper bound analysis of potential casualties due to loss of potable water service in Chapter 4 of the Supporting Documentation Volume (to be available in late 2001), suggests that the economic value of deaths is likely to be well below $2.50 per person per day of lost service, with the economic value of illnesses likely to be well below $1.50 per person per day. These upper bound values is low compared to the estimated economic impacts of loss of potable water service, $103 per person per day, and thus can probably be ignored as negligible for benefit-cost analysis. Actual casualties are likely to be less than these upper bound estimates.

Loss of wastewater service also has the potential for casualties, most commonly illness from drinking or exposure to contaminated water. However, any such illnesses are likely to be much less than those estimated above for potable water systems, since few people are likely to drink raw untreated water. Casualties arising from loss of function of wastewater treatment plants appear to be negligible for purposes of benefit-cost analysis.

6.6 Summary Guidance

The basic concepts of benefit-cost analysis of mitigation projects for utilities are the same as those for buildings (as discussed in previous sections). Significant differences are as follows:

Physical damage estimates for utility systems must be estimated by qualified individuals thoroughly familiar with the specific utility systems under evaluation, based on historical damage data, professional judgement and engineering calculations.

Displacement costs are not applicable to utility systems, since utility system components cannot be displaced to temporary quarters. Displacement costs should not be counted in benefit-cost analysis of mitigation projects for utility systems.

Loss of function of utility services has a great economic impact on regional economic activity in general and residential customers in particular. In addition, for loss of potable water service in earthquakes, there are additional losses due to fires following earthquakes. These economic impacts are summarized in Table 6.5 below.

Table 6.5
Economic Impacts of Loss of Utility Services
per Person Per Day of Lost Service

Loss of Electric Power	**Cost of Complete Loss of Service**	
Reduced Regional Economic Activity[1]	$87	
Impacts on Residential Customers	$101	
Total Economic Impact	**$188**	
Loss of Potable Water Service	**Cost of Complete Loss of Service**	**Cost of Water Unsafe for Drinking**
Reduced Regional Economic Activity[1]	$35	$8.75
Impacts on Residential Customers	$68	$34
Total economic impact (all hazards)	**$103**	**$43**
Fire Following Earthquake Losses	**Cost of Fire Damage**	
- Dry Climates	$35	
- Moderate Climates	$17.50	
- Wet Climates	$8.75	
Loss of Wastewater Service	**Cost of Complete Loss of Service**	**Cost of Partial Treatment Only**
Reduced Regional Economic Activity[1]	$33.50	$8.50
Impacts on Residential Customers	None	None
Total Economic Impact	**$33.50**	**$8.50**

[1] This value of reduced regional economic activity is based on national economic data. If desired, more detailed estimates could be made for specific metropolitan areas using NAICS data in the economic census referenced above.

7.1 Overview

In the context of emergency planning, disaster response, and disaster recovery, roads and bridges are often characterized as lifelines. This characterization reflects the importance that roads and bridges have on the functioning of modern society. Especially in a disaster, roads and bridges are often critical for disaster response and evacuation.

Roads and bridges are subject to physical damages from natural disasters such as earthquakes, hurricanes and floods. More importantly, however, roads and bridges are subject to loss of function; that is, closure to traffic. Such closures often have significant negative impacts on affected communities.

Hazard mitigation projects for roads and bridges may reduce physical damages in future disasters. However, in many cases, an important motivation or even the primary motivation in undertaking hazard mitigation projects for roads and bridges is not to reduce the physical damages alone, but rather to reduce the negative impacts that the closures of roads and bridges may have on the affected communities. That is, mitigation projects for roads and bridges are often focused primarily on keeping the roads and bridges open during disaster events.

The basic concepts of benefit-cost analysis of mitigation projects for roads and bridges are the same as those for buildings and are summarized in Table 7.1. The general principles and categories of benefits outlined in Section2 apply to roads and bridges as well as to ordinary buildings (Section3), critical facilities (Sections4 and 5), and utilities (Section6).

