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Estimating Economic Impacts of Building Codes

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Building Technology
Building Economics and Regulatory
Technology Division
Washington, DC 20234

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U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, ***Secretary***
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, ***Director***

PREFACE

The aim of this report is to help those involved in building regulation use economic analysis to determine the cost-effectiveness of code changes.

In considering a code change, it is sometimes tempting to focus on the physical impacts -- impacts on lives and injuries, the durability of a building component, Btu's of energy conserved, and so forth. However, knowledge of physical effects alone may not be sufficient for making a decision; a common basis may be needed for comparing these diverse impacts.

Economic analysis provides a common denominator -- dollar value -- which makes it possible to consolidate many of the impacts of a code change into a single figure. There are also other reasons to use economic analysis in making code decisions:

* It provides a framework which helps assure that all important effects are systematically considered.

* It shows which information is essential to the code change decision, sometimes pointing out glaring gaps in knowledge about code impacts.

This report is intended to assist government officials, architects, engineers, builders, and others to: (1) conduct in-depth analyses of code change impacts; and (2) further develop methods for doing such analyses. A simplified version of this report is presented in another National Bureau of Standards publication, Estimating Benefits and Costs of Building Regulations: A Step-by-Step Guide (NBSIR 81-2223, June 1981). The simplified version would be useful to those who wish to know the general method but are not concerned with the various refinements to the method. It would also be useful as a summary of this report.

I wish to thank Harold Marshall, Stephen Weber, James Pielert, Porter Driscoll, Belinda Reeder, Pat DonVito and Wayne Stiefel of the National Bureau of Standards for their valuable comments on drafts of this report. Thanks are also due to James Gross for his encouragement of this research. I am also indebted to other NBS staff members and to members of the building community who provided useful insights during this research. Mike Usle deserves credit for his assistance in making the calculations and preparing the lists of references. Thanks are due also to Forrest Wilson for providing the illustrations.

This report drew on a number of building economics publications by economists at the National Bureau of Standards. In addition, a report by John McConnaughey, An Economic Analysis of Building Code Impacts: A Suggested Approach, published by NBS in 1978, provided important stimulus to the research leading to this report.

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EXECUTIVE SUMMARY

This report describes a method for analyzing the cost effectiveness of changes in building code requirements.[1]

The method can help in identifying the least costly way to protect against building hazards and in deciding on the right level of protection to provide through building codes. If adequate data concerning building costs and safety are not available, the method can be used to help determine which data are most needed to estimate costs and benefits of proposed code changes.

Throughout the report, sample worksheets have been completed for a hypothetical problem in order to illustrate the method. Blank worksheets, tables of discount factors, and additional references are provided. The seven steps in the analysis are described below and summarized in figure i on page xi.

During the past few years, there have been many claims that building code requirements sometimes unnecessarily increase building costs. These claims are very briefly summarized in chapter 1 of this report.

Chapter 2 explains how to <u>define the problem</u>. This involves describing the exact code changes to be analyzed and identifying several representative cases for study. Estimating effects for representative cases shows the cost effectiveness of the proposed change under different circumstances and lays the basis for estimating overall impacts in the code jurisdiction.

Chapters 3 and 4 explain discounting and how to <u>estimate impacts on building-related costs</u>. This includes effects on construction costs, operation and maintenance costs over the building's life, and government costs for fire protection, police protection, and code administration.

Chapters 5 and 6 are concerned with <u>estimating impacts on building safety and performance</u>. One approach is to estimate safety impacts in terms of the number of fatalities or injuries and leave it up to those responsible for building regulation to make the trade-off between dollars and lives. An alternative approach is to estimate life safety impacts in dollar terms. Since there is no single generally accepted way to assign dollar values to life safety, chapter 6 discusses several methods of valuing life safety.

Chapter 7 discusses two methods of <u>comparing benefits and costs</u>. Of the several measures which are commonly used to compare benefits and costs, the one recommended here for most applications is the net benefits measure.

Chapter 8 shows how to <u>estimate aggregate impacts</u>. This step involves calculating the overall impact of a code change for all buildings in a specific code jurisdiction. The recommended approach is to multiply the effects for

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[1] A simplified version of this method is described in Rawie, Carol Chapman, <u>Estimating Benefits and Costs of Building Regulations: A Step-by-Step Guide</u>, NBSIR 81-2223 (Washington, D.C.: National Bureau of Standards, 1981).

a particular type building by the number of buildings of that type expected to be constructed in the jurisdiction and sum the products.

Chapter 9 explains how to perform a sensitivity analysis. Sensitivity analysis is a technique for finding out how changes in data or assumptions affect final results. It shows which information is most needed to improve the estimates of benefits and costs and whether possible errors in data might drastically alter the predicted impacts.

