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# ESTIMATING BENEFITS AND COSTS OF BUILDING REGULATIONS

## A Step by Step Guide

Carol Chapman Rawie

June 1981



U.S. Department of Commerce
National Bureau of Standards
Washington, DC 20234

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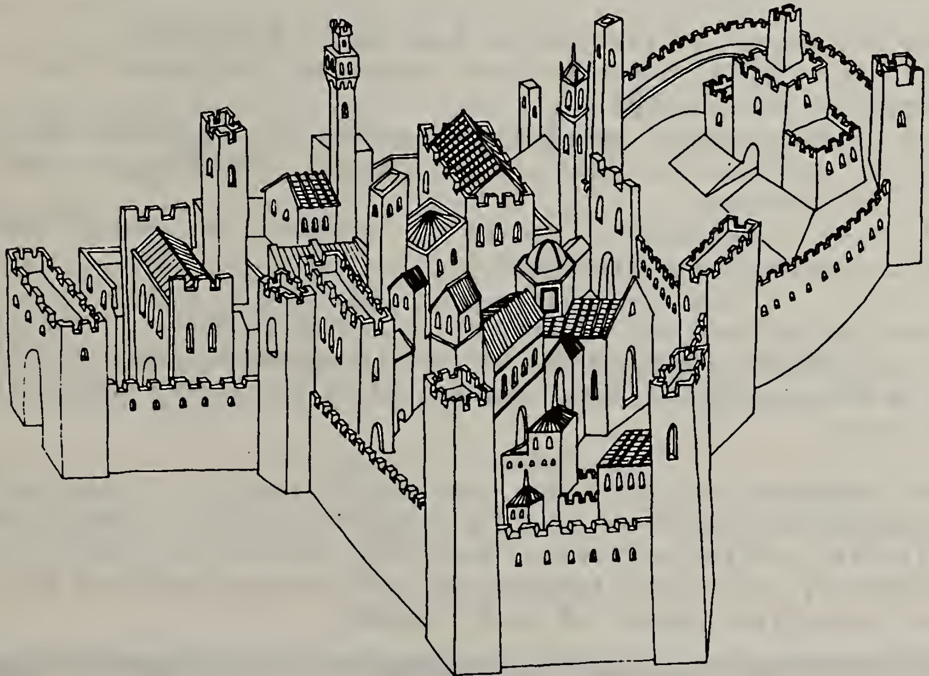
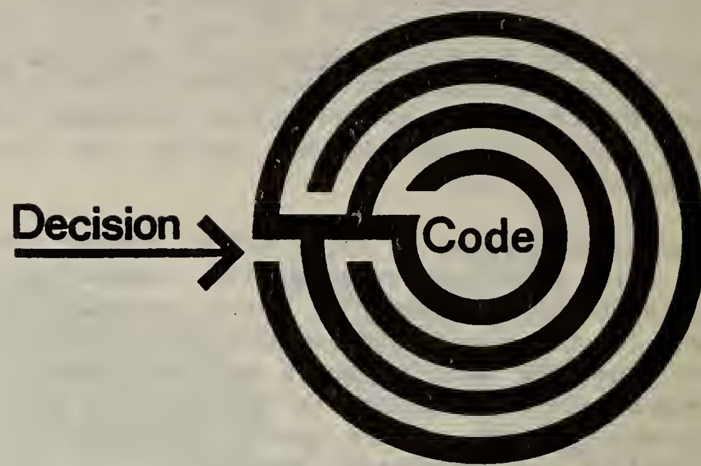
# Preface

This publication provides techniques for measuring cost effectiveness of alternative code requirements. A 1978 NBS report, An Economic Analysis of Building Code Impacts: A Suggested Approach, by John McConnaughey, provided impetus for the research underlying this handbook. A report by Carol Rawie, Estimating Economic Impacts of Building Codes, to be published by the NBS Building Economics and Regulatory Technology Division, provides a more comprehensive treatment of the topics discussed here. Preparation of this handbook was funded through the NBS Design and Construction Technology Applications Program (DACTAP).

The author wishes to thank DACTAP manager Porter Driscoll for his encouragement of this work and constructive suggestions concerning it. Appreciation is extended to Alan Gomberg, Harold Marshall, James Pielert, and Stephen Weber of NBS for their valuable comments on various drafts. The author is also indebted to other NBS staff members and to members of the building community who provided helpful comments on the report, and to Michael Usle, who assisted in several aspects of the study. Special credit is due Forrest Wilson for his skillful and imaginative graphics.



# To the Reader




THE AIM OF THIS GUIDE is to help those involved in building codes use economic analysis to make decisions about code changes. Consider for a moment the following building code decisions:

* Should all houses be required to have smoke detectors?
* Should the National Electric Code requirement for ground fault circuit interrupters be adopted?
* Should reduced-sized venting be permitted in plumbing systems?
* Which of several versions of an energy conservation requirement should be adopted?
* Which code requirements should be applied to rehabilitation or historic preservation projects?

These decisions can not only affect the safety and performance of the building, but they also can affect construction and operating costs. Many building code changes have major economic effects that should be considered carefully before decisions are made.

This handbook explains how to apply economic analysis -- in particular, benefit-cost analysis — to building code decisions. It is a how-to guide for building officials, elected officials, builders, architects, engineers, trade association members, and others involved in code change decisions who need to determine the cost effectiveness of such changes.

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# Reasons To Use Economic Analysis In Setting Building Code Requirements

REASONS TO USE ECONOMIC ANALYSIS IN SETTING BUILDING CODE REQUIREMENTS

Economic analysis is valuable because it:

* Brings out the facts. Economic analysis helps assure that all important effects are considered. For example, it focuses attention on the price that must be paid for additional safety and performance. It shows which information is essential to the code change decision and provides a framework for acquiring and organizing the needed information.

* Assists in making choices. Economic analysis provides a common denominator -- dollar value -- which makes it possible to consolidate many of the diverse impacts of a code change into a single figure which can be weighed against nonmonetary impacts.

* Is useful even when information is not readily available. Even if there is considerable doubt about the benefits or costs of a code change, economic analysis may point to the correct code decision or it may show what other data are needed to make the right decision.

But this does not mean a formal economic analysis is needed for all code change decisions. Rather, an economic analysis is most useful when:

* The proposed change is important, with potentially high impacts.

* The proposed change is controversial.

* The magnitude of economic effects is uncertain without an economic analysis.

* Data are available on the most important impacts of the code change.

In 1980, the U. S. House of Representatives published a report, Cost-Benefit Analysis: Wonder Tool or Mirage? We mention it because the limitations of cost-benefit analysis pointed out in that report may also apply in analyzing building regulations. For example, there are often problems obtaining adequate data on building hazards. As another example, there may be important impacts not easily included in a simple analysis, such as long-run effects of code changes on construction innovation or income distribution.

Because of such difficulties, economic analysis is most useful as one of several inputs to the decisionmaking process. In this role it can provide valuable and sometimes surprising insight into the effects of code changes.

# Steps in the Analysis

This handbook describes a step-by-step process of analyzing a proposed code change to determine whether it is cost effective. Sample worksheets filled out for a hypothetical code change are provided to illustrate the process. There are also blank worksheets in appendix D which can be removed and duplicated for future use. A glossary of economic terms begins on page 61. References for additional information are listed at the end of each chapter.

There are seven steps in analyzing economic impacts of proposed code changes:


Page

**1** DEFINE THE PROBLEM .......... 5

* Record key information about the code change
* Select representative cases to analyze (typical design, construction year, location, building analysis period)

**2** ESTIMATE IMPACTS ON BUILDING COSTS .......... 11

* Estimate changes in construction, operation and maintenance costs
* Estimate effects on government costs

**3** ESTIMATE IMPACTS ON SAFETY AND PERFORMANCE .......... 25

* Determine how the code revision changes the likelihood of accidents
* Estimate the change in fatalities, injuries, and property losses
* Estimate effects on other aspects of building performance

**4** COMPUTE NET MONETARY BENEFITS .......... 39

* Adjust figures to reflect future construction dates
* Calculate present value of Net Monetary Benefits

**5** ESTIMATE AGGREGATE IMPACTS .......... 43

* Sum impacts on all affected buildings in the code jurisdiction

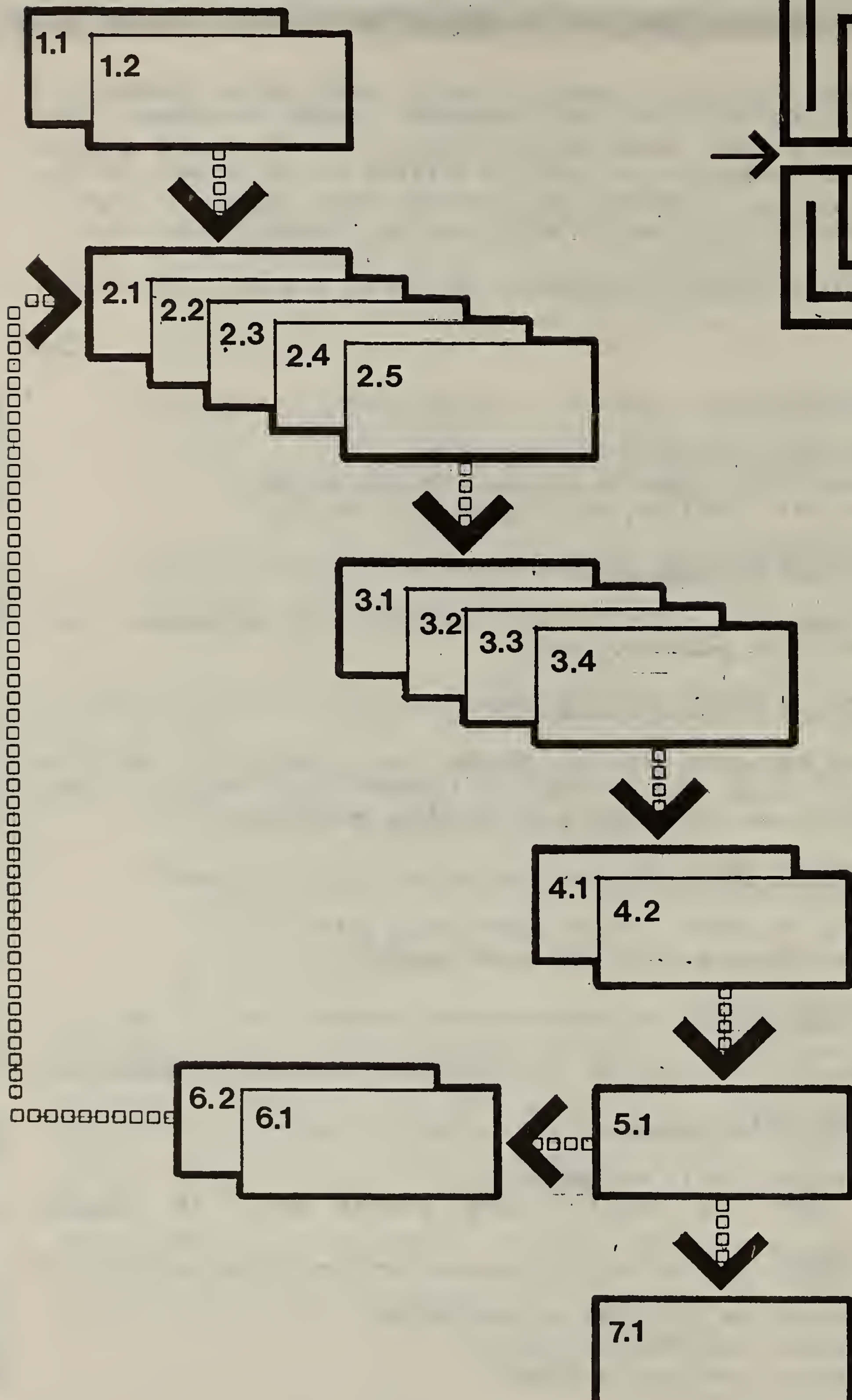
**6** PERFORM A SENSITIVITY ANALYSIS .......... 47

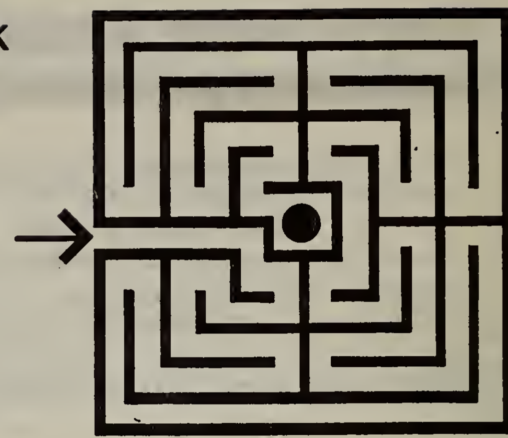
* Identify uncertainties in the variables
* Recalculate costs and benefits using altered values of variables

**7** WRITE UP THE RESULTS .......... 53

* State key assumptions and areas of uncertainty
* Describe important quantitative effects
* Describe important qualitative effects

# WORKSHEETS HOW THEY WORK



# Before You Begin

Before beginning the analysis, there are a few points to keep in mind concerning the scope of this handbook and the method of analysis.

First, while it is desirable to estimate important effects in terms of dollars or some other numerical measure, for some effects there may not be sufficient information to do this. These other effects should be described verbally so that those making code change decisions can take them into consideration.

Second, the method in this guide can be used in deciding whether to delete, add, or modify a code requirement. It can be used to compare several versions of a code change to see which produces the greatest net benefits. Also, it can be used to compare several proposed code changes which have similar benefits in order to find the least costly way to obtain these benefits.

Third, this guide explains how to estimate all important impacts of a code change, regardless of whether they affect builders, building owners, tenants, taxpayers, or others. However, the method also can be used if you wish to calculate effects only on particular groups.

Fourth, this guide is concerned with building codes. Although economic analysis is useful in making decisions related to zoning, subdivision, or environmental regulations, the particular methods and worksheets in this handbook were devised specifically for building codes and may not always be suitable for analyzing these other types of regulation. The same is true for product safety regulations applied to building furnishings.

Finally, all the steps in this guide are not needed for each code change analyzed. You will only need to complete the steps and fill out the worksheets that are appropriate for the code change you are studying. In some cases you may need to devise new worksheets for situations not covered in this guide.

## Decision

# 1. Define the Problem

The steps in this guide and the use of the worksheets are illustrated with a sample problem involving a fictitious Fire Safety Feature (FSF). All of the examples in this guide are hypothetical. In cases where the same worksheet would have to be filled out several times in order to complete the analysis, we present only one version of the worksheet, omitting other computations in order to save space.

In the first step you will decide on the scope of the analysis, select a unit of analysis, describe the exact code change to be analyzed, select representative cases for the analysis, and choose a code analysis period. You will use worksheets 1.1 and 1.2.

<u>Scope</u>. The first step is to decide on the scope of the analysis. For example, will you analyze effects on the local jurisdiction, the state, the region, or even the nation as a whole? Also, you will need to decide whether to analyze code changes from the viewpoint of a specific interest group, such as builders or owners, or from the viewpoint of the community as a whole. For the most part, the discussion in this guide assumes you are analyzing effects of a code change on everyone in the code jurisdiction.

<u>Describe the code change</u>. Next, determine which parts of the code section will be altered and record pertinent information for easy reference later on. Worksheet 1.1 is provided for this purpose. Its use is illustrated for the example below, which involves a code change for a fictitious jurisdiction.

<u>Unit of analysis</u>. Third, choose a unit of analysis. If possible, this should be a unit which is closely related to the code change impacts and for which there are data on the number of units constructed. For example, the effects of a plumbing code change might be analyzed per bathroom. An attic insulation requirement might be analyzed per square foot of attic space. In the example, Fire Safety Feature impacts are calculated per dwelling unit.

Example: IDENTIFYING WHAT IS REQUIRED BY A PROPOSED CODE CHANGE

<u>Problem</u>: A hypothetical proposed provision of the Springfield County building code reads as follows: *Except for sprinklered buildings, all new buildings in residential use groups R-2, R-3, and R-4 of two stories or more in height must have at least one Fire Safety Feature of design A or B installed in the kitchen of each dwelling unit.*

Use groups R-2, R-3, and R-4 are defined in the Springfield County code as including single-family houses and multifamily dwellings except hotels and motels. The current code provision, which would be deleted if the revision is approved, requires a Fire Safety Feature of design C.

What are the key changes required under the proposed provision?

<u>Solution</u>: Pertinent information that should be presented for this proposed code change is shown in worksheet 1.1.

# Worksheet 1.1

*hypothetical example*

## PROPOSED CODE CHANGE

Title or number of code change *Fire Safety Feature (FSF) Requirement*

| | |
|---|---|
| Occupancy or Use Group Affected | *New buildings in use groups R-2, R-3, and R-4; single and multifamily dwellings except hotels and motels.* |
| Construction Type Affected | *All types of construction two stories or more in height.* |
| Building Part or System Affected | *Kitchen.* |
| Conditions or Exceptions | *Does not apply to sprinklered buildings.* |
| Original Requirement | *FSF/design C required.* |
| Proposed Changes | *One FSF/design A or B required for each dwelling unit; design C no longer required.* |

1

# 1 SELECT REPRESENTATIVE CASES

Often the effects of a code change vary from building to building. As a practical matter, it is impossible to analyze the impacts of a code change for all types of buildings. Therefore, you should choose a few representative cases for analysis and use the resulting case studies as a basis for calculating the total effect.

Choosing a representative case involves selecting a reference building, identifying construction practices with and without the code change, and selecting certain other characteristics such as location and construction year. The exact characteristics to select depend on the code change being analyzed.

Reference buildings should reflect the various types of buildings that will be constructed during the code analysis period and would be affected by the code change. It may be convenient to select actual buildings as the reference buildings. But if you cannot find an actual building which is sufficiently typical, you may wish to use a hypothetical design. Publications which may help in choosing reference designs are listed at the end of this chapter.

There are several questions to keep in mind when selecting a reference design:

* Which building features will determine the impact of the code change? For example, the type of heating system is relevant in analyzing cost-effectiveness of an energy conservation provision, but may not be relevant in analyzing a fire safety provision.

* What kinds of buildings will be prevalent in the code jurisdiction? Although predicting construction trends is difficult, in some cases it may be important to select representative buildings that represent likely future practices. Failure to anticipate building trends will result in an incorrect basis for deciding whether to make the code change.

* Which types of building construction will be affected by the code change after taking into account exceptions and expected waivers?

* Are major rehabilitation or historic preservation projects common in the jurisdiction? If so, to what extent would the code change apply to them?

Usually it is helpful to choose several reference designs. How many you choose depends on the code change, the diversity of the affected building population, and the time and money available for the analysis.