Table 7.1
Primary Categories of Benefits
Mitigation Projects for Roads and Bridges

Primary Categories of Damages/Benefits	Notes for Utility Mitigation Projects
1. Physical Damages	Damage estimates must be made by engineers knowledgeable about roads and bridges and their vulnerability to each type of hazard.
2a. Loss-of-Function Impacts (i.e., Displacement costs)	Not applicable to road and bridge mitigation projects; roads and bridges cannot be displaced to temporary quarters.
2b. Loss-of-Function Impacts (i.e., Economic impacts of loss of service)	Economic impacts of road or bridge closures are the generally the largest category of benefits; see detailed guidance in this section.
3. Casualties	Not generally significant, except for seismic mitigation projects for bridges.
4. Emergency Management Costs	Not generally considered; most road and bridge mitigation projects have a negligible impact on a communities overall emergency management costs

7.2 Physical Damage Estimates

Roads and bridges vary in their materials and designs. The vulnerability of roads and bridges to flood, wind, or seismic damage varies drastically depending on the type of components, their age, their design and condition. As such, it is necessary to make facility-specific estimates based on historical damage data and professional judgement. Because of the somewhat specialized nature of road and bridge engineering, damage estimates should always be made in close consultation with qualified individuals thoroughly familiar with the specific components under evaluation.

7.3 Functional Downtime Estimates

Functional downtime estimates for roads and bridges are somewhat different than for buildings or utilities. For roads and bridges there are two aspects of functional downtime. The first aspect is the closure time or the time period during which the road or bridge is closed to normal traffic while repairs are made. Closure times may range from a few hours to several days to several weeks in unusual cases. The second aspect is the delay or detour time. Delay or detour time is the average amount of extra time that motorists spend taking alternative routes because of road or bridge closures. Delay or detour time may be only a few minutes if an alternative route is only a block or two away. Typically delay or detour times are fractions of an hour. In rare cases, delay or detour times may be an hour or more if, for example, a bridge is closed and the nearest alternative bridge is a long distance away.

For road and bridge closures, functional downtime is expressed in two steps:

1. Estimate the number of days for the damaged road or bridge to be repaired and reopened to normal traffic flow
2. Estimate the average delay or detour time for motorists while the bridge is closed.

For example, assume that a culvert fails in a flood and a road is washed out. A county highway department estimates that the repair time is one week and that the average delay or detour time caused by the closure is about 20 minutes. When a disaster event causes numerous road or bridge closures, repairs are almost always made first to the most important roads or bridges. Thus, secondary or rural roads and bridges are generally expected to have longer closure times than primary roads.

Estimates of repair times and delay or detour times are made based on historical data and experience. Local highway department staff is generally very experienced with closures and is the best source of repair time estimates and delay or detour times.

7.4 Economic Impact of Road and Bridge Closures

The economic impact of road and bridge closures is analogous to estimating the impact on a community of loss of public services provided from a building. Closure of a road or bridge represents loss of a public service - the availability of a transportation route.

The economic impact of road and bridge closures is estimated from the number of vehicles per day using the route, the average delay or detour time, and the average value of people's time. The primary economic impact of road and bridge closures is loss of time.

There are four steps in estimating the direct economic impacts of road or bridge closures:

1. Estimate the functional downtime; that is, the repair time to restore normal traffic flow on the road or bridge

2. Determine the average daily traffic count for the closed road or bridge
3. Estimate the average delay or detour time arising because of the closure
4. Place a typical or average dollar value per person hour or per vehicle hour of delay or detour

Each of these steps is discussed in detail below.