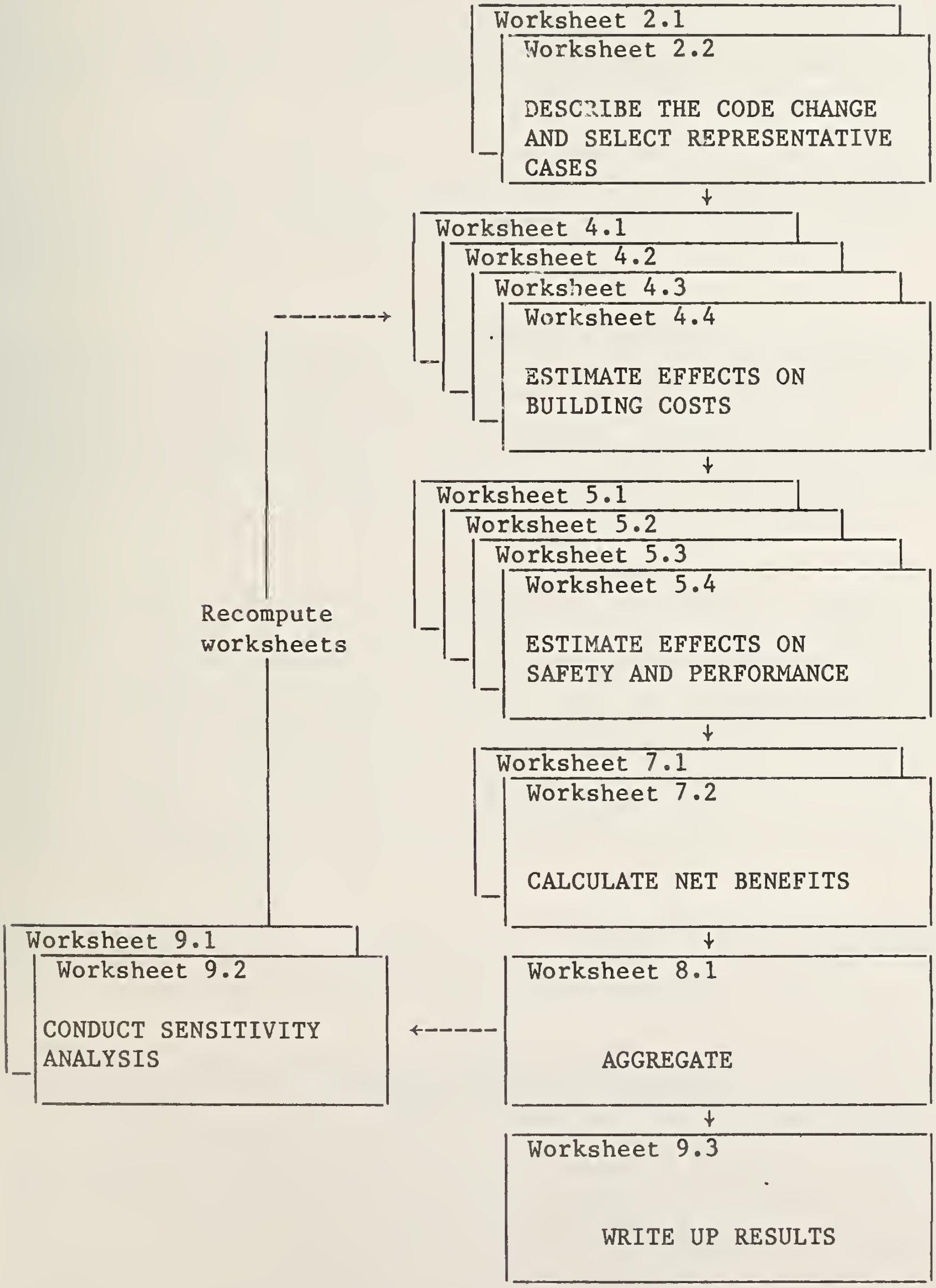
Chapter 9 also briefly explains how to write up the results of the benefit-cost analysis in a way that highlights important effects of a code change. Four kinds of information will be useful to decisionmakers: key assumptions, quantitative impacts, qualitative impacts, and areas of uncertainty.

Chapter 10 describes the need for further information concerning the numbers of building accidents, costs of building accidents, and what people are willing to pay to reduce risk.

Blank worksheets and an extensive list of references are given in the Appendices.

Decisions are being made daily in the building community which affect the costs of buildings throughout the country. Yet often these decisions must be made with only a general notion of the ultimate impacts of the code requirements on building safety and performance. It is hoped that this report will provide a means of obtaining and organizing information to help in making such decisions.