Worksheet 1.2 is provided to record characteristics of representative cases. Its use is illustrated on page 9 for the example on the facing page.

# EXAMPLE: SELECT REPRESENTATIVE CASES FOR ANALYSIS 1

Problem: The code change described in the example on page 5, requiring a Fire Safety Feature in residential buildings, is proposed for adoption in 1981. The code jurisdiction is made up of two towns, Poker Flat and Springfield, for which the following number of new dwelling units will be constructed between 1981 and 1990:

| | Springfield | Poker Flat |
|---|---|---|
| Single-family houses | 2000 | 500 |
| Multifamily low-rise units | 580 | 20 |
| Residential high-rise units | 400 | 0 |

Fifty percent of the single-family houses in Springfield are expected to be one-story and 75 percent of the residential high-rises are expected to be sprinklered. All other buildings will not have sprinkler systems and will be at least two stories. With the code requirement, almost all single-family houses are expected to use design A of the FSF, and all multifamily low-rise and high-rise buildings are expected to use design B.

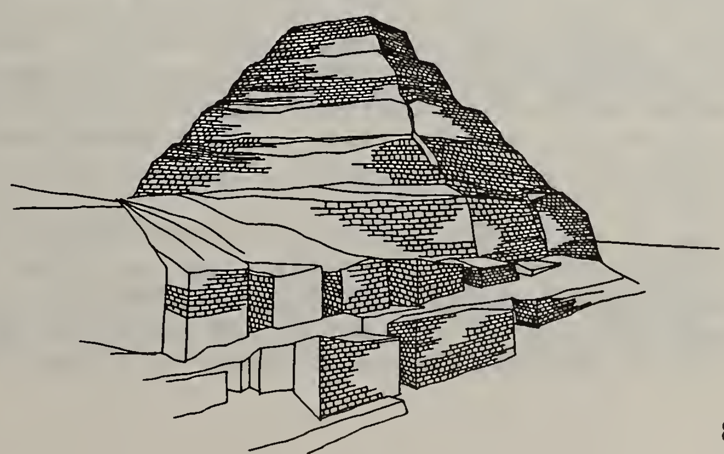
What representative cases should be selected as a basis for analyzing costs and benefits of the code change?

Solution: Representative cases are selected as follow: Case I, a single-family house constructed in Springfield in 1985; builder installs a FSF/design A in lieu of installing design C; Case II, a single-family house constructed in Poker Flat in 1985; builder installs a FSF/design A in lieu of installing design C; Case III, an apartment in a multifamily low-rise building constructed in Springfield in 1985; builder installs FSF/design B in lieu of installing design C; and Case IV, an apartment in a residential high-rise constructed in Springfield in 1985; builder installs FSF/design B in lieu of installing design C.

These four cases are described in worksheet 1.2.

Code analysis period. While selecting representative cases, you should also select a code analysis period and enter it on worksheet 1.2. Impacts of the code change will be estimated for buildings constructed within this period. For example, you may select the period over which the requirement is likely to be in effect before it is carefully reviewed for possible revision. The code analysis period should be the same for all representative cases. The period used in the example on the next page is 1981 to 1990, ten years.

Other items on worksheet 1.2 are discussed following the worksheet.



# Worksheet 1.2

*hypothetical example*

## REPRESENTATIVE CASES

Code analysis period *1981 - 1990* Unit of analysis *Dwelling unit*

| Characteristics | Representative Case I | II | III | IV |
|---|---|---|---|---|
| Location | *Springfield* | *Poker Flat* | *Springfield* | *Poker Flat* |
| Date Constructed | *1985* | *1985* | *1985* | *1985* |
| Type of Building | *Single-family house* | *Single-family house* | *Multifamily low-rise* | *Residential high-rise* |
| Practice Without the Code Change | *Design C* | *Design C* | *Design C* | *Design C* |
| Practice With the Code Change | *Design A* | *Design A* | *Design B* | *Design B* |
| Building Analysis Period (Years) | *25* | *25* | *25* | *25* |
| Other Factors | | | | |

Location. The building location affects construction costs and determines climate and other factors which may be relevant in analyzing the code impacts.

Date constructed. Because costs change, the effect of a code requirement may depend on the construction date. For example, prices of innovative fire safety devices may decline over time in real terms as wider use allows mass production. Rapidly rising energy prices may mean that energy conservation requirements have a greater effect on structures built in 1990 than in 1985.

Type of building. The construction type, height, area, or other physical characteristics of a building may be listed on worksheet 1.2 as part of a representative case. You may also wish to list the use group, the number, age, and type of occupants, and any other information about the design and use of the building that seems pertinent to the proposed code change.

Practice without the code change. This item in worksheet 1.2 refers to the practice the builder would use in the absence of a code change when constructing the feature affected by the code change. If construction practices are changing rapidly, then in specifying a baseline practice you should consider not only current building practices but also likely trends. For example, even without a code change requiring smoke detectors, is there a trend toward their use?

Practice with the code change. This item describes how builders will respond to the code change. If the code allows some flexibility, you may wish to consider several alternative ways of meeting requirements, perhaps including innovative practices. (If it is not possible to define innovative practices well enough to include them in a representative case, you may wish to list possible innovative methods of compliance later on when you present the results of your analysis. This information may be useful in choosing between more flexible and less flexible versions of a code requirement.)

Building analysis period. This period usually reflects the expected lifetime of the building. Thus, it may differ for each reference building. If there is great uncertainty about actual building lifetimes, it may be necessary to simply assume an expected lifetime, such as 25 years. If good estimates concerning code change impacts are available only for a shorter period, the assumed building analysis period may be shorter than the expected life.

Other characteristics. Other characteristics may also be assumed, depending on the code change. For example, in jurisdictions where there is extensive rehabilitation under way which is covered by the code for new buildings, you may wish to select a rehabilitation project as a representative case.

*For further information on construction data and reference designs*

Annual Housing Survey: 1977, United States and Regions, U.S. Bureau of the Census, Series H-150-77, U.S. Government Printing Office, Washington, D.C. 20402, 1979.

Characteristics of Apartments Completed: 1978, U.S. Bureau of the Census, Series H-131A, U.S. Government Printing Office, Washington, D.C. 20402.

Economic Aspects of Fire Safety in Health Care Facilities: Guidelines for Cost-Effective Retrofits, R. E. Chapman, P.T. Chen and W. G. Hall, NBSIR 79-1902, National Bureau of Standards, 1979, pp. 52-61. Available from National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA. 22161. (Prototypical hospital.)

New One-Family Houses Sold and for Sale, U.S. Bureau of the Census, Series C25, U.S. Bureau of the Census, Washington, D.C. 20233. (Monthly.)

Three Proposed Typical House Designs for Energy Conservation Research, S.R. Hastings, NBSIR 77-1309, National Bureau of Standards, Washington, D.C., 1977. Available from NTIS, 5285 Port Royal Road, Springfield, VA.22161.

# 2. Estimate Impacts On Building Costs

This section explains how to estimate the economic effects of a code change on building-related costs. In it, you will use worksheets 2.1 through 2.5.

A code change may affect building costs only, or it may also affect the costs of government services such as fire protection, police protection, or code administration. Both kinds of costs are discussed in this section.

There are three points to keep in mind in analyzing cost items:

First, in estimating cost impacts, the existing code requirement can be used as a baseline. For example, if the original provision imposes a cost of $100 per building, and the proposed provision imposes a cost of $105 per building, the relevant impact is the <u>difference</u> between the two requirements, or $5.

Second, the discussion in this chapter and the next assumes that the building in question is constructed in the <u>present</u> year. Later, chapter 4 explains how to apply the estimates to buildings constructed in <u>future</u> years.

Third, costs should be estimated before tax deductions, since full costs are relevant in examining codes from the social perspective. For example, the cost of meeting an energy conservation requirement should be estimated without considering cost-savings due to tax credits. For further discussion of tax effects, see the discussion on pages 13 and 14 and the references listed at the end of this chapter.

<u>Construction costs</u>

Worksheet 2.1 is provided to list effects on materials, labor, equipment, overhead and profits, and other construction costs. You should take into account costs associated with plan-checking delays, construction modifications needed to obtain approval, certification requirements, and record-keeping requirements. However, fees paid by builders to the code jurisdiction should not be counted here since the code administration costs covered by the fees will be counted in government costs, discussed later.

You should also consider longer run, indirect effects on costs. For example, variations in code requirements from jurisdiction to jurisdiction may decrease the efficiency of builders who operate in several jurisdictions. Even if you cannot estimate dollar amounts for such indirect effects, if they are important they should be described in non-dollar terms so that they will not be overlooked in the code change decision.

Worksheet 2.1 summarizes the effects of code changes on construction costs for the hypothetical case involving a Fire Safety Feature which was introduced earlier. The data in this and other worksheets are for Representative Case I described in worksheet 1.2. Because of limited space, computations for other representative cases are not shown in this guide. However, in your analysis you should fill out the worksheets for each representative case. A blank worksheet is provided at the back of this guide for summarizing costs. Sources of construction cost data are listed at the end of this chapter.

# Worksheet 2.1

*hypothetical example*

## IMPACT ON UNIT INITIAL COSTS[a]

Representative case *I* (from worksheet 1.2)

| Type Cost | Proposed Requirement | - | Original Requirement | = | Change |
|---|---|---|---|---|---|
| Materials and Components | $ *100* | - | $ *50* | = | $ *50* |
| Wages and Salaries | $ *40* | - | $ *20* | = | $ *20* |
| Construction Equipment | $ *0* | - | $ *0* | = | $ *0* |
| Builder's overhead (general & admin.) | $ *60* | - | $ *30* | = | $ *30* |
| Other costs | $ *0* | - | $ *0* | = | $ *0* |
| TOTAL | $ *200* | - | $ *100* | = | $ *100* |

[a] Costs may be calculated per building, per dwelling unit, per square foot, or for some other basic unit of analysis.

Construction delays. Adding a code requirement may increase the time it takes to get plans and site work approved. If possible, the costs of these delays should be counted in analyzing code change impacts. For example, there might be higher construction costs if personnel and equipment are idled because of delays. Even if it is not possible to reflect costs of delays in worksheet 2.1, the extent and nature of added delays should still be described in presenting the results of your analysis so that this effect can be considered by those making code change decisions.

In estimating costs of delays, you should count only differential cost increases, i.e., increases which reflect a rise in construction costs in excess of the general rate of inflation. You should not count cost increases which merely reflect inflation in general. A method of computing differential cost changes is described on page 16.

If occupancy is delayed due to a code change, the lost value of the space should be counted in estimating impacts on building performance. (Methods of estimating effects on performance are treated later in this guide.)

# 2 OPERATION AND MAINTENANCE

Code requirements may affect costs of operating and maintaining buildings (O&M costs) over a period of years. To compare effects that occur at different times, it is necessary to find their present value through a process called discounting. The next section describes methods of discounting.

Discounting. A one-dollar cost or benefit of a code change is worth less if it occurs in the future than if it occurs in the present, even in the absence of inflation. This is because money received now can be invested at a profit which is lost if the money is not received until later. Therefore, future dollar effects must be discounted to their present value. This is done by means of a discount factor, a number (such as ".3855") which can be computed from a formula or looked up in a table.

To determine the discount factor, first it is necessary to select a discount rate, a percent which reflects the investment returns foregone by deferring income to the future, or the returns gained by deferring costs. The discount rate used should reflect the rates of return that could be earned by the people who will be affected by the code change.

Rates of return may be stated in two ways. Market or nominal rates are the actual rates observed in the market. They include percentage points to compensate for inflation. Real rates, on the other hand, cannot be directly observed and must be computed (or assumed). In inflationary times, they are lower than market rates because they show the real rate of return on an investment after subtracting out the effects of inflation.

If code change impacts are stated in constant dollars, as they are in this guide, then the discount rate should be based on real rates of return. If the code impacts are stated in current dollars, then the discount rate should be based on market rates.

Some market rates that may be useful in determining discount rates include the business prime rate of interest, before-tax returns to business investment, construction loan rates, savings account rates of interest, mortgage and auto loan rates, municipal and corporate bond rates, and treasury bill rates. The following formula can be used to find the real rates corresponding to these market rates:

$$r = \frac{1 + r'}{1 + i} - 1$$

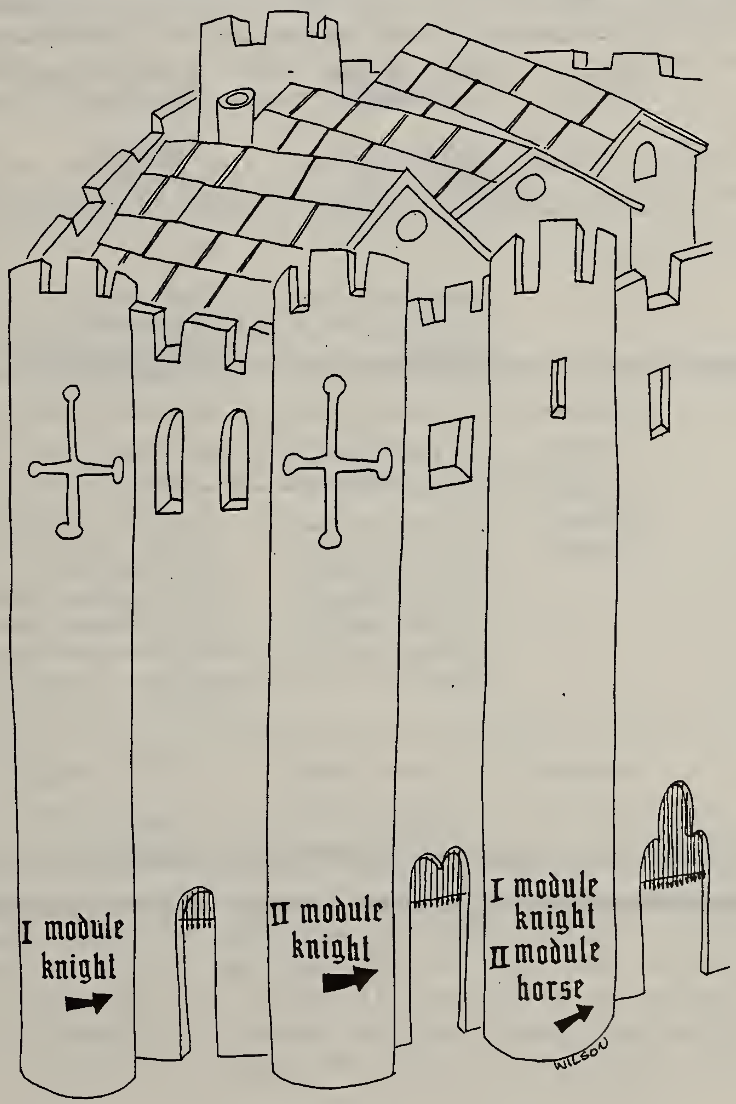
where "r" is the real rate of interest, "r'" is the market rate, and "i is the rate of inflation. Thus, with a 10 percent rate of inflation, an investment that returns 20 percent nominally would return only [(1+.2)/(1+.1)] - 1 = .091, or 9.1 percent, in real terms.

Various building studies have used real discount rates ranging from 1 percent to 10 percent or higher. Ten percent is the rate specified by the Federal Office of Management and Budget for evaluating most Federal investments.

# 2

This guide uses a before-tax rate of return. The before-tax rate of return should be used in analyzing a code change from the national perspective, because while taxes paid are lost to the taxpayer, they still represent gains to the nation as a whole. However, in analyzing a code change strictly from the viewpoint of the local community, you may wish to consider the rate of return on investment <u>after</u> Federal and State taxes, since such taxes are lost to the local community.

After selecting the discount <u>rate</u>, the next step is to decide what kind of discount <u>factor</u> to use. Three kinds of discount factors are described on the next two pages in the box and in the text. Tables of discount factors are included in appendix A.



# 2 SINGLE PRESENT WORTH FACTOR (SPW)

Single Present Worth factor (SPW). A Single Present Worth factor is useful for discounting effects that occur only once, such as a $100 cost incurred in ten years. The present value (P) of the one-time future cost or benefit (F) is calculated from the formula, P = F X SPW. The SPW can be selected from table I in appendix A for the assumed discount rate and the year of the impact, or it can be calculated using the formula in table I.

This factor is particularly useful for discounting non-recurring (or irregularly recurring) repair and replacement costs.

SUMMARY OF DISCOUNT FACTORS

| TYPE FACTOR | Single Present Worth (SPW)<br><br>(table I, appendix A) | Uniform Present Worth (UPW)<br><br>(table II, appendix A) | Modified Uniform Present Worth (UPW*)<br><br>(tables III-IV, appendix A) |
|---|---|---|---|
| USE | P? ← F<br><br>Find present value of single future amount. | P? ← A + A + ...<br><br>Find present value of annually recurring amount. | P? ← A + A + ...<br><br>Find present value of annual amount with differential cost increase. |
| FORMULA | P = (SPW) X (F) | P = (UPW) X (A) | P = (UPW*) X (A) |
| SAMPLE PROBLEM | Find present value of cost equal to $100 in constant dollars, incurred in 10th year, if discount rate is 10%. | Find present value of $100 cost (constant dollars) incurred each year for 20 years, with 10% discount rate. | Find present value of $100 cost at present prices, incurred each year for 20 years, with differential price rise of 5%/year and 10% discount rate. |
| SOLUTION | P = .3855 ($100)<br>= $38.55 | P = 8.514 ($100)<br>= $851.40 | P = 12.7178 ($100)<br>= $1271.78 |

Uniform Present Worth factor (UPW). The Uniform Present Worth factor is used for costs and benefits that recur annually and are expected to be the same each year. For example, it might be used to discount a cost equal to $100/year (in constant dollars) that will occur throughout a 20-year building life. The present value (P) of the annually-recurring cost or benefit (A) is determined by the formula P = A X UPW. The UPW can be found in table II in appendix A for the assumed discount rate and the period over which impacts occurs, or it can be calculated using the formula in table II.

This factor is useful for analyzing uniformly recurring effects such as annual inspection costs and routine maintenance.

Modified Uniform Present Worth factor (UPW*). The Modified Uniform Present Worth factor is used for discounting costs and other impacts whose real value (value in constant dollars) rises at a constant percentage rate. It is particularly useful when underlying prices rise faster or slower than the general rate of inflation. For example, this factor would be useful for discounting energy-related operating costs in cases where there is a continual increase in the price of energy relative to other prices.

The example below shows how to compute real (differential) rates of cost increase. The formula in the example can also be used for computing differential cost decreases.

Example: FINDING THE DIFFERENTIAL COST INCREASE

Problem: Find the differential ("real") rate of increase in a cost item if the overall rate of inflation is 10 percent and the nominal (observed) rate of cost increase is 15 percent.