7.4.1 Functional Downtime (Repair Time) for Roads and Bridges

For roads and bridges, functional downtime is the time period for which the road or bridge is closed to normal traffic flow. For a given road or bridge that is damaged in a disaster event, the repair time depends on the severity of damage, on the number of other damaged roads or bridges, and, very importantly, on the priority placed on repair and reopening by the local highway department. When there are multiple outages, local highway departments almost always prioritize repairs so that the most important roads or bridges are reopened first. Small residential or rural roads are likely to be repaired much later than major arteries with high traffic flows.

Repair times can range from a few hours if there are only a few outages, to several days to several weeks, depending on the number of damaged roads or bridges. Repair times are very rarely longer than two or three weeks, except for major bridge structures, which might take many months or even a year or two to replace if destroyed.

Estimating repair times requires somewhat specialized knowledge of the local highway transportation system, of the availability of local resources, and of local priorities, and is thus best made in close cooperation with local traffic officials.

7.4.2 Average Daily Traffic Counts

Average daily traffic counts for most roads or bridges are available from local highway officials. Traffic counts are used for road/bridge design purposes and for traffic control, planning and management purposes. Local highway officials generally can provide actual traffic counts for specific segments of roads or bridges, or at least reasonable estimates based on traffic counts for similar nearby roads and bridges.

Traffic counts are usually presented as the number of vehicles per day or per hour. Traffic counts may be presented as total vehicles or separately for different classes of vehicles (e.g., cars, light trucks, heavy trucks). Traffic counts are usually presented as the number of single (one-way) trips, but are sometimes presented as the number of round trips. The difference between one-way and round-trip counts is important and the unit of measure (one-way or round-trip) must always be noted carefully.

7.4.3 Average Delay or Detour Times

When a given road or bridge is closed because of high water, unsafe conditions, or physical damage, the delay or detour varies markedly, depending on local conditions. Delay or detour times can range from five minutes or less to several hours (in rare cases).

Road and systems are networked systems of interconnected elements. In, networked systems, some elements may be redundant; that is, alternative paths may be available if such elements fail. Other elements may be nearly unique; that is, no practical alternative paths are available. The extent of loss of function that results from specific damage depends on the characteristics of each specific road and bridge system. For example, damage that closes one city street may have very little impact on traffic if the resulting detour is only one city block while repairs are made. However, closure of a rural road or a bridge may result in a substantial detour (duration and mileage) with a correspondingly significant economic impact.

The length of delay or detour that is likely to result from the closure of a particular road or bridge depends entirely on specific local conditions and so no generalizations can be drawn. The length of delay or detour depends on:

> The traffic count for the closed road or bridge
>
> The layout of the local road and bridge system (what alternative routes are available, how suitable the alternative routes are, how heavy the normal traffic is on these routes, and the distance between the closed road or bridge and the alternative route)

Local highway officials are the best source of delay or detour time estimates. Local highway officials have knowledge of past closures, of what detours or alternative routes are available, and knowledge of the local road and bridge system and local traffic patterns. Estimated delay or detour times will never be exact and will vary depending on the time of the day and on the day of the week. However, knowledgeable local highway officials should be able to make reasonable estimates: Will closure of this bridge result in a 5 minute detour, a 30 minute detour, or a several hour detour?

7.4.4 Economic Impact Per Person Per Hour of Delay or Detour Time

The economic impacts of road or bridge closures are estimated by combining the number of days of road or bridge closure, the average daily number of vehicles using the road, the average delay or detour time per vehicle, and the estimated economic value per person per hour of delay or detour.

The estimated economic value per person hour of delay or detour is estimated using an approach similar to that used by the U.S. Department of Transportation (DOT) for highway planning purposes (The Value of Travel Time: Departmental Guidance for Conducting Economic Evaluations, U.S. Department of Transportation, memo from Frank E. Kruesi, Assistant Secretary for Transportation Policy, April 9, 1997).