Figure i STEPS IN THE ECONOMIC ANALYSIS



1. INTRODUCTION

1.1 PURPOSE AND BACKGROUND

The purpose of this report is to describe a method for estimating benefits and costs of building code changes. The method can be used in deciding whether to delete, add, or modify a code requirement. It can be used to compare alternative code changes to see which produces the greatest net benefits or has the lowest costs. And it can be used to compare groups of code changes.[1]

In 1978, a builders association in Portland, Oregon, placed signs on a house under construction pointing out ten code-required features which increased construction costs. This display symbolizes the concern of many builders, building users, and government officials about the effects of building codes on building costs.[2]

In the past few years, there have been many claims that building codes add unnecessarily to construction costs, but there have been few careful studies which document the extent of the impact. In 1979, the Federal Trade Commission held hearings at which Arthur Young & Company summarized past studies of the cost impacts of building codes. The company concluded that, although most of the studies had shortcomings, the consensus was that excessive building requirements imposed compliance costs ranging from one to five percent of home prices.[3]

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[1] In this report, "benefit-cost analysis" is a method of computing and comparing benefits and costs of a code change. Some economists take a broader view and include in benefit-cost analysis the statement of the problem, the statement of goals, and the search for alternative solutions, as well as evaluation of the alternatives. (The author is indebted to Pat Donvito of the National Bureau of Standards for this observation.) This report assumes that the problem, goals, criteria for approving a code change, and alternative solutions have already been identified; the benefit-cost analysis involves only evaluating these alternatives to see how well they satisfy the criteria.

[2] "Building Code Costs Demonstrated in Parade of Homes," Professional Builder, October 1978. See also Stanley Denn, "Builders Often Resist Tough Safety Codes, Citing Added Expense," Wall Street Journal, January 27, 1981.

[3] Young, Arthur and Company, Testimony Before the Federal Trade Commission on the Proposed Rule for Standards and Certification, May 1979. Studies reviewed by Arthur Young included research by the National Commission on Urban Problems (the Douglas Commission) which surveyed home manufacturers (Building the American City, Washington, D.C., 1968); a study by Richard Muth who used regression analysis to relate home prices to code restrictions ("The Effects of Constraints on House Costs," Journal of Urban Economics, January 1976); a study of Colorado code requirements which was sponsored by a builders association (Lincoln, James R., Coddington, Dean C. and Penberthy, John R., An Analysis of the Impact of State and Local Government Intervention on the Home Building Process in Colorado 1970-1975, Denver: Colorado Association for Housing and Building, 1976); and a study by Stephen Seidel of code-related costs at a New Jersey housing development (Housing Costs and Government Regulation, New Brunswick, N.J.: Rutgers Center for Urban Policy Research, 1978).

In a 1978 study, a Department of Housing and Urban Development (HUD) task force concluded that the problem of excessive building code requirements was most likely to occur in jurisdictions which did not follow an up-to-date version of a model code.[1] This report did not include any data on code costs. A General Accounting Office 1978 report concluded that building codes were generally not a major factor contributing to rising housing prices, but that there might be some potential for reducing costs through code changes.[2] A 1979 study by the California Building Officials Organization dealt with the effects of codes on housing costs, among other topics.[3]

These studies have not really answered the question of which code requirements unnecessarily add to building costs, nor have they adequately assessed the extent of any adverse impact. There are several reasons for this: (1) Some studies apparently were based on opinions rather than on factual analysis; (2) In several studies, a code requirement was labeled "excessive" if it deviated from the model code; this criterion assumes that the model code provisions are neither too lenient nor too strict, which may not always be true; (3) Some of the criticized code requirements called for features that builders would have installed anyway, even without a building code requirement; and (4) The studies apparently did not subtract out whatever benefits would be realized from "unnecessary" features before they estimated the excess costs.

Responding to this lack of data, HUD sponsored research in 1980 to determine whether code requirements have significantly increased housing costs without corresponding benefits.[4]

In summary, there is much opinion and scattered evidence that building codes raise housing costs unnecessarily. But there is great uncertainty about the extent of the effect and which code provisions are to blame, and there are very few analyses to show the overall costs and benefits of the provisions most often criticized.

The controversy and concern about this important question suggests that studies such as the one HUD is sponsoring are very much needed. Future studies should follow a rigorous methodology which adequately accounts for benefits as well as costs of code requirements and which carefully defines a baseline representing what would have happened without the code requirement.

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[1] U.S. Department of Housing and Urban Development, Final Report of the Task Force on Housing Costs (Washington, D.C., 1978).