Solution:

$$e = \frac{1 + e'}{1 + i} - 1$$

e = real rate of cost increase
e' = nominal rate of cost increase for the item
i = overall rate of inflation

$$e = \frac{1 + .15}{1 + .10} - 1 = 4.5\%$$

The present value (P) of future costs or benefits (A) whose real value is rising at a fixed percentage rate can be calculated from the formula P = A X UPW*. The UPW* can be selected from tables III through V in appendix A for the differential rate of increase in costs, discount rate, and period over which costs occur, or calculated using the formula in table III.

# 2

Record O&M data and discount factors. Now you are ready to calculate the discounted value of the change in O&M costs resulting from a code change.

First, enter the amount of the cost change and its timing on worksheet 2.2. O&M costs that might be affected include regularly recurring costs such as energy, water use, security, cleaning, and routine maintenance. (Do not include insurance costs here since this type of cost is covered in the section of this guide on building safety and performance.) Affected costs may also include irregularly recurring costs of repair, replacement, and fire safety training. In the example on the facing page, repair costs for the FSF are assumed to be zero under the original code requirement and $25 after ten years for the proposed requirement.

Second, identify the appropriate factor for discounting each cost change. For example, in part A of worksheet 2.2, the $25 one-time impact on repair costs will be discounted with a Single Present Worth factor. The factor, .3855, was selected from table I in appendix A for a 10 percent discount rate and ten years. A SPW factor was also selected for discounting replacement costs listed in part A.

A Uniform Present Worth factor was selected for discounting routine maintenance costs since these are equal annual costs. The factor, 9.077, was selected from table II in appendix A for 10 percent and a period of 25 years (the building analysis period).

In part B of the worksheet, energy prices were expected to rise more rapidly than prices in general. Therefore, a Modified Uniform Present Worth factor, 9.8919, was selected from table IV in appendix A for the assumed differential price rise of 1 percent and a period of 25 years.

In part B also, replacement costs under the proposed code requirement were expected to decline relative to prices in general at a differential rate of five percent per year, due to a growing market and larger scale production of the FSF/design C. Because replacement is a one-time cost, it is treated differently from regularly recurring costs subject to differential price changes. In particular, the five percent differential price decline will be taken into account on worksheet 2.4 (see page 20) and so need not be considered in selecting the SPW. The SPW discounting factor, .1486, was selected from table I in appendix A for 20 years and 10 percent.

Third, after selecting discount factors, the data in worksheet 2.2 should be transferred to either worksheet 2.3 (for costs rising at the same rate as inflation) or to worksheet 2.4 (for costs changing at a different rate than inflation). By carrying out the calculations indicated in the worksheets, you can determine the impacts of the code change on operation and maintenance costs over the building analysis period, discounted to the construction year.

Sources of information related to operation and maintenance costs are listed at the end of this chapter.

# Worksheet 2.2

*hypothetical example*

## IMPACT ON UNIT OPERATION AND MAINTENANCE COSTS[a]

Representative case *I*　　　　Discount rate *10* %

Building analysis period (from worksheet 1.2) *25* years

**A. COSTS RISING AT THE RATE OF INFLATION**

| Cost Type | Proposed Requirement Amount[b] | Timing[c] | SPW[d] | UPW[d] | Original Requirement Amount[b] | Timing[c] | SPW[d] | UPW[d] |
|---|---|---|---|---|---|---|---|---|
| *Repair* | $ *25* | *once at 10 yrs.* | *.3855* | | $ *0* | | | |
| *Replacement* | $ | | | | $ *50* | *once at 20 yrs.* | *.1486* | |
| *Routine maintenance* | $ *15* | *annual* | | *9.077* | $ *5* | *annual* | | *9.077* |

**B. COSTS RISING AT A RATE DIFFERENT FROM INFLATION**

| Cost Type | Differential-Price Change | Proposed Requirement Amount[b] | Timing[c] | SPW[d] | UPW*[d] | Original Requirement Amount[b] | Timing[c] | SPW[d] | UPW*[d] |
|---|---|---|---|---|---|---|---|---|---|
| *Energy* | *1%* | $ *20* | *annually for 25 years* | | *9.8919* | $ *10* | *annually for 25 years* | | *9.8919* |
| *Replacement* | *-5%* | $ *100* | *once at 20 yrs.* | *.1486* | | $ | | | |

[a]The unit of analysis should be the one listed on worksheet 1.2.

[b]At present prices.

[c]How often and when (years after construction year).

[d]From discount factor tables I through V in appendix A for assumed discount rate, timing of impact, and (for UPW*) the rate of differential price change.

# Worksheet 2.3

*hypothetical example*

## O&M COSTS RISING AT THE RATE OF INFLATION

Representative case *I*

| FUTURE ONE-TIME COSTS | Amount[a] | X | SPW[a] | = | Discounted Value | Total |
|---|---|---|---|---|---|---|
| Proposed Requirement | $ 25 | X | .3855 | = | $ 9.6375 | $ 2.21 |
| | $ | X | | = | $ | |
| Original Requirement | - $ 50 | X | .1486 | = | - $ 7.43 | |
| | - $ | X | | = | - $ | |

| EQUAL ANNUAL COSTS | Amount[a] (Proposed - Original) | X | UPW[a] | = | Discounted Value | Total |
|---|---|---|---|---|---|---|
| | ($ 15 - $ 5) | X | 9.077 | = | $ 90.77 | $ 90.77 |
| | ($ - $ ) | X | | = | $ | |

| | |
|---|---|
| TOTAL DISCOUNTED TO CONSTRUCTION YEAR | $ 92.98 |

[a]From worksheet 2.2, part A.

# Worksheet 2.4

*hypothetical example*

## O&M COSTS RISING AT A RATE DIFFERENT FROM INFLATION

Representative case *I*

| FUTURE ONE-TIME COSTS[a,b] | | Amount | X | $(1+e)^t$ | X | SPW | = | Discounted Value |
|---|---|---|---|---|---|---|---|---|
| Proposed Requirement | | $ *100* | X | *.3585* | X | *.1486* | = | $ *5.33* |
| | | $ | X | | X | | = | $ |
| Original Requirement | - | $ | X | | X | | = | $ |
| | - | $ | X | | X | | = | $ |

| RECURRING ANNUAL COSTS[a] | Amount at Present Prices | | | X | UPW* | = | Discounted Value |
|---|---|---|---|---|---|---|---|
| | (Proposed | - | Original) | X | UPW* | = | Discounted Value |
| | ($ *20* | - | $ *10* ) | X | *9.8919* | = | $ *98.92* |
| | ($ | - | $ ) | X | | = | $ |

[a]Amount, SPW, and UPW* are from worksheet 2.2, part B.

[b]$(1 + e)^t = (1 + -.05)^{20} = .3585$, where the rate of differential price rise "e" and time period "t" are from worksheet 2.2, part B.

# 2 GOVERNMENT COSTS

This section explains how to calculate the impacts of a code change on government costs for building code enforcement, fire protection, police protection, or other building-related services.

To estimate the effects on code enforcement and other fire department or department costs, it is necessary to make an assumption about the effectiveness of enforcement and the use of waivers. Then you would estimate the budget needed to achieve the target compliance rate and to handle the expected number of waivers.

To determine the effects of a code change on enforcement costs, you might ask yourself the following questions: Will a new concept or technology (such as solar energy systems) require training building officials or hiring additional staff? Is a new building aspect regulated that may require new enforcement procedures? Is a performance requirement involved that will require extensive effort to determine compliance? Will periodic inspection be required to assure continued compliance?

Impacts on government costs should be discounted using one of the discount factors described earlier in this section. They should be calculated per building or other unit of analysis, such as the dwelling unit, so that they can be added to other impacts calculated on a similar basis. Worksheet 2.5 illustrates how to estimate government costs for the hypothetical FSF requirement in terms of costs per dwelling unit.

## Effects on particular groups

This guide focuses primarily on the effect of a code change on the community as a whole. However, often it is helpful to know how a code change will affect a specific group such as building owners, tenants representing various income levels, designers, builders, materials and other product suppliers, taxpayers, insurance companies, or insurance customers. No worksheets are specifically provided for these estimates, but worksheets in this guide may be adapted for this purpose.

There are two questions to answer in estimating effects on particular groups:

First, you should determine who is most directly affected by the code change. For example, construction cost changes directly affect the builder or building owner, construction workers, and materials suppliers. Operating and maintenance costs are paid by the building owner and/or user. These can be estimated from worksheets 2.1, 2.3 and 2.4, possibly with adjustments for tax effects. You can estimate effects on suppliers of various construction products by breaking down construction costs into their components — e.g., estimating the change in the required amount of lumber, cement, or electrician's labor. Fire department and other costs paid for from government funds can be estimated from worksheet 2.5.

Second, you should determine how costs or benefits are shifted in the form of price or quality changes. This is necessary in order to determine accurately who ultimately gains or loses from a code change.

# Worksheet 2.5

*hypothetical example*

## IMPACTS ON GOVERNMENT COSTS PER UNIT

Representative case *I* Discount rate *10 %* Building analysis period *25 years*

Assumptions *100% compliance; no waivers*

| | Government Function | Timing[a] | Amount[b] | X | SPW[c] | = | Discounted Value | Total |
|---|---|---|---|---|---|---|---|---|
| ONE-TIME COST[d] | | | | | | | | |
| Proposed Requirement | *Plan check, inspection, training* | *Construction year* | $ *30* | X | *1* | = | $ *30* | |
| | | | $ | X | | = | $ | |
| Original Requirement | *Plan check, inspection* | *Constr. year* | -$ *20* | X | *1* | = - | $ *20* | $ *10* |
| | | | -$ | X | | = - | $ | |

| | Government Function | Timing[a] | Amount[b] (Proposed | - Original) | X | UPW[e] | = | Discounted Value | Total |
|---|---|---|---|---|---|---|---|---|---|
| EQUAL ANNUAL COSTS | | | ($ | - $ ) | X | | = | $ | $ |
| | | | ($ | - $ ) | X | | = | $ | |

| | |
|---|---|
| TOTAL CHANGE IN GOVERNMENT COSTS | $ *10* |

[a]Years after construction year. [b]Cost per building or other unit of analysis.

[c]From table I in appendix A for assumed discount rate and timing of cost.

[d]The cost occurs only one time for a particular building although it is an ongoing cost for the building department.

[e]From table II, appendix A, for assumed discount rate and building analysis period.

Ideally, estimates of effects on particular groups should take into account factors such as the extent to which builders pass on construction cost changes to building purchasers, landlords pass through energy costs to tenants, businesses shift costs to customers, hospitals raise prices, or the government alters fees and taxes to reflect changed enforcement or fire protection costs.

In practice it may be difficult to trace this shifting of costs in the market. If it cannot be estimated in dollar terms, any important shifting of costs and benefits should be described in qualitative terms. This will help decision-makers understand who ultimately pays for, and gains from, code changes.

To accurately estimate effects on particular groups, it may be necessary to consider tax effects. References dealing with impacts on particular groups, including tax effects on building owners, are listed with other information sources below.

*For more information on construction costs*

Building Construction Cost Data, Robert Snow Means Co., Inc., Duxbury, MA. (Published annually; construction costs.)

Building Cost File, Van Nostrand Reinhold Co., New York. (Published annually; construction costs.)

Dodge Manual for Building Construction Pricing and Scheduling, McGraw-Hill Information Systems Company, New York. (Published annually; construction costs, including remodeling/renovation costs.)

State and local builders associations, trade associations, materials and equipment suppliers, and contractors are sources of data on construction costs, materials, component, and system prices, and overhead and profits.

*For more information on operation and maintenance costs*

Dollars and Cents of Shopping Centers, Urban Land Institute, 1200 18th St., N.W., Washington, D.C. 20036, 1978. (Shopping center O&M data, e.g., maintenance and utilities, by size of shopping center.)

HAS Six-Month National Data, American Hospital Association, Hospital Administrative Services Division, 840 Lake Shore Dr., Chicago, IL. 60611. (Hospital operations data.)

Income/Expense Analysis: Apartments, Condominiums and Cooperatives, Institute of Real Estate Management, 430 N. Michigan Ave., Chicago, IL. 60611. (Apartment building O&M data: by building location, age, and type of ownership. IREM is also a source of information on office building income and costs.)

Office Building Experience Exchange Report, Building Owners and Managers Association International, 1221 Massachusetts Ave., N.W., Washington, D.C. 20005. (Office building O&M data by age, height, size and location.)

Residential Alterations and Repairs, Series C50, U. S. Bureau of the Census, Washington, D.C. 20233. (Quarterly publication; alteration and maintenance expenditures.)

*For more information on energy costs*

Department of Energy, Energy Information Administration, 45 Federal Register 5620, January 23, 1980. (Energy price forecasts.)

Life-Cycle Cost Manual for the Federal Energy Management Program, Rosalie Ruegg, National Bureau of Standards Handbook 135, U.S. Government Printing Office, Washington, D.C. 20402, December 1980. (Methods for analyzing energy conservation and renewable energy features in Federal buildings.)

State Energy Data Report, Statistical Tables and Technical Documentation, 1960 through 1978, Department of Energy, Energy Information Administration, Washington, D.C. 20461, April 1980. (Energy consumption annually for 1960 through 1978, by State, fuel type, and major end-use sector.)

Economic Analysis: Energy Performance Standards for New Buildings, U.S. Department of Energy, Office of Conservation and Solar Energy, Office of Building and Community Systems, Washington, D.C. 20585, November 1979.

Energy Conservation in Buildings: An Economics Guidebook for Investment Decisions, H. E. Marshall and R. T. Ruegg, NBS Handbook 132, U.S. Government Printing Office, Washington, D.C. 20402, May 1980. (Tax effects, pp. 37-38 and 43-50.)

Energy Conservation in New Building Design: An Impact Assessment of ASHRAE Standard 90-75, Arthur D. Little, Inc., U.S. Department of Energy, Washington, D.C., March 1976.

# 3. Estimate Impacts On Safety and Performance

This section explains how to determine the effects of a code change on building safety and performance. In this unit you will use worksheets 3.1 through 3.3.

Building codes can affect property damages, lives lost, and injuries due to building accidents. Some types of property losses are listed in the box on the facing page. A code requirement can also affect the performance or usefulness of a building. These effects should be measured against the existing code requirement as a baseline. For instance, if ten lives would be lost under the existing requirement and nine lives would be lost under the proposed requirement, the "safety impact" of the code change would be one life saved.

Building safety

One of the most difficult problems in deciding whether to approve code changes is determining the effects of a code change on safety. Frequently, the cause-and-effect relationship between a particular feature of a building and an accident is poorly understood. If it is not possible to determine what the physical effect of a code change will be, then clearly one cannot place an accurate dollar value on it. However, even when the data are poor, economic analysis can still be helpful by identifying the information that is essential to the analysis. This is accomplished by performing a sensitivity analysis, which is discussed in chapter 6.

For property losses, where possible you should use dollars to measure the effects of the code revision. However, for life safety effects, there are two possible approaches.

The approach recommended here is to report life safety effects in terms of the number of lives saved or injuries avoided. This approach does not avoid the need to balance dollars against life safety. Instead, it shifts this difficult and sometimes controversial task to those who make code change decisions. The analyst can assist decisionmakers by providing information on the number of lives saved and injuries prevented, the timing of safety effects, and net monetary effects of the code change.

Another approach would be to actually estimate dollar values for lives saved and injuries prevented as a result of the code change. This approach has the advantage that it measures all safety effects in units -- dollars — which can be readily compared with other effects and which can be discounted to put them on a common time basis. However, following this approach requires the analyst to assign a dollar value to lives saved and injuries prevented. This raises a number of difficult practical, theoretical, and philosophical questions. If you wish to pursue this approach, several references which deal with the issue of assigning dollar values to life safety are listed at the end of this chapter.

## TYPES OF PROPERTY LOSSES

* Damage to the building, including demolition and cleanup.

* Damage to building contents.

* Loss of company profits and benefits to customers due to disruption of business.

* Costs of temporary shelter for residents or for commercial enterprises.

* Moving costs (residents or businesses).

* Costs of insurance administration. Legal fees and administrative costs should be counted, but not claims payments, which are already counted in estimating damages.

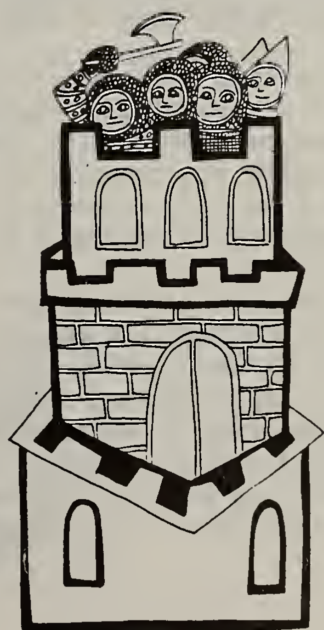
* Miscellaneous costs such as costs of child care, lost wages for residents as they deal with the aftermath of an accident, and extra meal costs for displaced residents.

* Property losses to neighboring buildings.

* Losses which are difficult to quantify in dollars, such as loss of family mementos, psychological effects of property damages, and loss of family pets.

* Any savings in operating expenses because a damaged building is not being used should be deducted from the costs of the accident.

3



# 3 STEPS TO FOLLOW

This guide takes a simplified approach to estimating the economic impacts of code changes on building safety. The analysis should be done for each of the representative cases which you identified in worksheet 1.2. The method consists of eight steps which you can carry out using worksheets 3.1 and 3.2.

1. Determine what types of building accidents or resulting outcomes might be affected by the code change. For example, the hypothetical fire safety code change described earlier might affect the frequency of three types of fires: (1) those which are confined to the source of the fire such as, for example, a stove; (2) room fires; and (3) building fires. A code change concerning wiring might affect the frequency of ignitions. A code change related to stairs might affect the frequency of falls leading to injury. If possible, try to select categories of events which are directly related to the code change and/or for which frequency and loss data are available. Fill in this information on worksheets 3.1 and 3.2.

2. Estimate how the proposed code revision would change the probability of each of these events occurring in the reference building in a single year. In the example, the change is given per dwelling unit. Fill in the information on worksheets 3.1 and 3.2.

In the example, the annual probability per dwelling unit of a room fire occurring declines by .001 (.1%, or one chance in a thousand) as a result of the code change. Only the change in probability is recorded on worksheet 3.1, but you may wish to estimate the "before" and "after" probabilities in order to determine the amount of change. For example, a change of .001 might represent a change from .006 to .005 (from 0.6% to 0.5%).

If there is no change in ignitions, a decrease in room and building fires means that the number of fires confined to the source must increase, since fewer small fires grow to be large fires. Therefore, worksheets 3.1 and 3.2 show an increase of .002 in confined fires.