The DOT memo referenced above has a detailed analysis of economic theory and references to its approach. For the present purposes, a condensed summary of the analysis is presented. The key point is that time saved from travel has economic value, whether such time is devoted to remunerative work or personal leisure/recreation. Furthermore, if travel is associated with unpleasant conditions of crowding (or delays and detours), exposure to weather, risk, effort or boredom, cutting the time it requires will be beneficial. In simple terms, people would, on average, be willing to pay something to avoid such unpleasant travel conditions.

The simplest assumption consistent with economic theory is that each hour of time lost in travel delays or detours is worth the same amount, whether such time is personal or business time. In other words, the last hour of work time and the first hour of leisure/recreation time are assumed to have equal value. This is the assumption that should be used for valuing the direct economic impact of the time lost by closures of roads and bridges. For benefit-cost analyses of FEMA-funded hazard mitigation projects, 100% of the national average hourly wage (plus benefits) should be the value of travel time lost by road and bridge closures. As described in Section 6.4.1, the average employer cost for employee compensation is $21.16 per hour according to U.S. Department of Labor.

The U.S. DOT also has data on average vehicle occupancies. For 1996, the total highway passenger miles were 3.962 trillion. A passenger mile is one person traveling one mile by automobile, motorcycle, light truck, heavy truck, or bus. For 1996, the total highway vehicle miles were 2.482 trillion. The ratio of these two numbers, 1.596 is the average vehicle occupancy. Applying this occupancy value and the $21.16 per person per hour value derived above yields a value of $33.78 per vehicle hour of lost travel time.

The U.S. Census Bureau population estimate for November 2000 indicates that 74.47% of the population is 18 or over, with 25.53% under 18. If these ratios are applied to the average vehicle occupancy, assuming that drivers are 18 or over, then the average vehicle occupancy is 1.444 adults and 0.152 children under 18. This estimated proportion of adult and child passengers does not consider that some drivers are under 18 (about 3% of the total population is between 16 and 18) but this is offset by the fact that the proportion of children as passengers is likely lower than in the population as a whole, because there are few children as passengers for commuting or business travel. Combining these data, we estimate that the average vehicle occupancy is about 1.45 adults and 0.15 children.

If lost time for children were assumed to have no economic value (a somewhat extreme assumption), then the estimate of $33.78 per vehicle hour of lost travel time would be reduced by nearly 10% to $30.68. More reasonably, lost time for children has an economic value, but less than that for adults. Taking the midpoint of these two extremes (counting children's lost time the same as adults or counting children's lost time at zero) yields an estimate of $32.23, which appears to be a reasonable estimate. Thus, the average economic value of lost travel time as $32.23 per vehicle hour of delay or detour due to road and bridge closures.

The above analysis considers all traffic to be of equal economic value. However, there are two other possible economic impacts from closures of roads and bridges that need to be evaluated for possible inclusion in benefit-cost analysis, namely:

1. Economic impacts for commercial traffic
2. The impact of road and bridge closures on emergency vehicles

For commercial travel (including heavy trucks) the analysis presented above includes only the value of the driver's time. As discussed above, typical delay or detour times are short, on the order of a few minutes to perhaps an hour or two. For such short delays there are unlikely to be major economic impacts such spoilage of perishables goods or interruption of normal economic activity. Therefore, no adjustments for commercial traffic need be made.

For emergency vehicles, the delay or detour times may increase the response time and thus lower the quality of emergency response. However, the fraction of normal traffic that is emergency vehicles is extremely small, a very small fraction of 1% of total traffic. Furthermore, delays and detours may be shorter for emergency vehicles as such vehicles typically have expedited access to the transportation system and some emergency response vehicles have off-road capabilities or higher ground clearances and thus can travel on roads closed to normal traffic. Thus, the impact of road and bridge closures on emergency vehicle response is assumed to be minor.

For purposes of benefit-cost analysis, the economic impact of road or bridge closures is estimated as $32.23 per vehicle hour of delay.