[2] Comptroller General, Why Are New House Prices So High, How Are They Influenced By Government Regulations, and Can Prices Be Reduced (Washington, D.C.: General Accounting Office, 1978).

[3] California Building Officials Organization, California's Building Departments: A Critical Evaluation and Commentary, July 1979.

[4] Request for Proposals, Cost Impact of Duplicate Life and Safety Requirements in Codes, H-5220 (Washington, D.C.: U.S. Department of Housing and Urban Development, 1980).

This report describes a methodology that can be used to analyze changes in individual building code requirements.

1.2 SCOPE

The scope of this report has been defined in the following ways: it is concerned with building codes, not with zoning and environmental regulations, nor with regulation of building components;[1] it does not treat impacts on national employment or inflation;[2] it emphasizes estimating the overall impacts of a code change rather than estimating gains or losses to particular groups;[3] and it is concerned with the process of estimating economic values of physical effects. It does not provide a method for estimating the physical effects themselves.[4]

Before beginning the analysis, there are three points the reader should keep in mind concerning benefit-cost analysis and the use of this report.

First, a full-fledged benefit-cost analysis is most likely to be warranted if the proposed code change is important (for example, if it affects a great number of buildings); if the proposed change is controversial; if the magnitude of economic effects is very uncertain without a formal analysis; and if data are available on the most important impacts of the code change.

Second, benefit-cost analysis is still a very imprecise tool, especially where underlying data are lacking, as is often the case in the building area. Some attempts at analyzing benefits and costs of code changes may simply show important areas of ignorance. No benefit-cost analysis should be blindly accepted by those making regulatory decisions.

Third, in using the method described in this report, it is only necessary to complete the steps and fill out the worksheets that are appropriate for the particular code change being studied. For example, the safety-related worksheets would probably not be needed for analyzing energy conservation codes. New worksheets may be needed for situations not covered in this report.

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[1] However, the concepts presented here can be applied to other types of regulation as well.

[2] These "macroeconomic" impacts depend heavily on public policy and overall economic conditions and, hence, are very difficult to predict.

[3] The method can be adapted to calculate impacts on particular groups such as builders, homeowners, or construction materials suppliers. See section 4.4.

[4] Sources of information which may be useful in estimating physical impacts are listed in appendix D, and several publications listed in appendix E, such as the report by S.G. Helzer et al, Decision Analysis of Strategies for Reducing Upholstered Furniture Fire Losses, National Bureau of Standards Technical Note 1101 (Washington, D.C.: U.S. Government Printing Office, 1979), demonstrate how physical impacts have been estimated by researchers.

2. DEFINING THE PROBLEM

To analyze the economic impacts of a proposed building code change, it is necessary to determine the scope of the problem. This involves choosing the perspective that will be used in the analysis and recording pertinent information about the code change to be analyzed. The analyst must also choose representative cases to be used in analyzing the impacts, the basic unit of analysis, and the periods of time for which impacts will be analyzed.

Perspective

The first step is to decide what perspective to take, that is, will the analysis deal with impacts on the local jurisdiction, or on a larger geographical area? Within that geographical area, will the code change be analyzed from the viewpoint of a specific interest group -- such as builders, materials suppliers, homeowners, or union members -- or from the viewpoint of the community as a whole? For the most part, the discussion in this report assumes the reader will analyze effects on everyone in the selected geographical area.

Describing the code change

The next step is to determine which parts of the code section will be altered and record pertinent information for easy reference later on. Worksheet 2.1 is provided for this purpose. Its use is illustrated in example 2.1 which involves a hypothetical code change for a fictitious jurisdiction called Springfield County.

Example 2.1: IDENTIFYING WHAT IS REQUIRED BY A PROPOSED CODE CHANGE

Problem: 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?

Solution: Pertinent information that should be presented for this proposed code change is shown in worksheet 2.1.

Worksheet 2.1 *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.*

Units of analysis

The third step is to choose a unit of analysis, i.e., the unit for which impacts will be calculated. 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 floor space. A unit should be chosen such that impacts are proportional to the number of units and, if possible, such that data are available on the number constructed. The impacts of the hypothetical Fire Safety Feature (FSF) code change described above will be calculated per dwelling unit.

2.1 SELECTING REPRESENTATIVE CASES

Often, the effects of a code change depend on characteristics -- such as system type, building design, and location -- that may 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 under all significant conditions. Therefore, to make the analysis feasible, it is useful to choose a few representative cases for study and use these case studies as a basis for calculating aggregate impacts.

Choosing a representative case involves selecting a reference building, identifying construction practices with and without the code change, and selecting certain other characteristics which will influence the impact of a code change.