Estimating effects on probabilities of accidents may be the most difficult task in the entire analysis. One approach is to determine how often relevant types of events are likely to occur without the code change and then to estimate the percent of these that would be prevented by the code change. Later in this chapter, several examples are given of how researchers have attempted to estimate the safety effects of code changes.

Sources of accident and loss information include published data bases, technical reports, insurance company figures, the opinions of experts, and so on. However, since information is often sparse about the safety effects of building features, estimates may have to be based on "informed judgment" or on admittedly arbitrary assumptions. At the end of this chapter we have listed a few sources of information about building accidents and losses; other sources of information -- especially from agencies within your own jurisdiction -- should also be tapped.

3. Determine the dollar value of property losses from each type of event. Property losses include not only the actual damage to the building and its contents, but also many less obvious costs. An example is costs due to disruption of a company's business. The box on page 26 lists some costs to consider in estimating effects of a code change. Fill in this information on worksheet 3.1.

4. Multiply the dollar loss per event by the change in the probability that the particular event will occur. Do this for each type of event and add these figures to get the annual expected dollar loss. Fill in this information on worksheet 3.1.

5. Multiply the annual dollar loss by a Uniform Present Worth (UPW) discounting factor. This will give the discounted expected value of property losses. The UPW is found in table II in appendix A. Fill in this information on worksheet 3.1.

6. Estimate the number of fatalities and/or injuries resulting from each type of accident or other event. Sources of loss information are included with the references listed at the end of this chapter. A report by Helzer, Buchbinder, and Offensend described later in this chapter shows how one group of researchers estimated the losses associated with various types of fires. Fill in this information on worksheet 3.2.

7. Multiply the value which you estimated in Step 6 by the change in probability estimated in Step 2 that the particular type of event will occur. Add these products for fatalities and for each type of injury. This shows the change in the expected annual number of fatalities and various types of injuries due to the code change. Fill in this information on worksheet 3.2.

8. Multiply the fatalities or injuries prevented annually by the number of years. You should use the number of years in the building analysis period or the life of the required feature, whichever is less. This will show the expected life safety impacts over time. Write this information on worksheet 3.2.

# Worksheet 3.1

*hypothetical example*

## IMPACT ON EXPECTED PROPERTY LOSSES PER UNIT

Representative case *I* Discount rate *10* %

Building analysis period *25 years*

| Accident Type | Change in Annual Probability of Accident[a] | X | Average Cost per Accident (Constant $) | = | Change in Annual Expected Property Loss |
|---|---|---|---|---|---|
| Confined fire | *+.002* | X | $ *500* | = | $ *1.00* |
| Room fire | *-.001* | X | $ *2,000* | = | $ *-2.00* |
| Building fire | *-.001* | X | $ *10,000* | = | $ *-10.00* |
| TOTAL CHANGE IN ANNUAL EXPECTED LOSS | | | | | $ *-11.00* |
| UPW[b] | | | | X | *9.077* |
| TOTAL CHANGE IN DISCOUNTED EXPECTED LOSS OVER TIME | | | | | $ *-99.85* |

[a]Probability of accident after code change minus probability of accident before code change, based on available information and engineering judgment.

[b]From table II, appendix A, for assumed discount rate and building analysis period or life of required feature.

# Worksheet 3.2

*hypothetical example*

## IMPACT ON EXPECTED LIFE SAFETY PER UNIT

Representative case *I*

| Accident Type | Change in Annual Probability of Accident[a] | X | No. of Deaths and Injuries per Accident | = | Expected Change in: Deaths | Major Injuries | Minor Injuries |
|---|---|---|---|---|---|---|---|
| Confined fire | *+.002* | X | *.005* (deaths) | = | *+.00001* | | |
| | | | *.05* (major inj. | = | | *+.0001* | |
| | | | *.5* (minor inj.) | = | | | *+.001* |
| Room fire | *-.001* | X | *.02* (deaths) | = | *-.00002* | | |
| | | | *.1* (major inj.) | = | | *-.0001* | |
| | | | *1.0* (minor inj.) | = | | | *-.001* |
| Building fire | *-.001* | X | *.1* (deaths) | = | *-.0001* | | |
| | | | *.5* (major inj.) | = | | *-.0005* | |
| | | | *2.0* (minor inj.) | = | | | *-.002* |
| TOTAL CHANGE IN ANNUAL EXPECTED LOSS | | | | | *-.00011* | *-.0005* | *-.002* |
| Building analysis period or life of required feature | | | | X | *25* | *25* | *25* |
| TOTAL CHANGE OVER TIME | | | | | *-.00275* | *-.0125* | *-.05* |

[a]From worksheet 3.1.

# 3 THREE STUDIES OF SAFETY IMPACTS

This section gives examples, drawn from three studies, of how researchers have estimated safety effects of code changes. The reports and many of the data sources mentioned in them are listed with other references at the end of this chapter.

Ground Fault Circuit Interrupters. In a 1978 report, John McConnaughey assessed effects of a code requirement for Ground Fault Circuit Interrupters (GFCI's), which protect against electric shocks. McConnaughey calculated impacts for the housing stock as a whole. However, to help the reader relate McConnaughey's approach to the method in this guide, we divide by the number of buildings to find the per-building impact.

The first step was to determine the number of electric shock deaths without the code change. For 1963-1974, there was an average of 290 deaths per year due to electric shock in the home. Data for this estimate came from the Department of Health and Human Services' National Center for Health Statistics, including its publication, Vital Statistics of the United States.

Since the code change affected only new homes, McConnaughey was concerned with estimating the number of electric shock deaths in the 2.4 percent of the housing stock that is new homes. If hazards were similar in old and new homes, this number would be 290 x 2.4 percent. However, new residences are likely to have fewer electric shock deaths because receptacles are grounded. McConnaughey estimated that grounding would prevent 50 percent of the potential deaths in new homes, based on a newspaper clipping study and an NBS study of GFCI usage.

Thus, the number of electric shock deaths occurring in new buildings annually would be 290 x 2.4 percent x 50 percent = 3.48. Dividing by the number of new buildings (1,736 million) gives an annual probability of .000002 that there will be an electric shock death in a single building of (3.48/1,736,000).

To determine the percent of accidents prevented by the code change, McConnaughey estimated the percent of fatalities occurring outdoors or in bathrooms -- the areas potentially protected by GFCI's. This number, 45.5 percent, was also based on the newspaper clipping study. Next, he estimated the effectiveness of the GFCI in preventing these deaths, taking into account homeowner practices and causes of deaths, to be 77 percent.

Multiplying these figures together (.000002 x .455 x .77) shows the impact of the code change on the annually expected number of deaths per building, .0000007. This is the figure that would be entered on worksheet 3.2 under the "Total Change in Annual Expected Loss."

Mobile home wind safety. In a study for the Department of Housing and Urban Development, Jeffrey Walters analyzed effects of potential regulations on mobile home wind safety.

The first step was to find existing frequency and cost of wind damages to mobile homes. Using insurance company data, Walters estimated the average frequency without the potential regulations. However, since the primary concern was structural failure, the frequency figures were adjusted downward to reflect only accidents involving structural failure. These adjustments were based on the expert opinions of leading mobile home insurers. Walters estimated fatalities and injuries based on mortality statistics from the National Weather Service's publication, Storm Data. These data were adjusted to allow for underreporting. The change in frequency of accidents due to the regulation was estimated based on the definitions of wind zones and on NBS technical research. An insurance company also provided data on property losses due to wind damage to mobile homes. These data were adjusted, based on engineering judgment, to find costs due to structural failure only.

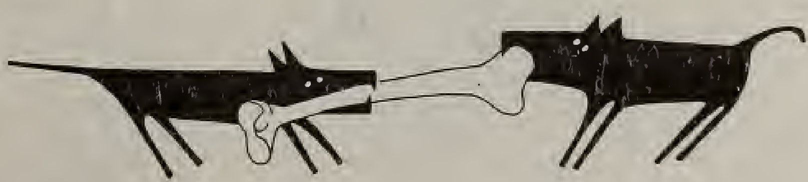
The report concluded that the potential code revision would be cost effective in 70 m.p.h. wind zones. In 105 m.p.h. wind zones, it would not be cost effective, and in 90 m.p.h. wind zones, it may be cost effective depending on the type mobile home and the weight given to intangible benefits.

Fire safety. In a third study, Helzer and Buchbinder of the NBS Center for Fire Research and Offsensend of SRI Inc. estimated the effect of potential standards on the likelihood of upholstered furniture fires. They identified 12 situations defined by three factors: whether someone is home, when the fire is discovered, and the extent of flame damage.

In estimating probabilities of various types of fires, the researchers drew on U.S. Fire Administration fire incidents data. In estimating loss of life and property for the 12 situations, they drew on U.S. Fire Administration statistics which related losses to the extent of flame damage. However, because of the lack of detailed data, they used expert judgment to estimate fire probabilities and how certain factors — such as whether someone was home -- would affect the losses.

The changes in likelihood of various situations were estimated based on engineering judgment and assumptions concerning the extent of compliance.

The report concluded that, under certain assumptions, the cost-plus-loss for the nation of a "no action" policy would be $6.33 billion. For a smoke detector requirement, the cost-plus-loss would be $5.95 billion, and for an upholstered furniture flammability standard, it would be $5.96 billion. Varying the underlying assumptions in a sensitivity analysis affected the cost-plus-loss figures, sometimes significantly.



BONE OF CONTENTION

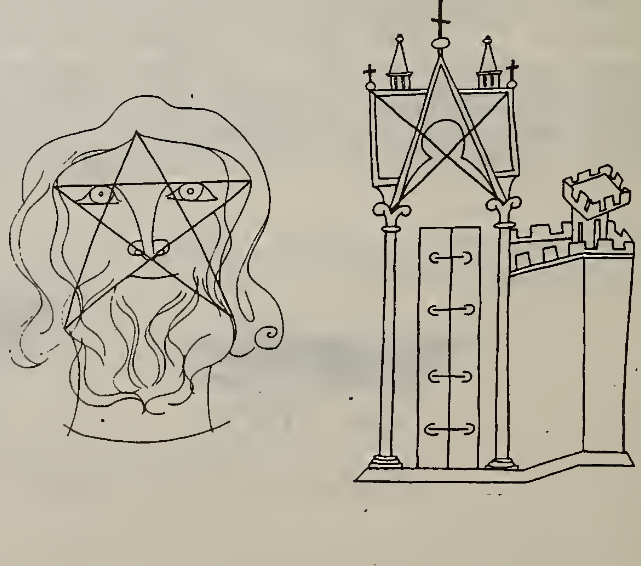
# 3 BUILDING PERFORMANCE

At the beginning of this section, we noted that code changes affect the performance or usefulness of a building in many ways. A few of these impacts are discussed here and ways are presented to estimate the costs resulting from such changes.

Amount of usable space. Building code requirements may reduce the space available for the building's primary functions. One measure of the value of the lost space is rentals foregone. If the change in space is small relative to the size of the market for that type of space, the change will not affect rental rates, and current rentals can be used to value the space. Worksheet 3.3 illustrates a method of calculating the costs of space foregone because of a code change. Effects are calculated for the building analysis period and discounted to the construction year.

Fire safety requirements that apply only to buildings which exceed certain floor area and height limits might lead to construction of a smaller building in order to avoid those requirements, or a building may not be constructed at all if code requirements make it excessively expensive. In such cases, the owner sacrifices rentals or other benefits of the lost space, but also avoids some construction and operating costs. Worksheet 3.3 can also be used to calculate these impacts.

How space is used. Building codes may also affect how all or part of a building is used. For example, a basement may not be finished for use as a "habitable room" if doing so would trigger code requirements for minimum ceiling height. The code could even affect the type of occupancy for an entire building; it might inhibit the use of buildings for occupancies with more stringent construction requirements. For example, fire safety requirements might inhibit use of buildings as nursing homes. There would be a loss equal to the foregone benefits of the displaced use as compared with the actual use. This effect may be difficult to quantify; but if it cannot be quantified, it should at least be described qualitatively so that decisionmakers can weigh it in considering code revisions.



# Worksheet 3.3

*hypothetical example*

## IMPACTS PER UNIT OF A CHANGE IN SPACE

Representative case *I* Discount rate *10* % Building analysis period *25 years*

| Change in Usable Space | X | Annual Rent per Sq. Ft.[a] | = | Change in Annual Revenues | X | UPW[b] | = | Changes in Discounted Revenues (A) |
|---|---|---|---|---|---|---|---|---|
| *-2* sq. ft. | X | $ *7.00* | = | $ *-14.00* | X | *9.077* | = | $ *-127.08* |

| Change in Built Space | X | Construction Cost per Sq. Ft. | = | Change in Construction Costs (B) |
|---|---|---|---|---|
| *0* sq. ft. | X | $ | = | $ |

| Net Discounted Value (A - B) |
|---|
| $ *-127.08* |

[a]Rental excluding any owner-paid operating costs.

[b]From table II, appendix A, for assumed discount rate and building analysis period.

Rehabilitation. If a rehabilitation project would be subject to new building requirements, a code change may forestall rehabilitation by making it economically impractical. If this occurs, the net benefits of the foregone rehabilitation (increased value of the space minus the rehabilitation costs) are lost and represent a cost of the code change.

Delays in occupancy. A code change may lead to delays in occupancy because of the time needed to obtain approvals, resulting in a loss of rentals or other benefits of that space during the delay.

Efficiency and amenities. Codes may also affect a building's durability, efficiency, comfort, privacy, convenience, and attractiveness. For example, a code change permitting surface-mounted flat conductor cable wiring makes it more convenient and efficient to change wiring layouts.

One measure of these lost benefits may be the effect on the value of rental or purchased space of the foregone feature. Or, you may be able to estimate the lost value in other ways. For example, lost benefits might be measured by the resulting reduction in a firm's profits, or by how much a tenant or owner spends to compensate for an inconvenient or unappealing design.

If there is no way to estimate the dollar impacts of a change in efficiency or amenities, you should still describe them qualitatively so that they will not be completely overlooked in making code change decisions.

Residual value. The feature required by a code change may have some residual value after the building analysis period. For example, a sprinkler system may still provide protection or have salvage value beyond a 25-year building analysis period. Estimating residual values may be difficult, but errors in making such estimates may not be serious because impacts that occur in the distant future are heavily discounted. For example, with a 10 percent discount rate, a $1,000 impact occurring after 25 years has a present value of only $92. In some cases, residual value can be neglected altogether. Use worksheet 3.4 to calculate the impacts on discounted residual value.

Effects on particular groups

If you wish to estimate effects of changes in building performance and safety on particular groups, it may be useful to review the discussion on page 21.

Building safety and performance impacts will directly affect the building owner and/or user, but their monetary effects may be shifted to other groups. For example, businesses may adjust prices to reflect changes in building efficiency or property losses. Code restrictions which interfere with a building's performance may decrease land values and, therefore, the tax base, with an ultimate effect on taxpayers and/or recipients of tax-supported services. The same is true for code restrictions which interfere with rehabilitation. If you are not able to estimate the ultimate impacts on various groups in dollar terms, it may still be useful to describe how effects are likely to be shifted. This will help decisionmakers understand the true effects of a code change.

# Worksheet 3.4

*hypothetical example*

## IMPACTS ON UNIT RESIDUAL VALUE

Representative case *I* Discount rate *10* %

Building analysis period *25* years

| Change in Residual Value[a] | X | SPW[b] | = | Change in Discounted Residual Value |
|---|---|---|---|---|
| $ *20* | X | *.0923* | = | $ *1.85* |

[a]At end of building analysis period. The change will be positive for an increase in the building's residual value.

[b]From table I, appendix A for assumed discount rate and building analysis period.

*For more information on building accidents*

An Economic Analysis of Building Code Impacts: A Suggested Approach, J. S. McConnaughey, NBSIR 78-1528, National Bureau of Standards, 1978. Available from National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA. 22161. (Method of estimating risks.)

NEISS Data Highlights, U.S. Consumer Product Safety Commission, Washington, D.C. 20207. (Published quarterly; data on consumer product injuries.)

Vital Statistics of the United States, Vol. II, Mortality Part A, U.S. Department of Health, Education, and Welfare, National Center for Health Statistics. (Data on causes of death)

*For more information on fire hazards*

Assessment of the Potential Impact of Fire Protection Systems on Actual Fire Incidents, Applied Physics Lab, Johns Hopkins University, Laurel, MD., October 1978. (Detectors, alarms, and automatic suppression systems.)

Decision Analysis of Strategies for Reducing Upholstered Furniture Fire Losses, S. G. Helzer, F. L. Offensend, and B. Buchbinder, National Bureau of Standards Technical Note 1101. U.S. Government Printing Office, Washington, D.C., 20402, 1979. (Method of estimating risk.)

"Fire and Fire Losses Classified," Fire Journal, National Fire Protection Association, 470 Atlantic Ave., Boston, MA. 02210. (Published annually; fire deaths, incidents, dollar losses; by cause and occupancy.)

Fire Deaths in the United States: Review of Data Sources and Range of Estimates, Geraldine Fristrom, National Fire Data Center, U.S. Fire Administration, Washington, D.C. 20472, 1977. (Summaries of data on fire deaths from various sources; descriptions of sources of data on fire incidents, deaths, and property losses.)

Fire in the United States: Deaths, Injuries, Dollar Loss, and Incidents at the National, State and Local Levels, U.S. Fire Administration, Washington, D.C. 20472, December 1978.

Fire Incident Data Organization (FIDO), National Fire Protection Association, 470 Atlantic Ave., Boston, MA. 02210. (Computerized reports on major fires.)

Fire Protection Handbook, National Fire Protection Association, 470 Atlantic Ave., Boston, MA. 02210. (Published every six or seven years; cumulative fire experience; fatalities, age, time of day, other factors.)

"Highlights of the National Household Survey," U.S. Fire Administration, Washington, D.C. 20472, 1976. (Fire frequency, including unreported fires.)

"Indirect Costs of Residential Fires," M. J. Munson and J. C. Ohls, Fire Journal, January 1979, pp. 42-48.

"Methodology for Estimating Costs of Burn Injuries and Property Losses," G. S. Stacey and K. S. Smith, Fire Technology, August 1979, pp. 195-209.

National Fire Incident Reporting System, U.S. Fire Administration, Washington, D.C. 20472. (Computerized system.)

"Pittsburgh Burn Study," J. I. Barancik and M. A. Shapiro, Graduate School of Public Health, University of Pittsburgh, May 1972. (Fire injury costs.)

A System for Fire Safety Evaluation of Health Care Facilities, H. E. Nelson and A. J. Shibe, NBSIR 78-1555, National Bureau of Standards, Washington, D.C., 1978.

*For more information on other types of hazards*

Crime in the United States: Unified Crime Reports, Federal Bureau of Investigation, U.S. Department of Justice, Washington, D.C. 20535. (Annual.)