7.5 Casualties

Failure of a road or bridge may occasionally result in deaths or injuries from vehicular accidents at the failure location. However, such incidents are extremely rare. Closure of a road or bridge, or even a major washout of a section of road or complete washout of a bridge very rarely results in casualties. Historical experience suggests that deaths from such accidents would be many times less than 1 person per 1,000,000 in a community affected by a typical road or bridge closure. Based on the statistical value of human life (deaths and injuries), such rare incidents are generally negligible compared to the economic impact of delay and detour times discussed above.

The statistical value of casualties avoided may be important for one type of hazard mitigation project: seismic retrofit of bridges subject to collapse in earthquakes. For example, if one of the approximately 300-foot long segments of the Bay Bridge between Oakland (CA) and Treasure Island were to fail completely in an earthquake, the expected death rate would be a very high percentage of the average "occupancy" of the bridge segment. For high traffic bridges that could be subject to complete failure in earthquakes, the value of casualties avoided should be evaluated individually for each mitigation project.

Estimating casualty rates from bridge failures from earthquakes requires professional judgement. Such estimates should be made in close consultation with seismic engineers thoroughly familiar with seismic bridge engineering.

7.6 Summary Guidance

The suggested approach for benefit-cost analysis of hazard mitigation projects for roads and bridges has five steps, each of which must be done for both the before and after mitigation states of the road or bridge, as a function of the severity of disaster:

1. Estimate the physical damages to road or bridges in dollar terms
2. Estimate the repair time to restore normal traffic flow,
3. Estimate the average delay or detour time
4. Obtain the average daily traffic count for the road or bridge
5. Calculate the economic impacts of loss of function of the road or bridge, using the above data and the per vehicle per hour value of lost travel time of $32.23

For floods, these estimates are made as a function of flood depth or flood frequency. For hurricanes or earthquakes, these estimates are made as a function of wind speed or peak ground acceleration

(PGA), respectively. Data sources and guidance for making these estimates calculations are summarized in Table 7.2 below. For earthquakes only, the additional category of casualties losses is also considered for bridge mitigation projects.

Table 7.2
Summary Guidance for Benefit-Cost Analysis
of Hazard Mitigation Projects for Roads and Bridges

Parameter	Data Sources
1. Physical damages to road or bridge	Historical data and professional judgement from individuals knowledgeable about roads and bridges
2. Repair time to restore normal traffic flow	Historical data and professional judgement or estimates from local traffic officials
3. Average delay or detour time	Historical data or estimates from local traffic officials
4. Average daily vehicle count	Historical data or estimates from local traffic officials
5. Economic impact of road or bridge closure	$32.23 per vehicle hour of delay or detour

As an example, consider a situation in which a culvert washout closes a road until repairs are made. For benefit-cost analysis, estimates are made of the physical damage costs and loss-of-function economic impacts for each flood depth or flood frequency, both before and after mitigation. As an example, we show a typical calculation of the damages and losses before mitigation for one flood frequency (a 25-year event).

Example

Physical damages, the actual cost t repair the road and culvert, are estimated from historical sources to be **$6,500**. Local traffic officials estimate the number of days of closure to be **3 days**, the average delay or detour time to be **30 minutes**, and the average daily vehicle count to be **1,200**.

To determine the economic impact of the road closure, we take the product of the repair time (3 days), average delay or detour time (0.5 hours), average daily vehicle count (1,200 vehicles per day), and the cost per vehicle hour of the delay or detour ($32.23) (see Table 7.2), or:

3 x 0.5 x 1,200 x $32.23 = $58,014 for the economic impact of the road closure.

Add the physical damage cost: + 6,500

for total damages and losses: **$64,514**

In this example, nearly 90% of the total damages and losses arise from the economic impact of the road closure. Only 10% of the total damages and losses are from the repair costs. For benefit-cost analysis of mitigation projects for roads and bridges, it is always extremely important to count the benefits of avoiding road closures. To not do so would be to grossly undercount the benefits of mitigation projects for roads and bridges.