Worksheet 2.2 is provided to record pertinent characteristics of representative cases. Its use is illustrated in example 2.2, which is a continuation of example 2.1. Particular aspects of the representative case are discussed below.

The reference design

It is important for reference buildings to be representative of buildings that will be constructed during the code analysis period and would be affected by a proposed code change. It may be convenient to select actual buildings as reference buildings. But if there are no actual buildings which are sufficiently representative, hypothetical designs can be used.

There are several ways to select reference designs. One approach would be to estimate how many buildings of various types will be constructed in the code jurisdiction during the code analysis period and select several typical designs. Table D.1 in appendix D shows some sources of data on the numbers of various types of buildings. In some cases, reference designs might be selected partly because information from engineering models or field data collection is available for these particular building types. Finally, reference designs described in previous studies might be used.[1]

[1] For example, reference designs are described in the following publications: Hastings, Robert, Three Proposed Typical House Designs For Energy Conservation Research, NBSIR 77-1309 (Washington, D.C.: National Bureau of Standards, 1977); and Chapman, Robert E.; Chen, Phillip T.; and Hall, William G., Economic Aspects of Fire Safety in Health Care Facilities: Guidelines for Cost-Effective Retrofits, NBSIR 79-1902 (Washington, D.C.: National Bureau of Standards, 1979).

Example 2.2: SELECTING REPRESENTATIVE CASES FOR ANALYSIS

Problem: The code change described in example 2.1, 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 follows: 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 2.2 on page 9.

There are several questions to keep in mind when specifying 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 usually not in analyzing a fire safety provision.)

* Which buildings will be affected by the code change after taking into account exceptions and expected waivers?

* Are major rehabilitation and/or historic preservation projects common in the jurisdiction; if so, how will new code requirements be applied to them?

Location. The building location should usually be identified because it affects wages and materials costs and, therefore, construction costs. It also determines climate and other factors which may be relevant in analyzing the impact of the code change.

Date constructed. Because costs change, the effect of a code requirement may depend on when the building is to be constructed. For example, prices of innovative fire safety devices may decline in real terms as wider use allows mass production. Escalating energy prices (prices rising faster than the rate of inflation) mean that energy conservation requirements may have a greater effect on buildings constructed in 1990 than in 1985.

Type of building. The type of building is important to specify. For instance, for residential buildings, is it a single-family residence, a low-rise apartment building, or a high-rise? How many stories is it? How many square feet? What is the construction type? It may also be useful to list the number, age, and type of occupants and any other information about design and use that seems pertinent to the proposed code change.

Practice without the code change. This is the practice that the builder would use in the absence of a code change when constructing the feature affected by the code change. It is also called the "baseline practice" since it is the baseline for measuring code impacts. In situations where construction practices are changing relatively rapidly, the baseline practice should reflect likely trends.

Worksheet 2.2 *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*	*Multi-family 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				

For example, suppose a code change would require a certain amount of insulation. For a reference building constructed in 1980, the "baseline" against which improvements should be measured is the insulation used in current new construction. However, for a reference building constructed in 1990, the baseline should be the greater amounts of insulation that would be used even without a code requirement. If today's level of insulation were used as a baseline in analyzing the 1990 building, the analysis would incorrectly suggest that the code change was responsible for improvements which would have taken place in any case.

Practice with the code change. This item describes how builders will respond to the code change. The responses selected should reflect probable interpretations of the code change. If the code allows some flexibility, alternative ways of meeting requirements might be considered, perhaps including innovative practices. (If it is not possible to define innovative practices well enough to include them in a representative case, it may still be useful to list possible innovations in presenting the results of the analysis. This information may help 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 and so may differ for each reference building. If there is great uncertainty about actual building lifetimes, it may be necessary to simply assume a lifetime, such as 25 years. If good estimates concerning code change impacts are available only for a shorter period, or if the code-mandated feature has a shorter lifetime, the building analysis period may be shorter than the expected building life.

Other factors. Other factors may be important to specify. For example, project size may be important. The scale of construction affects unit costs, and it may also affect whether the builder will be a leader or a follower in adopting new designs. Builders may respond differently if they are constructing large housing developments than if they are building houses one by one.

Another significant factor is whether new construction or modifications to existing buildings are involved. In many jurisdictions, if the alterations on existing buildings represent more than 25 percent of the building's value, then changes may be required to comply with code requirements for new structures; if alterations represent more than 50 percent of the building's value, then the entire building must meet code requirements for new structures.[1] Where owners rehabilitate low-priced, decaying buildings, the new work may easily amount to more than 25 percent or even 50 percent of of the building's value.