Defensible Space: Crime Prevention through Urban Design, Oscar Newmann, Macmillan, New York, 1972. (Effect of housing project design on crime.)

Economic Benefit-Cost and Risk Analysis of Results of Mobile Home Safety Research: Wind Safety Analysis, J. L. Walters, U.S. Department of Housing and Urban Development, Washington, D.C. 20410, 1979.

Natural Disasters: Some Empirical and Economic Considerations, G. T. Sav, NBSIR 74-473, National Bureau of Standards, Washington, D.C. 20234, February 1974. (Losses from hurricanes, floods, earthquakes, and tornadoes.)

Storm Data, National Oceanographic and Atmospheric Administration, National Weather Service, National Climatic Center, Ashville, SC. (Monthly.)

*For more information on estimating the dollar value of life safety*

A Survey of Methods for Estimating the Cost Value of a Human Life, M. Cornell et al., U.S. Coast Guard, Washington, D.C. 1976.

The Value of Life: An Economic Analysis, M. W. Jones-Lee, University of Chicago Press, Chicago, 1976.

1975 Societal Costs of Motor Vehicle Accidents, B. M. Faigin, National Highway Traffic Safety Administration, Department of Transportation, Washington, D.C., 1976.

Economics of Protection Against Progressive Collapse, R. E. Chapman and P. F. Colwell, NBSIR 74-542, National Bureau of Standards, Washington, D.C. 20234.

# 4. Compute Net Monetary Benefits

Benefits are the desirable effects of a code change; costs are the undesirable effects. For example, if adding a requirement increases property protection, this would be a benefit. If deleting a requirement decreases property protection, this would be a cost. This chapter explains how to compute the present value of net monetary benefits per unit.

Earlier, in worksheets 2.3 through 3.1, we calculated code change impacts based on the assumption that the reference buildings were constructed in the current year. To analyze a building constructed in future years, two further adjustments are needed to find the accurate present value of code change impacts.

Adjust for differential price changes. Chapter 2 described how to discount when the cost of an item is rising at a rate different from overall inflation, using a UPW* factor. However, that procedure accounted only for real cost changes that occur after the building is constructed. A further adjustment is needed to account for real cost changes that occur between the present year and the construction year. In the hypothetical example, the present year is taken to be 1980. Thus, for a building constructed in 1985, it is necessary to account for the fact that energy prices will rise relative to other prices between 1980 and 1985 as well as after 1985.

To account for real cost changes before the construction year, transfer data from worksheets 2.2, 2.3, and 2.4 to worksheet 4.1. Then, multiply the change in O&M cost subject to differential cost changes by a "cost change factor" of $(1 + e)^t$, computed using the annual rate of differential cost change "e" and years before construction "t." Next, sum the various O&M costs to find total O&M costs adjusted for differential cost change. The result is a value which fully reflects the change in relative prices. This is illustrated in worksheet 4.1 for the hypothetical code change.

Discount to present value. At this point, all monetary impacts have been discounted to the future construction year. For example, in the illustration, impacts occuring from 1985 through 2005 were discounted to 1985. Now it is necessary to further discount to find the present values. The method for doing this is described below.

# Worksheet 4.1

*hypothetical example*

## ADJUSTING O&M COSTS FOR DIFFERENTIAL COST CHANGES

Representative case *I* Years before building constructed *5* years[a]

| Rate of Differential Cost Change (Worksheet 2.2) | Change in O&M Costs (Worksheet 2.4) | X | Cost Change Factor[b] | = | Adjusted O&M Costs |
|---|---|---|---|---|---|
| *1* %/yr. | $ *98.92* | X | *1.051* | = | $ *103.96* |
| *-5* %/yr. | $ *5.33* | X | *.774* | = | $ *4.13* |
| + O&M costs from worksheet 2.3 | | | | + | $ *92.98* |
| TOTAL O&M COSTS ADJUSTED FOR DIFFERENTIAL COST CHANGES, DISCOUNTED TO CONSTRUCTION YEAR | | | | | $ *201.07* |

[a]Based on construction date in worksheet 1.2.

[b]The cost change factor is $(1 + e)^t$ where "e" is the rate of differential cost change listed above and in worksheet 2.2, and "t" is the number of years before the building is constructed:

First line: $(1 + e)^t = (1 + .01)^5 = 1.051$.

Second line: $(1 + e)^t = (1 + .05)^5 = .774$.

4

First, enter the values of changes in building performance on worksheet 4.2. Where building performance improves, use a positive number. Otherwise, use a negative number. These values are taken from worksheets 3.3, 3.4, and other worksheets you may have devised to estimate changes in performance.

Second, enter the changes in building costs and property losses on worksheet 4.2. Use positive numbers for cost or loss increases and negative numbers for cost or loss reductions. The cost changes are taken from worksheets 2.1, 2.5, and 4.1. Property loss changes are from worksheet 3.1.

Third, select a Single Present Worth factor from table 1 in appendix A for the assumed discount rate and the number of years before the building is constructed, and enter it on worksheet 4.2.

Fourth, multiply the SPW factor by the values discounted to the construction year to find the present value of each impact. Sum the first group of values to find the total effect on building performance, and sum the second group to find the total effect on building cost plus property loss. In the example, each cost and benefit item was separately multiplied by the SPW factor to show the present value of individual items.

The final step is to subtract the change in cost-plus-loss from the change in building performance. This shows Net Monetary Benefits discounted to present value. In the hypothetical example, Net Monetary Benefits are negative, -$209. At first it might seem that the code change is not cost effective for this particular case. However, worksheet 4.2 shows only monetary effects; there are also life safety impacts not shown in worksheet 4.2. Therefore, we cannot determine just by looking at worksheet 4.2 whether the code change would be cost effective for Representative Case I.

The Net Monetary Benefits on worksheet 4.2 are given only for a single unit, such as a dwelling unit or building, and they refer only to one representative case. Worksheet 4.2 should be calculated for each representative case. Also, since the example analyzes the code change from the perspective of the community as a whole, the Net Monetary Benefits figure includes all monetary effects, without distinguishing whether they accrue to builders, building owners, tenants, taxpayers, or other groups in the economy.

*For further information on benefit-cost analysis*

Efficient Allocation of Research Funds: Economic Evaluation Methods with Case Studies in Building Technology, H. E. Marshall and R. T. Ruegg, National Bureau of Standards Special Publication 558, U.S. Government Printing Office, Washington, D.C. 20402, 1979. (pp. 11-18)

Energy Conservation in Buildings: an Economics Guidebook for Investment Decisions, H. E. Marshall and R. T. Ruegg, National Bureau of Standards Handbook 132, U.S. Government Printing Office, Washington, D.C. 20402, 1980.(pp.13-21)

Principles of Engineering Economy, E. L. Grant and W. G. Ireson, 5th Edition, Ronald Press, New York, 1970.

# Worksheet 4.2

*hypothetical example*

## PRESENT VALUE OF NET MONETARY BENEFITS PER UNIT

Representative case *I* Discount rate *10* %

Years before building constructed *5* years Unit of analysis *Dwelling unit*

| Worksheet Number | Type Impact | Change in Building Performance[a] | X | SPW[b] | = | Present Value |
|---|---|---|---|---|---|---|
| 3.3 | Building Space[c] | $ *-127.08* | X | *.6209* | = | $ *-78.90* |
| 3.4 | Residual Value[c] | $ *1.85* | X | *.6209* | = | $ *1.15* |
| | (Other Impact)[c] | $ | X | | = | $ |
| TOTAL EFFECT ON PERFORMANCE | | $ *-125.23* | X | *.6209* | = | $ *-77.75* |

| Worksheet Number | Type Impact | Change in Building Cost[a] | X | SPW[b] | = | Present Value |
|---|---|---|---|---|---|---|
| 2.1 | Initial Costs[d] | $ *100.00* | X | *.6209* | = | $ *62.09* |
| 2.5 | Government Cost[d] | $ *10.00* | X | *.6209* | = | $ *6.21* |
| 4.1 | O&M Costs[d] | $ *201.07* | X | *.6209* | = | $ *124.84* |
| 3.1 | Property Loss[d] | $ *- 99.85* | X | *.6209* | = | $ *-62.00* |
| TOTAL EFFECT ON COST-PLUS-LOSS | | $ *211.22* | X | *.6209* | = | $ *131.14* |

| Total Effect on Performance | - | Total Effect on Cost-Plus-Loss | = | Net Monetary Benefits |
|---|---|---|---|---|
| $ *-77.75* | - | $ *131.14* | = | $ *-208.89* |

[a]Value discounted to construction year.

[b]From table I, appendix A, for assumed discount rate and number of years before building is constructed.

[c]Use a positive number for increases in value.

[d]Use a positive number for increases in cost and loss.

# 5. Estimate Aggregate Impacts

Up to now, we have focused on calculating the per unit effects of a code change for individual buildings. But these calculations do not show the overall impact of a code change. To find the overall impact, it is necessary to add up or "aggregate" the effects on many buildings into one number. This section describes how to do this using worksheet 5.1. But first, let us look briefly at when it is worth calculating aggregate impacts.

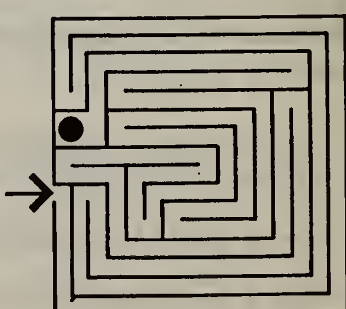
Aggregating may be necessary in situations where the code change has differing effects on different buildings, and where it is not feasible to apply the requirement only to buildings where it is cost effective. In such cases, it is necessary to aggregate to find out whether the code change is cost effective overall.

For example, suppose a proposed fire safety requirement would result in expected net benefits of $200 for each house occupied by someone who smokes, but would have an expected net cost of $100 for all other houses. The code change would only be cost effective in communities with a large number of smokers. In such cases, aggregating would be helpful to show whether the code change is cost effective for the community as a whole.

Aggregating may not be essential if a code change is cost effective for all buildings, or if the code change is not cost effective for any type of building. In such cases, it may be possible to accept or reject on the basis of effects on individual buildings.

Also, if a code change has Net Benefits for some occupancies or construction types, and net costs for others, it may be possible to modify the proposed code change so that it applies only to types of buildings for which it is cost effective. In such cases, aggregating might not be essential to make the code change decision.

Even in such cases, however, aggregating may be useful when presenting life safety effects. By aggregating, effects can be presented in terms of the number of lives statistically expected to be saved for the entire jurisdiction. This figure, rounded to a whole number such as "six," may be more meaningful to those using the analysis than the probability of saving a life in one building or dwelling unit, which is likely to be a small fraction such as ".00275."



Worksheet 5.1 illustrates the procedure for calculating aggregate impacts of a code change.

First, estimate how many buildings or other units will be affected by the code change during the code analysis period, for each representative case. Affected buildings which were not included in the original representative cases may be assigned to a representative case for the purpose of aggregating. For example, duplexes might be grouped with single-family houses, or buildings constructed in 1983 might be grouped with buildings constructed in 1985.

For a model code or voluntary state code, you will need to determine which jurisdictions follow the code. It may be necessary to reduce the estimate of the number of affected buildings to allow for delays in adopting the model or state code. Do not count buildings that will not be affected by the code change because of exceptions, waivers, non-compliance, or because the builder would have adopted the code-mandated design in any case.

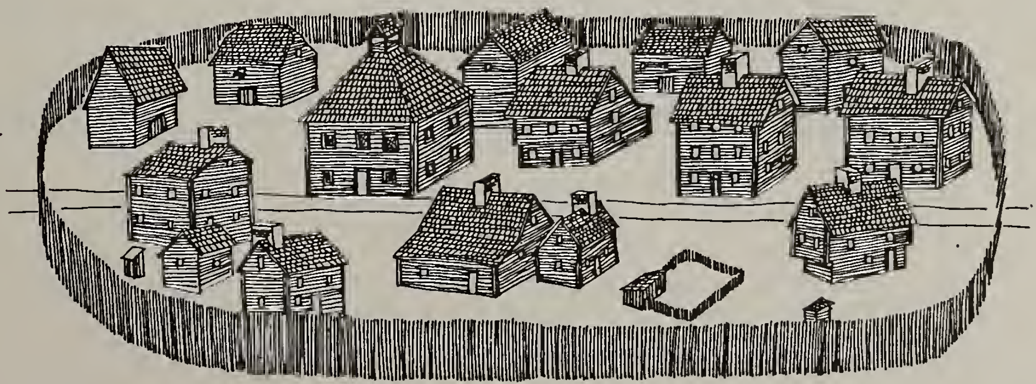
In the example on worksheet 5.1, the number of dwelling units for each case was determined from the information on page 8 and entered onto worksheet 5.1. For example, 50 percent of the 2000 single-family houses in Springfield are one story. Since the code change does not apply to one-story buildings, the number of buildings in Case I is the remaining 1000.

Second, multiply the number of buildings (or other units) by the per-unit impacts calculated for that representative case. Do this for each representative case, as is illustrated in worksheet 5.1, and sum the products. You will need separate worksheets for aggregating monetary effects, lives, major injuries, and minor injuries. You may also calculate aggregates for construction cost changes, energy cost changes, and any other effect of interest to decisionmakers. This guide shows only calculations for Net Monetary Benefits and lives saved.

*For further information on aggregating*

Arthur D. Little, Inc., Energy Conservation in New Building Design: An Impact Assessment of ASHRAE Standard 90-75, U.S. Department of Energy, Washington, D.C., 1976. (Example of aggregating.)

5



# Worksheet 5.1

*hypothetical example*

## AGGREGATE IMPACTS[a]

Type impact(s) *Net Monetary Benefits** Unit of analysis *Dwelling unit*

| Representative Case | Number of Affected Units[b] | X | Impact per Unit[c] | = | Impacts for All Units |
|---|---|---|---|---|---|
| *I SFH/Springfield/1985* | *1,000* | X | *$ -208.89* | = | *$ -208,890* |
| *II SFH/Poker Flat/1985* | *500* | X | *- 91.50* | = | *- 45,750* |
| *III Low-rise/Springf./1985* | *600* | X | *- 95.72* | = | *- 57,432* |
| *IV High-rise/Springf./1985* | *100* | X | *-203.61* | = | *- 20,361* |
| TOTAL FOR ALL UNITS | | | | | *$ -332,433* |

[a]This worksheet should be filled out separately for each impact of interest.

[b]May include buildings similar to buildings specified in representative cases.

[c]From worksheets 3.2 (life safety) or 4.2 (monetary impacts).

* *Underlying calculations for Case I are shown in worksheets 1.1 through 4.2 in this guide. The underlying calculations for Cases II, III, and IV, using similar worksheets, are not shown due to limited space.*

# Worksheet 5.1

*hypothetical example*

## AGGREGATE IMPACTS[a]

Type impact(s) *Lives Saved* Unit of analysis *Dwelling unit*

| Representative Case | Number of Affected Units[b] | X | Impact per Unit[c] | = | Impacts for All Units |
|---|---|---|---|---|---|
| *I SFH/Springfield/1985* | *1,000* | X | *.00275* | = | *2.750* |
| *II SFH/Poker Flat/1985* | *500* | X | *.00275* | = | *1.375* |
| *III Low-rise/Springf./1985* | *600* | X | *.003* | = | *1.800* |
| *IV High-rise/Springf./1985* | *100* | X | *.0001* | = | *.01* |
| TOTAL FOR ALL UNITS | | | | | *5.935* |

[a]This worksheet should be filled out separately for each impact of interest.

[b]May include buildings similar to buildings specified in representative cases.

[c]From worksheets 3.2 (life safety) or 4.2 (monetary impacts).

# 6. Perform A Sensitivity Analysis

Sensitivity analysis is a way of finding out how changes in data or assumptions will affect the final results. For example, how would doubling the assumed code analysis period affect the calculated net benefits? The box on this page lists some factors that may be altered as part of a sensitivity analysis.

One reason for performing a sensitivity analysis is to decide which estimates should be further refined. If the code change decision would be affected by a relatively small error in estimating a factor, then it may be desirable to spend more effort improving that estimate.

Another reason for doing a sensitivity analysis is to aid decisionmakers who will be using the results of the benefit-cost analysis. It shows whether disagreeing with assumptions or underlying data is sufficient reason to reject the results of the analysis. For example, suppose the basic analysis uses a discount rate of 10 percent, but a code official believes the rate should be 8 percent and a builder believes it should be 15 percent. A sensitivity analysis would show whether changing the rate from 10 percent to 8 percent or to 15 percent would significantly alter the estimated Net Benefits. If it does not, then both parties might still accept the general conclusions of the analysis.

## What to alter in a sensitivity analysis

- Current levels of accidents
- Effect of code change on accidents
- Cost per accident
- Discount rate
- Building analysis period
- Code analysis period
- Method and cost of compliance by builders
- Use of waivers and extent of non-compliance
- Durability of code-mandated feature
- Owner/tenant behavior with respect to maintenance and replacement
- Rate of energy price escalation
- Any important and controversial assumption
- Any important piece of data about which there is substantial uncertainty

# HOW TO DO A SENSITIVITY ANALYSIS 6

This section describes how to do sensitivity analysis. The method is illustrated on worksheet 3.3 on page 51, and on worksheets 6.1 and 6.2, for the hypothetical Fire Safety Feature requirement. These worksheets are for Representative Case I. A sensitivity analysis is needed for each representative case in order to determine the sensitivity of the aggregate figures.

There are seven steps in the sensitivity analysis:

1. Identify "sensitive" variables. Start by listing the important variables on worksheet 6.1, along with the value used in the original analysis. Since it is time-consuming to alter variables in a sensitivity analysis, you will need to decide which variables to alter. Variables should be altered if they may be subject to significant errors or controversy. If a potential change in a variable might change the results of the analysis enough to affect the code change decision, this variable is a good candidate for the sensitivity analysis.

In the hypothetical example, the size of the safety impact is critical to the code change decision. There is much uncertainty about the effect of the FSF on the number of fires and, therefore, on safety. Thus, the effect of the code change on various types of fires should be varied in the sensitivity analysis.

2. Determine your approach. One method of testing for sensitivity is to change values one at a time. For example, you might recompute Net Benefits, changing only the discount rate, and then recompute Net Benefits changing only the code analysis period. A second approach is to change a number of variables at once. For example, you may recompute Net Benefits for an "optimistic case" and "pessimistic case," varying a number of factors each time. In the example, a number of factors are varied at once.

3. Determine values to use in the sensitivity analysis. You should select values which might occur under some plausible set of circumstances. Record these values on the top half of worksheet 6.2.

4. Recompute worksheets 2.1 through 4.2. You will need to repeat the calculations on most worksheets using the altered values. For the hypothetical example, it was necessary to recalculate worksheets 2.2 through 5.1. However, only the recalculation of worksheet 3.3 is shown in this guide.