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[1] Impacts of building codes on rehabilitation projects are discussed in: Gross, J.; Pielert, J.; and Cooke, P., Impact of Building Regulations on Rehabilitation--Status and Technical Needs, National Bureau of Standards Technical Note 998 (Washington, D.C.: Government Printing Office, 1979), and Berry, Sandra A., Proceedings of the National Conference on Regulatory Aspects of Building Rehabilitation, NBS Special Publication 549 (Washington, D.C.: National Bureau of Standards, 1979).

Thus, the economic effects of a code change may be quite different for rehabilitating or altering existing buildings than for new construction. For example, it may be considerably more expensive to modify an old building to meet new code requirements under the 50 percent rule than to meet the requirements during initial construction. If the code will apply in a jurisdiction with the "25-50 percent rule," if there is a great deal of rehabilitation going on, and if few waivers are granted, then the analysis should be carried out to determine the impacts of a code change for a rehabilitation project as well as for new construction.

Considerations in selecting a representative case

The analyst should keep in mind four points in selecting representative cases.

(1) If the population of affected buildings is very diverse, using a large number of reference buildings gives a better picture of the code's impacts and a sounder basis for aggregating. Ideally one would do the analysis for hundreds or thousands of different reference buildings. However, because of the cost of the analysis, it is necessary to divide the affected building population into groups of similar buildings and analyze impacts for a building representing each group.

(2) Availability of data should be considered in specifying reference buildings. For example, if climate is important, cities should be selected for which there is sufficient climate data.

(3) Within each group, a representative building should be selected for which impacts/unit are likely to be average for the group. This is not always the most prevalent type of building. For example, if a group represented by a single building includes many small buildings, a few medium-sized buildings, and many large buildings, a medium-sized building might have closest to average impacts and be used as a representative building, even though the small and large buildings are more common.

(4) If the effects of various features are interdependent, a common combination of features should be selected for the representative case.

Because of these potential difficulties, much architectural and engineering judgment is needed to select reference buildings.

2.2 CODE ANALYSIS PERIOD

Code changes do not last forever. Therefore, it is necessary to assume some code analysis period. Impacts will be estimated for all buildings constructed during this period, which is the same for all representative cases. In the example in worksheet 2.2, 1981 through 1990 was selected as the code analysis period.

The simplest approach is to select a single year (e.g., "1985") for the code analysis period. This shows impacts over time for all buildings constructed in one year. However, for a more complete estimate of likely benefits and costs, one would select the time period that the requirement is likely to be in effect before it is carefully reviewed. Field and Rivkin,[1] and Seidel[2] provide data on how often municipalities revise their codes. Another source of information is a California study which found that more than half of the building departments surveyed reviewed their codes every three to four years.[3]

Another approach is to select an analysis period for which reasonably good data forecasts are available. This period depends on particular data needs. For example, Marshall, Ruegg, and Wyly forecasted the impacts of reduced-size venting for plumbing through 1985 since this was the period for which housing start projections were available.[4]

If a code change is being phased in over a period of time, the code analysis period should cover at least the time it takes to put the requirement into force, since aggregate impacts are likely to increase from year to year during this time.

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[1] Field, Charles G. and Rivkin, Steven R., The Building Code Burden (Lexington, MA: Lexington Books, 1975), p. 46.

[2] Seidel, Housing Costs and Governmental Regulation, p. 83.

[3] California Building Officials, A Critical Evaluation and Commentary, p. III-25.

[4] Marshall, Harold E.; Ruegg, Rosalie T.; and Wyly, Robert S. "Cost Savings from Reduced Sized Venting," Plumbing Engineer, July-August 1977, pp. 35-42 and September-October 1977, pp. 45-46, 64-65.

3. DISCOUNTING

To compare effects that occur at different points in time, it is necessary to put all costs on a time-equivalent basis through a process called discounting.[1] This chapter describes how to allow for the timing of impacts through methods of discounting and treating inflation.

Future dollar effects can be discounted to their present value 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 (such as "10%") 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.[2]

3.1 DISCOUNT FACTORS

Three kinds of discount factors are described below and summarized in table 3.1. Tables of discount factors are given in appendix A.

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)(SPW). The SPW can be selected from table A.2 in appendix A for the assumed discount rate and the year of the impact, or it can be calculated using the formula in table A.1.

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

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

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[1] Discounting is necessary because 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.

[2] 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 in Circular A-94, "Discount Rates to be Used in Evaluating Time Distributed Costs and Benefits," March 27, 1972. Selection of the discount rate is discussed further in section 3.2

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)(UPW). The UPW can be found in table A.3 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 A.1.

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.

Example 3.1 shows how to compute real (differential) rates of cost increase. The formula in the example can also be used for computing differential cost decreases.