5. Record the results on worksheet 6.2. This should show the results of a sensitivity analysis for one representative case, before aggregating. It shows which variables were altered, how they were altered, and results using the original and altered values.

In the example, worksheet 6.2 was calculated for Case I for the original set of values and for a set of altered values. Using a lower discount rate, a reduced safety impact, and the assumption that the FSF is never replaced, Net Monetary Benefits fell from -$209 to -$291. Life safety benefits also declined.

# Worksheet 6.1

*hypothetical example*

## VALUES TO ALTER IN A SENSITIVITY ANALYSIS[a]

Representative case *I*

| Variable | Value in Base Case[b] | Include in Sensitivity Analysis?[c] |
|---|---|---|
| *FSF/design A price* | *$100* | *no* |
| *FSF/design A life* | *10 years* | *no* |
| *Replacement patterns* | *Replaced after 20 years* | *yes* |
| *Electricity cost* | *$10 and $20/year in base year prices* | *no* |
| *Residual value* | *$20* | *no* |
| *Discount rate* | *10%* | *yes* |
| *Number of affected bldgs* | *1,000* | *no* |
| *Change in probabilities:* | | |
| *of confined fire* | *+.002* | *yes* |
| *of room fire* | *-.001* | *yes* |
| *of building fire* | *-.001* | *yes* |
| | | |
| | | |
| | | |

[a]This should be filled out for each representative case in worksheet 1.2.

[b]Values in the basic analysis are from worksheets 2.1 through 3.4, and 5.1.

[c]The factor should be included in the sensitivity analysis if its value is very uncertain and if a change may affect the code decision.

# Worksheet 6.2

*hypothetical example*

## SENSITIVITY ANALYSIS[a]

Representative case *I*

| Variable | Original Values (Basic Analysis) | Altered Values (Sensitivity Analysis) |
|---|---|---|
| *Replacement patterns* | *20 years* | *never* |
| *Discount rate* | *10%* | *8%* |
| *Change in probability of:* | | |
| *confined fire* | *+.002* | *+.001* |
| *room fire* | *-.001* | *-.0005* |
| *building fire* | *-.001* | *-.0005* |
| | | |
| **Impact** | **Calculated Using Original Values** | **Calculated Using Altered Values** |
| Met Monetary Benefits[b] | *$ -209* | *$ -291* |
| Fatalities Prevented[c] | *.00275* | *.0011* |
| Major Injuries Prevented[c] | *.0125* | *.005* |
| Minor Injuries Prevented[c] | *.05* | *.02* |
| | | |

[a]This and previous worksheets should be recalculated for each representative case listed in worksheet 1.2.

[b]From worksheet 4.2 calculated using original and altered values.

[c]From worksheet 3.2 calculated using original and altered values.

# Worksheet 3.3

*hypothetical example*

## IMPACTS PER UNIT OF A CHANGE IN SPACE

Representative case *I* Discount rate *8* % Building analysis period *25 years*

| Change in Usable Space | X | Annual Rent per Sq. Ft.[a] | = | Change in Annual Revenues | X | UPW[b] | = | Changes in Discounted Revenues (A) |
|---|---|---|---|---|---|---|---|---|
| *-2* sq. ft. | X | $ *7.00* | = | $ *-14.00* | X | *10.675* | = | $ *-149.45* |

| Change in Built Space | X | Construction Cost per Sq. Ft. | = | Change in Construction Costs (B) |
|---|---|---|---|---|
| *0* sq. ft. | X | $ | = | $ |

Net Discounted Value (A - B)

$ *-149.45*

[a]Rental excluding any owner-paid operating costs.

[b]From table II, appendix A, for assumed discount rate and building analysis period.

6. Repeat steps one through five for each representative case. Assumptions and data may be varied differently for each representative case.

7. Compute new aggregate values. Worksheet 5.1 should be recomputed using the new values.

The analyst should present results of the sensitivity analysis with other findings so that decisionmakers can determine whether a change in underlying variables might affect the code change decision.

In some cases, changes in underlying variables may not significantly affect the results of the economic analysis. If so, decisionmakers could base their decision about a code change on the analysis, even if they disagree somewhat with underlying data or assumptions. In other cases, however, the uncertainty about underlying data may be so great that the economic analysis is not a reliable guide to making decisions. If so, decisionmakers should be cautious in using the results; more research may be needed to refine estimates of certain factors before making a code change.

For example, in the hypothetical example used in this guide, changing to more pessimistic assumptions reduced the projected aggregate number of lives saved from six to three. Some decisionmakers seeing this result might conclude that more research is needed before going ahead with the code change. Further sensitivity analysis could help pinpoint needs for more research.

Breakeven analysis. Another useful tool is breakeven analysis. However, it can only be used when all impacts are given in dollar terms. At the "break-even value" of a factor, benefits just equal costs; Net Benefits are zero.

For example, in calculating impacts of a code requirement for double-glazed windows, the breakeven price of fuel is the price for which costs of double glazing are just offset by benefits from energy savings. If the breakeven price were $2.00/gallon, then the code change would be cost effective for any price greater than $2.00. For any lower price, it would not be cost effective.

The references listed below contain examples of sensitivity analysis.

*For further information on sensitivity analysis*

Decision Analysis of Strategies for Reducing Upholstered Furniture Fire Losses, S. G. Helzer, F. D. Offensend, and B. Buchbinder, National Bureau of Standards Technical Note 1101, U.S. Government Printing Office, Washington, D.C., 20402, 1977. (pp. 113-129)

An Economic Analysis of Building Code Impacts: A Suggested Approach, J. S. McConnaughey, NBSIR 78-1528, National Bureau of Standards, 1978. Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA. 22161. (pp. 50-53)

Engineering Economic Analysis, Donald G. Newnan, Engineering Press, San Jose, CA., 1977.

# 7. Write Up the Results

The results of the analysis should be presented in a table which describes all important impacts. The table should highlight the most important effects of the code change -- even if you were not able to quantify these effects. This will assure that important qualitative effects are not overlooked by the people making code change decisions. The summary table should include the following information:

Assumptions. State the key assumptions used in the analysis. For example, what was the unit of analysis? What discount rate was used? What other important, possibly controversial, assumptions were made?

Quantitative impacts. List useful quantitative information, such as Net Monetary Benefits and the number of deaths and injuries prevented.

Qualitative impacts. Describe the impacts which cannot be quantified. For example, impacts on innovation, historic preservation, or national security might be difficult to quantify, but could be important in a some situations. The shifting of code impacts from one group to another might be described.

Uncertainty. State the areas of uncertainty in your results. Present results of the sensitivity analysis and/or verbally qualify the results.

Worksheet 7.1 is provided to help organize the results of the analysis. Its use is illustrated for the hypothetical Fire Safety Feature code change that has been used as an example throughout this guide.

Getting the most from your building dollars

Today, every community faces a dilemma: How can it obtain adequate building protection for its businesses and residents without an excessive rise in construction costs? One solution to this problem is to approve more cost-effective code revisions.

If all effects of a code change can be quantified in dollar terms, then the code change should be cost effective if Net Monetary Benefits are greater than zero. If there are several proposed versions of a code requirement, the version with the highest Net Benefits should be the most cost effective.

For most proposed code changes, however, some impacts are difficult or impossible to assess in monetary terms. Thus, usually the decisionmaker must weigh Net Monetary Benefits against impacts stated in nonmonetary terms in order to determine whether, on the whole, the code change is desirable.

If the tools of economic analysis are properly used, they provide a systematic method for estimating the cost of obtaining improved buildings and for comparing these costs with expected benefits. Results of an analysis, concisely presented in a table such as the one on worksheet 7.1, can help those who approve code changes make reasonable tradeoffs among competing demands for increased building safety, increased building performance, and reduced building cost. The result will be the construction of more cost-effective buildings throughout the code jurisdiction.

# Worksheet 7.1

*hypothetical example*

## RESULTS OF THE BENEFIT-COST ANALYSIS

Code change *Fire Safety Feature requirement*

SELECTED ASSUMPTIONS

| Subject | Value Used in Basic Analysis | Range of Values Used in Sensitivity Analysis |
|---|---|---|
| *Unit of analysis* | *Dwelling unit* | *Dwelling unit* |
| *Discount rate* | *10%* | *8 - 10%* |
| *Building analysis period* | *25 years* | *25 years* |
| *Code analysis period* | *1981-1990* | *1981-1990* |
| *Replacement patterns* | *After effective life* | *Never* |

COSTS AND BENEFITS

| Type Impact | Base Case[a] | Sensitivity Analysis[b] | Comment |
|---|---|---|---|
| Net Monetary Benefits | *$ -332,000* | *$ -500,000* | |
| Fatalities Prevented | *6* | *3* | *Safety effects occur over a 25-year period and are very uncertain.* |
| Major Injuries Prevented | *35* | *10* | |
| Minor Injuries Prevented | *100* | *40* | |

[a]From worksheet 5.1. [b]From worksheet 5.1 recomputed for sensitivity analysis.

7

# Appendix

APPENDIX A: TABLES OF DISCOUNT FACTORS[1]

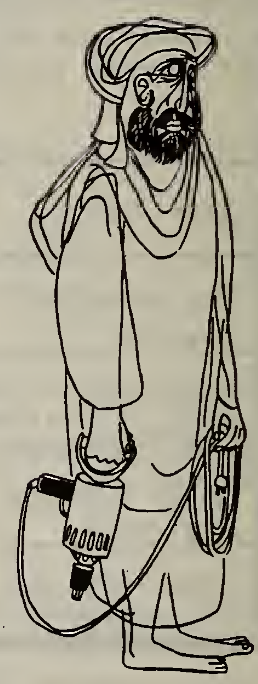
I. Single Present Worth Factors (SPW)

II. Uniform Present Worth Factors (UPW)

III. Modified Uniform Present Worth Factors for Discount Rate of 8 percent (UPW*)

IV. Modified Uniform Present Worth Factors for Discount Rate of 10 percent (UPW*)

V. Modified Uniform Present Worth Factors for Discount Rate of 12 percent (UPW*)



[1] Other tables of discount factors can be found in many building economics texts, such as Harold Marshall and Rosalie Ruegg, Energy Conservation in Buildings: An Economics Guidebook for Investment Decisions, National Bureau of Standards Handbook 132, U.S. Government Printing Office, Washington, D.C., 1980; or in investment analysis texts.

TABLE I

A

## SINGLE PRESENT WORTH FACTORS[a]

## (SPW)

P? ← F    P = (SPW) X (F)

Present Value    Future Amount

| Year | Discount Rate 8% | 10% | 12% | Year | Discount Rate 8% | 10% | 12% |
|---|---|---|---|---|---|---|---|
| 0 | 1.0000 | 1.0000 | 1.0000 | | | | |
| 1 | 0.9259 | 0.9091 | 0.8929 | 21 | .1987 | .1351 | .0926 |
| 2 | .8573 | .8264 | .7972 | 22 | .1839 | .1228 | .0826 |
| 3 | .7938 | .7513 | .7118 | 23 | .1703 | .1117 | .0738 |
| 4 | .7350 | .6830 | .6355 | 24 | .1577 | .1015 | .0659 |
| 5 | .6806 | .6209 | .5674 | 25 | .1460 | .0923 | .0588 |
| 6 | .6302 | .5645 | .5066 | 26 | .1352 | .0839 | .0525 |
| 7 | .5835 | .5132 | .4523 | 27 | .1252 | .0763 | .0469 |
| 8 | .5403 | .4665 | .4039 | 28 | .1159 | .0693 | .0419 |
| 9 | .5002 | .4241 | .3606 | 29 | .1073 | .0630 | .0374 |
| 10 | .4632 | .3855 | .3220 | 30 | .0994 | .0573 | .0334 |
| 11 | .4289 | .3505 | .2875 | 31 | .0920 | .0521 | .0298 |
| 12 | .3971 | .3186 | .2567 | 32 | .0852 | .0474 | .0266 |
| 13 | .3677 | .2897 | .2292 | 33 | .0789 | .0431 | .0238 |
| 14 | .3405 | .2633 | .2046 | 34 | .0730 | .0391 | .0212 |
| 15 | .3152 | .2394 | .1827 | 35 | .0676 | .0356 | .0189 |
| 16 | .2919 | .2176 | .1631 | 40 | .0460 | .0221 | .0107 |
| 17 | .2703 | .1978 | .1456 | | | | |
| 18 | .2502 | .1799 | .1300 | 45 | .0313 | .0137 | .0061 |
| 19 | .2317 | .1635 | .1161 | | | | |
| 20 | .2145 | .1486 | .1037 | 50 | .0213 | .0085 | .0035 |

[a] $P = F\frac{1}{(1+r)^t}$

where "P" is a present sum of money, "F" is a future sum, "r" is the discount rate, and "t" is the number of years.

## UNIFORM PRESENT WORTH FACTORS[a]

## (UPW)

P? ← A + A + A + . . .     P = (UPW) X (A)

Present Value     Annually Recurring Future Amounts

| Year | Real Discount Rate 8% | 10% | 12% | Year | Real Discount Rate 8% | 10% | 12% |
|---|---|---|---|---|---|---|---|
| 1 | 0.926 | 0.909 | 0.893 | 26 | 10.810 | 9.161 | 7.896 |
| 2 | 1.783 | 1.736 | 1.690 | 27 | 10.935 | 9.237 | 7.943 |
| 3 | 2.577 | 2.487 | 2.402 | 28 | 11.051 | 9.307 | 7.984 |
| 4 | 3.312 | 3.170 | 3.037 | 29 | 11.158 | 9.370 | 8.022 |
| 5 | 3.993 | 3.791 | 3.605 | 30 | 11.258 | 9.427 | 8.055 |
| 6 | 4.623 | 4.355 | 4.111 | 31 | 11.350 | 9.479 | 8.085 |
| 7 | 5.206 | 4.868 | 4.564 | 32 | 11.435 | 9.526 | 8.112 |
| 8 | 5.747 | 5.335 | 4.968 | 33 | 11.514 | 9.569 | 8.135 |
| 9 | 6.247 | 5.759 | 5.328 | 34 | 11.587 | 9.609 | 8.157 |
| 10 | 6.710 | 6.144 | 5.650 | 35 | 11.655 | 9.644 | 8.176 |
| 11 | 7.139 | 6.495 | 5.938 | 40 | 11.925 | 9.779 | 8.244 |
| 12 | 7.536 | 6.814 | 6.194 | 45 | 12.108 | 9.863 | 8.283 |
| 13 | 7.904 | 7.103 | 6.424 | 50 | 12.233 | 9.915 | 8.305 |
| 14 | 8.244 | 7.367 | 6.628 | 55 | 12.319 | 9.947 | |
| 15 | 8.559 | 7.606 | 6.811 | 60 | 12.377 | 9.967 | |
| 16 | 8.851 | 7.824 | 6.974 | 65 | 12.416 | 9.980 | |
| 17 | 9.122 | 8.022 | 7.120 | 70 | 12.443 | 9.987 | |
| 18 | 9.372 | 8.201 | 7.250 | 75 | 12.461 | 9.992 | |
| 19 | 9.604 | 8.365 | 7.366 | 80 | 12.474 | 9.995 | |
| 20 | 9.818 | 8.514 | 7.469 | 85 | 12.482 | 9.997 | |
| 21 | 10.017 | 8.649 | 7.562 | 90 | 12.488 | 9.998 | |
| 22 | 10.201 | 8.772 | 7.645 | 95 | 12.492 | 9.999 | |
| 23 | 10.371 | 8.883 | 7.718 | 100 | 12.494 | 9.999 | |
| 24 | 10.529 | 8.985 | 7.784 | | | | |
| 25 | 10.675 | 9.077 | 7.843 | | | | |

[a] $P = A \frac{(1+r)^t - 1}{r(1+r)^t}$ where "P" is a present sum of money, "A" is an annually recurring sum, "r" is the discount rate, and "t" is the number of years.

**TABLE III** **A**

## MODIFIED UNIFORM PRESENT WORTH FACTORS FOR DISCOUNT RATE AT 8%[a] (UPW*)

P? ← A + A + A + . . . P = (UPW*) X (A)

Present Value — Annually Recurring Future Amounts Valued at Present Prices

Rate of Differential Cost Change

| Year | 1% | 2% | 3% | 4% | 5% |
|---|---|---|---|---|---|
| 1 | 0.9352 | 0.9444 | 0.9537 | 0.9630 | 0.9722 |
| 2 | 1.8093 | 1.8364 | 1.8633 | 1.8903 | 1.9174 |
| 3 | 2.6276 | 2.6788 | 2.7307 | 2.7832 | 2.8364 |
| 4 | 3.3925 | 3.4745 | 3.5580 | 3.6431 | 3.7298 |
| 5 | 4.1078 | 4.2259 | 4.3470 | 4.4711 | 4.5985 |
| 6 | 4.7768 | 4.9356 | 5.0994 | 5.2685 | 5.4429 |
| 7 | 5.4023 | 5.6058 | 5.8170 | 6.0363 | 6.2640 |
| 8 | 5.9874 | 6.2388 | 6.5014 | 6.7757 | 7.0622 |
| 9 | 6.5345 | 6.8367 | 7.1541 | 7.4877 | 7.8382 |
| 10 | 7.0461 | 7.4013 | 7.7766 | 8.1734 | 8.5923 |
| 11 | 7.5246 | 7.9346 | 8.3703 | 8.8336 | 9.3263 |
| 12 | 7.9726 | 8.4382 | 8.9365 | 9.4694 | 10.0394 |
| 13 | 8.3906 | 8.9138 | 9.4765 | 10.0817 | 10.7328 |
| 14 | 8.7819 | 9.3631 | 9.9915 | 10.6712 | 11.4069 |
| 15 | 9.1479 | 9.7873 | 10.4826 | 11.2390 | 12.0622 |
| 16 | 9.4902 | 10.1880 | 10.9510 | 11.7857 | 12.6994 |
| 17 | 9.8103 | 10.5665 | 11.3977 | 12.3121 | 13.3189 |
| 18 | 10.1096 | 10.9239 | 11.8237 | 12.8191 | 13.9211 |
| 19 | 10.3895 | 11.2615 | 12.2300 | 13.3073 | 14.5066 |
| 20 | 10.6513 | 11.5803 | 12.6175 | 13.7774 | 15.0759 |
| 21 | 10.8961 | 11.8814 | 12.9871 | 14.2301 | 15.6293 |
| 22 | 11.1251 | 12.1657 | 13.3395 | 14.6660 | 16.1674 |
| 23 | 11.3992 | 12.4343 | 13.6757 | 15.0858 | 16.6905 |
| 24 | 11.5894 | 12.6880 | 13.9963 | 15.4900 | 17.1991 |
| 25 | 11.7287 | 12.9275 | 14.3020 | 15.8792 | 17.6936 |

[a] $P = A\left(\frac{1+e}{r-e}\right)\left[1-\left(\frac{1+e}{1+r}\right)^t\right]$ where "P" is a present sum of money, "A" is an annually recurring sum which is rising at rate "e", "r" is the discount rate, and "t" is the number of years.