The present value (P) of future costs or benefits whose real value is "A" at present prices, and is rising at a fixed percentage rate, can be calculated from the formula P = (A)(UPW*). To determine this factor, you will need to estimate the rate at which costs are increasing over and above the rate of inflation. The UPW* can be selected from tables A.4 through A.6 in appendix A for the differential rate of increase in costs, the discount rate, and the period over which costs occur, or it can be calculated using the formula in table A.1

Example 3.1: 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 for the item
e' = nominal rate of cost increase for the item
i = overall rate of inflation

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

Table 3.1 SUMMARY OF DISCOUNT FACTORS

TYPE FACTOR	Single Present Worth (SPW) (table A.2, appendix A)	Uniform Present Worth (UPW) (table A.3, appendix A)	Modified Uniform Present Worth (UPW*) (tables A.4-A.6, appendix A)
USE	P? ← F Find present value of single future amount.	P? ← A + A + ... Find present value of annually recurring amount.	P? ← $A(1+e) + A(1+e)^2 + \ldots$ Find present value of annual amount with differential cost increase.
FORMULA	P = (F)(SPW)	P = (A)(UPW)	P = (A)(UPW*)
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 an annual cost recurring for 20 years, which would be $100/year at current prices and is escalating at 5%/year, with a 10% discount rate.
SOLUTION	P = ($100)(.3855) = $38.55	P = ($100)(8.514) = $851.40	P = ($100)(12.7178) = $1271.78

3.2 DISCOUNT RATES

This section discusses several considerations in selecting the discount rate used in choosing discount factors from the tables in appendix A.

Discount rates reflect rates of return which could be earned by those affected by the code change. Rates of return may be stated in terms of either market or real rates.

Market (nominal) rates are the actual rates observed in the market. They include percentage points to compensate for inflation. If the code impacts are stated in current dollars, then the discount rate should be based on market rates of return.

Some market rates that may be useful in determining discount rates are the business prime rate of interest, 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.

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 report, the discount rate should be based on real rates of return.

The following formula can be used to find a real rate of return corresponding to a market rate:

$$r = \frac{1 + r'}{1 + i} - 1, \tag{3.1}$$

where:

r = the real rate of interest,
r' = the market rate of interest, and
i = 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.

The example in this report uses a before-tax rate of return as the basis for the discount rate. The before-tax rate of return reflects amounts that could be earned on an investment from the national perspective (the taxes paid are lost to the taxpayer, but they still represent gains to the economy as a whole). However, in analyzing a code change strictly from the viewpoint of the local community, you may wish to use the rate of return <u>after</u> Federal and State taxes, since this reflects the net gain to the local economy.

4. ESTIMATING IMPACTS ON BUILDING-RELATED COSTS

A code change may affect construction costs, energy costs, maintenance costs, other costs of operating a building, and even costs of disposal at the end of the building's life. It may also affect public costs related to buildings such as costs of code administration and fire protection. This section explains how to estimate impacts of a code change on building-related costs.

Impacts are measured by comparing costs without the code change to costs with the code change.

The approach recommended in this report is to estimate costs before taking into account any tax effects. For example, costs of adding insulation would be estimated before considering possible savings due to tax credits. Treatment of taxes was very briefly discussed in section 3.2.

The discussion in this chapter and the next assumes that the building in question is constructed during the current year. Later, in chapter 7, the report explains how to adjust the estimates to apply to buildings constructed in future years.

4.1 CONSTRUCTION COSTS

Construction costs are discussed in this section and operating and maintenance costs are discussed in the next section.

Worksheet 4.1 is provided to list effects on materials, labor, equipment, overhead and profits, and other construction costs. The analyst 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 in section 4.3. Section D.2 in appendix D shows some sources of construction cost data.

Worksheet 4.1 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 earlier on worksheet 2.2. Because of limited space, computations for other representative cases are not shown in this report. However, in an actual analysis, worksheets would be filled out for each representative case.

A blank worksheet is provided in appendix F to use in summarizing costs.

Qualitative considerations

Hard-to-quantify effects of a code change should also be presented in the results of the benefit-cost analysis. Three hard-to-quantify factors which may affect construction costs are described below.

The first factor is market uniformity.

Fragmentation of building markets because of codes that differ from jurisdiction to jurisdiction has been criticized as one source of high building costs.[1]

On the other hand, due to differences in local situations, code uniformity is not always desirable. For example, code requirements appropriate in one type of climate may be inappropriate in other climates. Jurisdictions with small fire-fighting budgets may wish to have stringent fire safety requirements. Citizens in one jurisdiction may prefer to spend more on life safety than citizens in another jurisdiction. Finally, varying prices for labor and building products may make code requirements which are reasonable in some jurisdictions excessively expensive in others.