## MODIFIED UNIFORM PRESENT WORTH FACTORS FOR DISCOUNT RATE AT 10%[a] (UPW*)

P? ← A + A + A + . . . P = (UPW*) X (A)

Present Value — Annually Recurring Future Amounts Valued at Present Prices

Rate of Differential Cost Change

| Year | 1% | 2% | 3% | 4% | 5% |
|---|---|---|---|---|---|
| 1 | 0.9182 | 0.9273 | 0.9364 | 0.9455 | 0.9546 |
| 2 | 1.7612 | 1.7871 | 1.8131 | 1.8393 | 1.9657 |
| 3 | 2.5353 | 2.5844 | 2.6340 | 2.6844 | 2.7354 |
| 4 | 3.2460 | 3.4027 | 3.4027 | 3.4834 | 3.5656 |
| 5 | 3.8986 | 4.0092 | 4.1225 | 4.2388 | 4.3581 |
| 6 | 4.4978 | 4.6449 | 4.7966 | 4.9531 | 5.1146 |
| 7 | 5.0480 | 5.2344 | 5.4278 | 5.6284 | 5.8367 |
| 8 | 5.5521 | 5.7810 | 6.0188 | 6.2669 | 6.5260 |
| 9 | 6.0159 | 6.2878 | 6.5722 | 6.8705 | 7.1839 |
| 10 | 6.4417 | 6.7577 | 7.0903 | 7.4411 | 7.8118 |
| 11 | 6.8328 | 7.1935 | 7.5755 | 7.9807 | 8.4113 |
| 12 | 7.1919 | 7.5977 | 8.0299 | 8.4909 | 8.9837 |
| 13 | 7.5216 | 7.9725 | 8.4553 | 8.9733 | 9.5300 |
| 14 | 7.8243 | 8.3199 | 8.8536 | 9.4293 | 10.0513 |
| 15 | 8.1022 | 8.6421 | 9.2266 | 9.8604 | 10.5490 |
| 16 | 8.3574 | 8.9408 | 9.5758 | 10.2680 | 11.0240 |
| 17 | 8.5918 | 9.2179 | 9.9029 | 10.6535 | 11.4776 |
| 18 | 8.8069 | 9.4747 | 10.2090 | 11.0177 | 11.9103 |
| 19 | 9.0044 | 9.7129 | 10.4957 | 11.3622 | 12.3235 |
| 20 | 9.1857 | 9.9337 | 10.7641 | 11.6878 | 12.7178 |
| 21 | 9.3512 | 10.1385 | 11.0154 | 11.9957 | 13.0942 |
| 22 | 9.5042 | 10.3285 | 11.2509 | 12.2870 | 13.4537 |
| 23 | 9.6446 | 10.5046 | 11.4714 | 12.5623 | 13.7968 |
| 24 | 9.7735 | 10.6679 | 11.6777 | 12.8225 | 14.1241 |
| 25 | 9.8919 | 10.8193 | 11.8710 | 13.0686 | 14.4367 |

[a] See footnote to table III for formula for P.

TABLE V

A

# MODIFIED UNIFORM PRESENT WORTH FACTORS FOR DISCOUNT RATE AT 12%[a] (UPW*)

P? ← A + A + A + . . . P = (UPW*) X (A)

Present Value — Annually Recurring Future Amounts Valued at Present Prices

Rate of Differential Cost Change

| Year | 1% | 2% | 3% | 4% | 5% |
|---|---|---|---|---|---|
| 1 | 0.9018 | 0.9107 | 0.9196 | 0.9286 | 0.9375 |
| 2 | 1.7150 | 1.7401 | 1.7654 | 1.7908 | 1.8164 |
| 3 | 2.4484 | 2.4955 | 2.5432 | 2.5915 | 2.6404 |
| 4 | 3.1097 | 3.1834 | 3.2585 | 3.3349 | 3.4129 |
| 5 | 3.7061 | 3.8099 | 3.9163 | 4.0253 | 4.1371 |
| 6 | 4.2438 | 4.3804 | 4.5212 | 4.6664 | 4.8160 |
| 7 | 4.7288 | 4.9000 | 5.0775 | 5.2616 | 5.4525 |
| 8 | 5.1662 | 5.3732 | 5.8292 | 5.8144 | 6.0492 |
| 9 | 5.5606 | 5.8042 | 6.0597 | 6.3276 | 6.6086 |
| 10 | 5.9162 | 6.1967 | 6.4924 | 6.8042 | 7.1331 |
| 11 | 6.2370 | 6.5541 | 6.8903 | 7.2468 | 7.6248 |
| 12 | 6.5262 | 6.8796 | 7.2563 | 7.6577 | 8.0857 |
| 13 | 6.7870 | 7.1761 | 7.5928 | 8.0393 | 8.5179 |
| 14 | 7.0222 | 7.4461 | 7.9023 | 8.3936 | 8.9230 |
| 15 | 7.2343 | 7.6920 | 8.1870 | 8.7227 | 9.3028 |
| 16 | 7.4256 | 7.9159 | 8.4487 | 9.0282 | 9.6589 |
| 17 | 7.5981 | 8.1198 | 8.6895 | 9.3119 | 9.9927 |
| 18 | 7.7536 | 8.3056 | 8.9108 | 9.5753 | 10.3057 |
| 19 | 7.8939 | 8.4747 | 9.1144 | 9.8200 | 10.5991 |
| 20 | 8.0204 | 8.6288 | 9.3017 | 10.0471 | 10.8741 |
| 21 | 8.1345 | 8.7691 | 9.4739 | 10.2580 | 11.1320 |
| 22 | 8.2373 | 8.8968 | 9.6322 | 10.4539 | 11.3737 |
| 23 | 8.3301 | 9.0132 | 9.7778 | 10.6357 | 11.6004 |
| 24 | 8.4137 | 9.1191 | 9.9118 | 10.8046 | 11.8129 |
| 25 | 8.4892 | 9.2156 | 10.0349 | 10.9614 | 12.0121 |

[a]See footnote to table III for formula for P.

## APPENDIX B: GLOSSARY OF ECONOMIC TERMS

AGGREGATE IMPACTS - Impacts on all affected buildings in a single code jurisdiction or other geographical area.

ANNUALLY RECURRING COSTS - Cost incurred each year in an equal amount or in an amount that is increasing at a constant rate throughout the study period.

BASELINE PRACTICE - The construction practice that would be used in absence of a code change.

BENEFIT-COST ANALYSIS - A means of evaluating alternatives by comparing the discounted value of total expected benefits with the discounted value of total expected costs for each alternative.

BREAKEVEN ANALYSIS - A method of finding that value of a variable for which costs and benefits of a code change are equal.

BUILDING ANALYSIS PERIOD - The period (often building life) for which effects are analyzed for a particular building.

CODE ANALYSIS PERIOD - The period for which effects are analyzed for a particular code change.

CONSTANT DOLLARS - Values expressed in terms of the general purchasing power of the dollar in a base year. Constant dollars do not reflect price inflation.

CURRENT DOLLARS - Values expressed in terms of the actual prices of each year. Current dollars reflect inflation.

DIFFERENTIAL RATE OF COST CHANGE - The expected rate of cost change for a given item over and above the general rate of inflation.

DISCOUNT FACTOR - A multiplicative number used to convert costs and benefits occurring at different times to a common basis.

DISCOUNT RATE - The rate of interest reflecting the time value of money that is used to convert benefits and costs occurring at different times to equivalent values at a common time.

DISCOUNTING - A technique for converting cash flows that occur over time to equivalent amounts at a common point in time.

MARKET INTEREST RATES - Interest rates actually paid by borrowers. Market rates generally include a premium to compensate for inflation.

MODIFIED UNIFORM PRESENT WORTH FACTOR - A factor used to convert a series of annually recurring costs which are escalating at a constant rate to their present value.

NET BENEFITS - The difference between benefits and costs evaluated in present value dollars.

NET MONETARY BENEFITS - The difference between benefits and costs, evaluated in present value dollars, where benefits and costs can be assigned dollar values without undue difficulty. Monetary benefits and costs include such impacts as building costs and cost-savings, and property losses.

NONMONETARY IMPACTS - Impacts, such as change in life safety, to which it is difficult to assign dollar values.

PRESENT VALUE - Past and future cash flows expressed in time-equivalent amounts as of the present time, adjusted for inflation and the time value of money.

REAL DISCOUNT RATE - The discount rate expressed in constant dollars.

REAL PRICE RISE - A rise in price of a particular component relative to the overall rate of inflation.

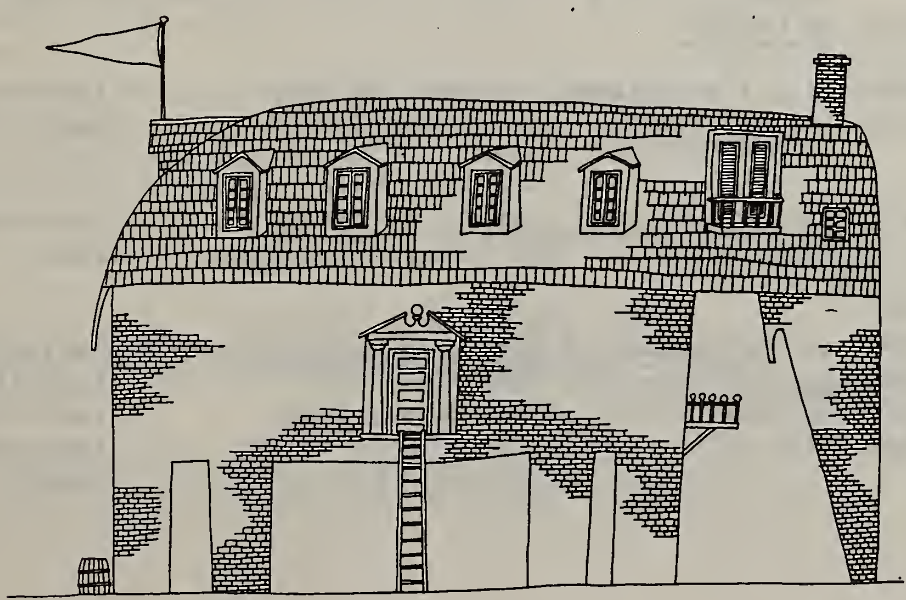
REAL RATE OF INTEREST - A rate of interest expressed in constant dollars. The real rate of interest shows the true return on an investment after allowing for effects of inflation.

RESIDUAL VALUE - The net value of an asset at the end of its economic life, at the end of the study period, or when it is no longer to be used.

SENSITIVITY ANALYSIS - Testing the outcome of an evaluation by altering the values of key factors about which there is uncertainty.

SINGLE PRESENT WORTH FACTOR (SPW) - A discount factor used to convert a future sum to its present value.

UNIFORM PRESENT WORTH FACTOR (UPW) - A discount factor used to convert a series of recurring sums to their present value.



| Title | Subject |
|---|---|
| BENEFIT-COST ANALYSIS | |
| Anderson, Lee G. and Settle, Russel F. Benefit-Cost Analysis: A Practical Guide. Lexington, MA.: Lexington Books, 1978. | Benefit-cost analysis |
| Arrow, Kenneth. "The Rate of Discount for Long-Term Public Investment," in Energy and the Environment: A Risk-Benefit Approach, edited by H. Ashley, R. L. Rudman and C. Whipple. New York: Pergammon Press, 1976, pp. 113-140. | Discounting |
| Brown, David B. "Cost/Benefit of Safety Investments Using Fault Tree Analysis." Journal of Safety Research, Vol. 5, No. 2 (June 1973), pp. 78-81. | Risk analysis |
| Grant, Eugene L. and Ireson, W. Grant. Principles of Engineering Economy, 5th Edition. New York: Ronald Press, 1970. | Investment analysis |
| Mishan, E.J. Cost-Benefit Analysis: New and Expanded Edition. New York: Praeger Publishers, Inc., 1976. | Benefit-cost analysis |
| Smith, Gerald W. Engineering Economy: Analysis of Capital Expenditures, 2nd Edition. Ames, Iowa: The Iowa State University Press, 1973. | Investment analysis |
| U.S. House of Representatives, Subcomm. on Oversight and Investigations. Cost-Benefit Analysis: Wonder Tool or Mirage? 96th Congress, 2nd Session, Washington, D.C., December 1980. | Cost-benefit analysis in regulatory decisionmaking |
| BUILDING ECONOMICS IN GENERAL | |
| The American Institute of Architects. Life-Cycle Cost Analysis: A Guide for Architects. Washington, D.C. 1977. | Life-cycle costs |
| Haviland, David S. Life-Cycle Cost Analysis 2: Using It in Practice. Washington, D.C.: The American Institute of Architects, 1978. | Life-cycle costs |
| McConnaughey, John S. An Economic Analysis of Building Code Impacts: A Suggested Approach, NBSIR 78-1528. Washington, D.C.: National Bureau of Standards, 1978. Available through NTIS. | Building codes, including ground fault circuit interrupter case study |

| Title | Subject |
|---|---|
| Rawie, Carol Chapman. Estimating Economic Impacts of Building Code Changes. Washington, D.C.: National Bureau of Standards (forthcoming). | Building codes |
| Stone, P. A. Building Economy. New York: Pergammon Press, 1976 (second ed.) | Building economics |

FIRE SAFETY

| | |
|---|---|
| Chapman, Robert E. "Cost-Effective Methods for Achieving Compliance to Fire Safety Codes," Fire Journal, Vol. 73, No. 5, September 1979, pp. 30-39, 123. | Fire safety in hospitals |
| Dardis, Rachel, and Thompson, Ruth. "Analyzing the Effectiveness of Alternative Fire Protection Strategies," Fire Journal, September 1979, pp. 27-30. | Upholstered furniture standard; smoke detectors |
| Helzer, Susan Godby, Offensend, Fred L., and Buchbinder, Benjamin. Decision Analysis of Strategies for Reducing Upholstered Furniture Fire Losses, Technical Note 1101. Washington, D.C.: U.S. Government Printing office, National Bureau of Standards, 1979. | Upholstered furniture fires; smoke detectors |
| Munson, Michael J. and Ohls, James C. "Indirect Costs of Residential Fires," Fire Journal, January 1979, pp. 42-48. | Fire costs |
| Potter, J. J., Smith, M. L., and Panwalk, S. S. "Cost Effectiveness of Residential Fire Detection Systems." Texas Technology University, Lubbock, Texas, 1976. | Fire detector cost effectiveness |
| Stacey, G. S. and Smith, K. S. "Methodology for Estimating Costs for Burn Injuries and Property Losses," Fire Technology, Vol. 15, No. 3, August 1979, pp. 195-209. | Fire losses |
| Waterman, T. E., Mniszewski, K. R., and Spadoni, D. J. Cost/Benefit Analysis of Fire Detectors. IIT Research Institute, Chicago, Il., Sept. 1978. (Report prepared for the U.S. Fire Administration, Washington, D.C.) | Fire detectors |

ENERGY

| | |
|---|---|
| Arthur D. Little, Inc. An Energy and Economic Impact Assessment of HUD's Minimum Property Standards, FEA/D-76/495. Washington, D.C.: U.S. Government Printing Office, 1976. | HUD Minimum Property Standards |
| Arthur D. Little, Inc. Energy Conservation in New Building Design: An Impact Assessment of ASHRAE Standard, 90-75. Washington, D.C.: U.S. Department of Energy, March 1976. | ASHRAE 90-75 |

# C

| Title | Subject |
|---|---|
| Marshall, Harold E. and Ruegg, Rosalie T. Energy Conservation in Buildings: An Economics Guidebook for Investment Decisions. National Bureau of Standards Handbook 132. Washington, D.C.: U.S. Government Printing Office, May 1980. | Solar energy; windows |
| Marshall, Harold E. and Ruegg, Rosalie T. "Life-Cycle Costing Guide for Energy Conservation in Buildings." Energy Conservation through Building Design, McGraw-Hill Architectural Record Books, 1979. | Energy conservation |
| Marshall, Harold E., Ruegg, Rosalie T., and Wilson, Forrest. Simplified Energy Design Economics: Principles of Economics Applied to Energy Conservation Investments in Buildings. National Bureau of Standards Special Publication 544. Washington, D.C.: U.S. Government Printing Office, 1980. | Energy conservation |
| Petersen, Stephen R. Economic Analysis of Insulation in Selected Masonry and Wood-Frame Walls. NBSIR 79-1789. Washington, D.C.: National Bureau of Standards, 1979. Available through NTIS. | Insulation |
| Petersen, Stephen R. The Role of Economic Analysis in the Development of Energy Standards for New Buildings. NBSIR 78-1471, Washington, D.C.: National Bureau of Standards, July 1978. Available through NTIS. | Energy conservation |
| Ruegg, Rosalie T. and Chapman, Robert E. Economic Evaluation of Windows in Buildings: Methodology. National Bureau of Standards Building Science Series 119, Washington, D.C.: U.S. Government Printing Office, April 1979. | Windows |
| Ruegg, Rosalie, T. Life-Cycle Costing Manual for the Federal Energy Management Program. National Bureau of Standards Handbook 135, Washington, D.C.: U.S. Government Printing Office, December 1980. | Energy conservation and renewable energy projects |
| U. S. Department of Energy. Economic Analysis: Energy Performance Standards for New Buildings. U. S. Department of Energy, Office of Conservation and Solar Energy, Office of Buildings and Community Systems, Washington, D.C. 20585, November 1979. | Proposed energy performance standards for new buildings |
| OTHER TOPICS | |
| Marshall, Harold E., and Ruegg, Rosalie T. Efficient Allocation of Research Funds: Economic Evaluation Methods with Case Studies in Building Technology, National Bureau of Standards Special Publication 558. Washington, D.C.: U. S. Government Printing Office, 1979. | Reduced-sized venting for plumbing; roofing shingles |

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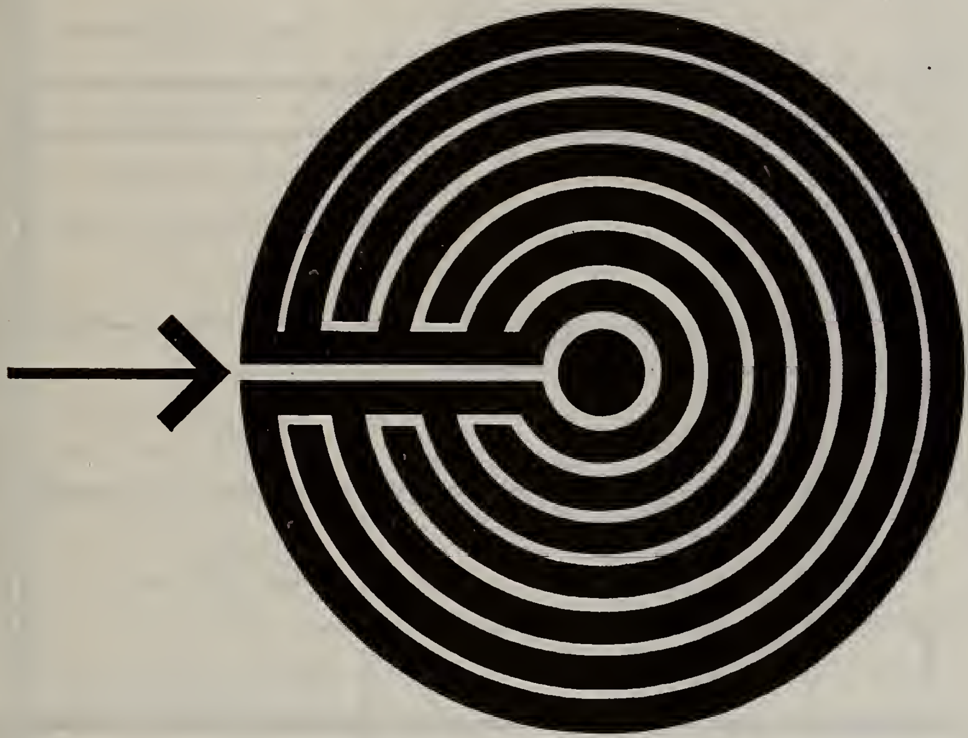
# Worksheets



# Worksheet 1.1

## PROPOSED CODE CHANGE

Title or number of code change ____________________

| | |
|---|---|
| Occupancy or Use Group Affected | |
| Construction Type Affected | |
| Building Part or System Affected | |
| Conditions or Exceptions | |
| Original Requirement | |
| Proposed Changes | |

# Worksheet 1.2

## REPRESENTATIVE CASES

Code analysis period _______________ Unit of analysis _______________

| Characteristics | Representative Case I | II | III | IV |
|---|---|---|---|---|
| Location | | | | |
| Date Constructed | | | | |
| Type of Building | | | | |
| Practice <u>Without</u> the Code Change | | | | |
| Practice <u>With</u> the Code Change | | | | |
| Building Analysis Period (Years) | | | | |
| Other Factors | | | | |

## IMPACT ON UNIT INITIAL COSTS[a]

Representative case _______ (from worksheet 1.2)

| Type Cost | Proposed Requirement | - | Original Requirement | = | Change |
|---|---|---|---|---|---|
| Materials and Components | $ ________ | - | $ ________ | = | $ ________ |
| Wages and Salaries | $ ________ | - | $ ________ | = | $ ________ |
| Construction Equipment | $ ________ | - | $ ________ | = | $ ________ |
| Builder's overhead (general & admin.) | $ ________ | - | $ ________ | = | $ ________ |
| Other costs | $ ________ | - | $ ________ | = | $ ________ |
| TOTAL | $ ________ | - | $ ________ | = | $ ________ |

[a] Costs may be calculated per building, per dwelling unit, per square foot, or for some other basic unit of analysis.

# Worksheet 2.2

## IMPACT ON UNIT OPERATION AND MAINTENANCE COSTS[a]

Representative case ______  Discount rate ______ %

Building analysis period (from worksheet 1.2) ______ years

**A. COSTS RISING AT THE RATE OF INFLATION**

| Cost Type | Proposed Requirement Amount[b] | Proposed Requirement Timing[c] | Proposed Requirement SPW[d] | Proposed Requirement UPW[d] | Original Requirement Amount[b] | Original Requirement Timing[c] | Original Requirement SPW[d] | Original Requirement UPW[d] |
|---|---|---|---|---|---|---|---|---|
| | $ | | | | $ | | | |
| | $ | | | | $ | | | |
| | $ | | | | $ | | | |

**B. COSTS RISING AT A RATE DIFFERENT FROM INFLATION**

| Cost Type | Differential-Price Change | Proposed Requirement Amount[b] | Proposed Requirement Timing[c] | Proposed Requirement SPW[d] | Proposed Requirement UPW*[d] | Original Requirement Amount[b] | Original Requirement Timing[c] | Original Requirement SPW[d] | Original Requirement UPW*[d] |
|---|---|---|---|---|---|---|---|---|---|
| | | $ | | | | $ | | | |
| | | $ | | | | $ | | | |

[a]The unit of analysis should be the one listed on worksheet 1.2.

[b]At present prices.

[c]How often and when (years after construction year).

[d]From discount factor tables I through V in appendix A for assumed discount rate, timing of impact, and (for UPW*) the rate of differential price change.

## O&M COSTS RISING AT THE RATE OF INFLATION

Representative case _____

| FUTURE ONE-TIME COSTS | Amount[a] | X | SPW[a] | = | Discounted Value | Total |
|---|---|---|---|---|---|---|
| Proposed Requirement | $ ________ | X | ________ | = | $ ________ | |
| | $ ________ | X | ________ | = | $ ________ | $ ________ |
| Original Requirement | – $ ________ | X | ________ | = | – $ ________ | |
| | – $ ________ | X | ________ | = | – $ ________ | |

| EQUAL ANNUAL COSTS | Amount[a] (Proposed – Original) | X | UPW[a] | = | Discounted Value | Total |
|---|---|---|---|---|---|---|
| | ($ ______ – $ ______) | X | ______ | = | $ ________ | $ ________ |
| | ($ ______ – $ ______) | X | ______ | = | $ ________ | |

| TOTAL DISCOUNTED TO CONSTRUCTION YEAR | $ ________ |
|---|---|

[a]From worksheet 2.2, part A.

# Worksheet 2.4

## O&M COSTS RISING AT A RATE DIFFERENT FROM INFLATION

Representative case ________

| FUTURE ONE-TIME COSTS[a,b] | Amount | X | $(1+e)^t$ | X | SPW | = | Discounted Value |
|---|---|---|---|---|---|---|---|
| Proposed Requirement | $ ________ | X | ______ | X | ______ | = | $ ________ |
| | $ ________ | X | ______ | X | ______ | = | $ ________ |
| Original Requirement | - $ ________ | X | ______ | X | ______ | = | $ ________ |
| | - $ ________ | X | ______ | X | ______ | = | $ ________ |

| RECURRING ANNUAL COSTS[a] | Amount at Present Prices | | | X | UPW* | = | Discounted Value |
|---|---|---|---|---|---|---|---|
| | (Proposed | - | Original) | X | UPW* | = | Discounted Value |
| | ($ ______ | - | $ ______) | X | ______ | = | $ ________ |
| | ($ ______ | - | $ ______) | X | ______ | = | $ ________ |

[a]Amount, SPW, and UPW* are from worksheet 2.2, part B.

[b]$(1 + e)^t$ = ( ___ + ___ )__ = __________, where the rate of differential price rise "e" and time period "t" are from worksheet 2.2, part B.

# Worksheet 2.5

## IMPACTS ON GOVERNMENT COSTS PER UNIT

Representative case ______ Discount rate ____ % Building analysis period ____ years

Assumptions ______________________________

| | Government Function | Timing[a] | Amount[b] | X | SPW[c] | = | Discounted Value | Total |
|---|---|---|---|---|---|---|---|---|
| ONE-TIME COST[d] | | | | | | | | |
| Proposed Requirement | ______ | | $ ______ | X | ______ | = | $ ______ | $ ______ |
| | ______ | | $ ______ | X | ______ | = | $ ______ | |
| Original Requirement | ______ | | -$ ______ | X | ______ | = - | $ ______ | |
| | ______ | | -$ ______ | X | ______ | = - | $ ______ | |

| | Government Function | Timing[a] | Amount[b] (Proposed - Original) | X | UPW[e] | = | Discounted Value | Total |
|---|---|---|---|---|---|---|---|---|
| EQUAL ANNUAL COSTS | ______ | | ($ ______ - $ ______ ) | X | ______ | = | $ ______ | $ ______ |
| | ______ | | ($ ______ - $ ______ ) | X | ______ | = | $ ______ | |
| TOTAL CHANGE IN GOVERNMENT COSTS | | | | | | | | $ ______ |

[a]Years after construction year. [b]Cost per building or other unit of analysis.

[c]From table I in appendix A for assumed discount rate and timing of cost.

[d]The cost occurs only one time for a particular building although it is an ongoing cost for the building department.

[e]From table II, appendix A, for assumed discount rate and building analysis period.

# Worksheet 3.1

## IMPACT ON EXPECTED PROPERTY LOSSES PER UNIT

Representative case ______ Discount rate _____ % Building analysis period ___ years

| Accident Type | Change in Annual Probability of Accident[a] | X | Average Cost per Accident (Constant $) | = | Change in Annual Expected Property Loss |
|---|---|---|---|---|---|
| ________ | ________ | X | $ ________ | = | $ ________ |
| ________ | ________ | X | $ ________ | = | $ ________ |
| ________ | ________ | X | $ ________ | = | $ ________ |
| TOTAL CHANGE IN ANNUAL EXPECTED LOSS | | | | | $ ________ |
| UPW[b] | | | | X | ________ |
| TOTAL CHANGE IN DISCOUNTED EXPECTED LOSS OVER TIME | | | | | $ ________ |

[a]Probability of accident after code change minus probability of accident before code change, based on available information and engineering judgment.

[b]From table II, appendix A, for assumed discount rate and building analysis period or life of required feature.

# Worksheet 3.2

## IMPACT ON EXPECTED LIFE SAFETY PER UNIT

Representative case______

| Accident Type | Change in Annual Probability of Accident[a] | X | No. of Deaths and Injuries per Accident | = | Expected Change in: Deaths | Major Injuries | Minor Injuries |
|---|---|---|---|---|---|---|---|
| | | | ______ (deaths) | = | ______ | | |
| ______ | ______ | X | ______ (major inj. | = | | ______ | |
| | | | ______ (minor inj.) | = | | | ______ |
| | | | ______ (deaths) | = | ______ | | |
| ______ | ______ | X | ______ (major inj.) | = | | ______ | |
| | | | ______ (minor inj.) | = | | | ______ |
| | | | ______ (deaths) | = | ______ | | |
| ______ | ______ | X | ______ (major inj.) | = | | ______ | |
| | | | ______ (minor inj.) | = | | | ______ |
| TOTAL CHANGE IN ANNUAL EXPECTED LOSS | | | | | ______ | ______ | ______ |
| Building analysis period or life of required feature | | | | X | ______ | ______ | ______ |
| TOTAL CHANGE OVER TIME | | | | | ______ | ______ | ______ |

[a]From worksheet 3.1.

# Worksheet 3.3

## IMPACTS PER UNIT OF A CHANGE IN SPACE

Representative case _____ Discount rate ____% Building analysis period ____years

| Change in Usable Space | X | Annual Rent per Sq. Ft.[a] | = | Change in Annual Revenues | X | UPW[b] | = | Changes in Discounted Revenues (A) |
|---|---|---|---|---|---|---|---|---|
| _____ sq. ft. | X | $ _____ | = | $ _____ | X | _____ | = | $ _____ |

| Change in Built Space | X | Construction Cost per Sq. Ft. | = | Change in Construction Costs (B) |
|---|---|---|---|---|
| _____ sq. ft. | X | $ _____ | = | $ _____ |

| Net Discounted Value (A - B) |
|---|
| $ _____ |

[a]Rental excluding any owner-paid operating costs.

[b]From table II, appendix A, for assumed discount rate and building analysis period.

## IMPACTS ON UNIT RESIDUAL VALUE

Representative case________ Discount rate _______%

Building analysis period______ years

| Change in Residual Value[a] | X | SPW[b] | = | Change in Discounted Residual Value |
|---|---|---|---|---|
| $____________ | X | ____________ | = | $____________ |

[a]At end of building analysis period. The change will be positive for an increase in the building's residual value.

[b]From table I, appendix A for assumed discount rate and building analysis period.

# Worksheet 4.1

## ADJUSTING O&M COSTS FOR DIFFERENTIAL COST CHANGES

Representative case _______ Years before building constructed _____ years[a]

| Rate of Differential Cost Change (Worksheet 2.2) | Change in O&M Costs (Worksheet 2.4) | X | Cost Change Factor[b] | = | Adjusted O&M Costs |
|---|---|---|---|---|---|
| ____%/yr. | $________ | X | ______ | = | $________ |
| ____%/yr. | $________ | X | ______ | = | $________ |
| + O&M costs from worksheet 2.3 | | | | + | $________ |
| TOTAL O&M COSTS ADJUSTED FOR DIFFERENTIAL COST CHANGE, DISCOUNTED TO CONSTRUCTION YEAR | | | | | $________ |

[a]Based on construction date in worksheet 1.2.

[b]The cost change factor is $(1 + e)^t$ where "e" is the rate of differential cost change listed above and in worksheet 2.2, and "t" is the number of years before the building is constructed:

First line: $(1 + e)^t$ = (1 + ____)__ = ______.

Second line: $(1 + e)^t$ = (1 + ____)__ = ______.

# Worksheet 4.2

## PRESENT VALUE OF NET MONETARY BENEFITS PER UNIT

Representative case ____ Discount rate ____%

Years before building constructed ____ years Unit of analysis ____________

| Worksheet Number | Type Impact | Change in Building Performance[a] | X | SPW[b] | = | Present Value |
|---|---|---|---|---|---|---|
| 3.3 | Building Space[c] | $ ________ | X | ______ | = | $ ______ |
| 3.4 | Residual Value[c] | $ ________ | X | ______ | = | $ ______ |
| | (Other Impact)[c] | $ ________ | X | ______ | = | $ ______ |
| TOTAL EFFECT ON PERFORMANCE | | $ ________ | X | ______ | = | $ ______ |

| Worksheet Number | Type Impact | Change in Building Cost[a] | X | SPW[b] | = | Present Value |
|---|---|---|---|---|---|---|
| 2.1 | Initial Costs[d] | $ ________ | X | ______ | = | $ ______ |
| 2.5 | Government Cost[d] | $ ________ | X | ______ | = | $ ______ |
| 4.1 | O&M Costs[d] | $ ________ | X | ______ | = | $ ______ |
| 3.1 | Property Loss[d] | $ ________ | X | ______ | = | $ ______ |
| | (Other Impact) | $ ________ | X | ______ | = | $ ______ |
| TOTAL EFFECT ON COST-PLUS-LOSS | | $ ________ | X | ______ | = | $ ______ |

| Total Effect on Performance | - | Total Effect on Cost-Plus-Loss | = | Net Monetary Benefits |
|---|---|---|---|---|
| $ ________ | - | $ ________ | = | $ ________ |

[a]Value discounted to construction year.

[b]From table I, appendix A, for assumed discount rate and number of years before building is constructed.

[c]Use a positive number for increases in value.

[d]Use a positive number for increases in cost and loss.

# Worksheet 5.1

## AGGREGATE IMPACTS[a]

Type impact(s) ____________________  Unit of analysis ________________

| Representative Case | Number of Affected Units[b] | X | Impact per Unit[c] | = | Impacts for All Units |
|---|---|---|---|---|---|
| __________ | __________ | X | __________ | = | __________ |
| __________ | __________ | X | __________ | = | __________ |
| __________ | __________ | X | __________ | = | __________ |
| __________ | __________ | X | __________ | = | __________ |
| TOTAL FOR ALL UNITS | | | | | __________ |

[a]This worksheet should be filled out separately for each impact of interest.

[b]May include buildings similar to buildings specified in representative cases.

[c]From worksheets 3.2 (life safety) or 4.2 (monetary impacts).

# Worksheet 6.1

## VALUES TO ALTER IN A SENSITIVITY ANALYSIS[a]

Representative case ___________

| Variable | Value in Base Case[b] | Include in Sensitivity Analysis?[c] |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

[a]This should be filled out for each representative case in worksheet 1.2.

[b]Values in the basic analysis are from worksheets 2.1 through 3.4, and 5.1.

[c]The factor should be included in the sensitivity analysis if its value is very uncertain and if a change <u>may</u> affect the code decision.

# Worksheet 6.2

## SENSITIVITY ANALYSIS[a]

Representative case ________

| Variable | Original Values (Basic Analysis) | Altered Values (Sensitivity Analysis) |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| **Impact** | **Calculated Using Original Values** | **Calculated Using Altered Values** |
| Met Monetary Benefits[b] | $ | $ |
| Fatalities Prevented[c] | | |
| Major Injuries Prevented[c] | | |
| Minor Injuries Prevented[c] | | |
| | | |

[a]This and previous worksheets should be recalculated for each representative case listed in worksheet 1.2.

[b]From worksheet 4.2 calculated using original and altered values.

[c]From worksheet 3.2 calculated using original and altered values.

# Worksheet 7.1

## RESULTS OF THE BENEFIT-COST ANALYSIS

Code change ______________________________

SELECTED ASSUMPTIONS

| Subject | Value Used in Basic Analysis | Range of Values Used in Sensitivity Analysis |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

COSTS AND BENEFITS

| Type Impact | Base Case[a] | Sensitivity Analysis[b] | Comment |
|---|---|---|---|
| Net Monetary Benefits | $ | $ | |
| Fatalities Prevented | | | |
| Major Injuries Prevented | | | |
| Minor Injuries Prevented | | | |
| | | | |

[a]From worksheet 5.1. [b]From worksheet 5.1 recomputed for sensitivity analysis.

## Acknowledgments

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4. TITLE AND SUBTITLE

ESTIMATING BENEFITS AND COSTS OF BUILDING REGULATIONS: A STEP BY STEP GUIDE

5. AUTHOR(S)

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6. PERFORMING ORGANIZATION (If joint or other than NBS, see instructions)

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10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

This is a how-to guide intended to help building officials, elected officials, builders, architects, engineers, and others determine the benefits and costs of proposed building code changes. The guide describes seven steps in the benefit-cost analysis. They are: (1) define the problem, including selecting prototype buildings to analyze; (2) estimate impacts on building-related costs, including government costs; (3) estimate impacts on building safety and performance; (4) select a method of relating benefits and costs (the recommended measure is Net Monetary Benefits together with information on physical life safety impacts); (5) estimate aggregate impacts on the code jurisdiction as a whole; (6) perform a sensitivity analysis; and (7) write up the results, being careful to present information on non-monetary as well as monetary effects. Worksheets are provided to assist in the analysis.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

Benefit-cost analysis; building economics; building regulation; codes; construction regulation; economics; energy conservation codes; fire safety codes; regulation.

13. AVAILABILITY

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