The second factor affecting construction costs is the prescriptive versus the performance nature of the requirements. Prescriptive code requirements have been criticized for excluding cost-effective products or designs.[2] They may discourage manufacturers from developing new products. Performance standards, on the other hand, are often said to be more conducive to innovation; but they may also be more difficult for code officials to interpret and enforce. In analyzing impacts of a code change, the analyst should take into account the possible long-run indirect effects due to the "prescriptive" or "performance" form of the provision.

The third factor affecting costs is construction delays. Adding a major code requirement (or set of requirements) may increase the time it takes to get plans and site work approved.[3]

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[1] McConnaughey, John, An Economic Analysis of Building Code Impacts: A Suggested Approach, NBSIR 78-1528 (Washington, D.C.: National Bureau of Standards, 1978), pp. 77-78; Field and Rivkin, The Building Code Burden, pp. 27-30; Oster, Sharon and Quigley, John, "Regulatory Barriers to the Diffusion of Innovation," in Cooke, Patrick, Ed., Research and Innovation in the Building Regulatory Process: Proceedings of the First NBS/NCSBCS Joint Conference, NBS Special Publication 473 (Washington, D.C.: National Bureau of Standards, June 1977), p. 115; and Seidel, Housing Costs and Government Regulation, pp. 85-86 and 92-93. However, a study by Arthur Young & Co. asserts that there has been little reliable research on compliance costs resulting from production inefficiency attributable to lack of code uniformity. See Young, Arthur and Company, Testimony Before the Federal Trade Commission on the Proposed Rule for Standards and Certification, pp. 43-44.

[2] Field and Rivkin, The Building Code Burden, pp. 27-30. A "prescriptive" code provision is one which requires a specific method of construction or type of product, although it may allow use of "equivalent" products at the discretion of the local building official. A performance standard states performance criteria and methods of test or evaluation.

[3] The times required for plan checking and site inspections are discussed in California Building Officials Organization, A Critical Evaluation and Commentary (pp. I-4-5) and Hendrickson, P.L. et al, An Analysis of the Impact of State and Local Government Intervention on the Home Building Process in Colorado 1970-1975, pp. 6-8.

The costs of any additional delays should be counted in analyzing code change impacts. For example, there might be higher construction costs if personnel and equipment are idled or inefficiently employed because of delays. Even if it is not possible to estimate costs of the delays, the extent and nature of added delays should still be described so that this effect can be considered by those making code change decisions.

Worksheet 4.1 *hypothetical example*

IMPACT ON UNIT INITIAL COSTS[a]

Representative case *I* (from worksheet 2.2)

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.

4.2 OPERATION AND MAINTENANCE COSTS

Some code requirements are designed to decrease costs of operating and maintaining buildings (O&M costs). Other code requirements may increase O&M costs; for example, a requirement for a smoke control system might impose periodic testing costs. In some cases, the cumulative impact on O&M costs over the years may be much greater than effects on initial construction costs.

O&M costs that might be affected by code changes include regularly recurring energy costs and non-energy costs such as water use, security, cleaning, testing, inspection, and routine maintenance. (However, insurance costs should not be included since this type of cost is covered in the section of this report that deals with building safety and performance.) O&M costs also include irregularly recurring costs such as costs associated with repair, replacement, fire safety training, and planned alterations.

O&M costs include replacement of code-mandated components which wear out. In estimating replacement costs it is necessary to determine both the expected life of the component and whether the component will actually be replaced when it wears out. For example, how long will weatherstripping required under an energy conservation code last? Will it be replaced when it wears out?

Three steps are needed in calculating 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 4.2. Sources of information for operation and maintenance costs are listed in section D.3 in appendix D. In the example, 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. (See chapter 3 on discounting.) For example, in part A of worksheet 4.2, the $25 one-time impact on repair costs will be discounted with a Single Present Worth factor. The factor, .3855, was selected from table A.2 in appendix A for a 10 percent discount rate and 10 years. A SPW factor was also selected for discounting replacement costs listed in part A for the original code requirement.

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 A.3 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 A.5 in appendix A for the differential price rise of one percent and a period of 25 years.

IMPACT ON UNIT OPERATION AND MAINTENANCE COSTS[a]

Representative case *I* Discount rate *10* %

Building analysis period (from worksheet 2.2) *25* years

A. COSTS RISING AT THE RATE OF INFLATION

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

[a] The unit of analysis should be the one listed on worksheet 2.2.

[b] At present prices.

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

[d] From discount factor tables A.2 through A.6 in appendix A for assumed discount rate, timing of impact, and (for UPW*) the rate of differential price change.

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 4.4 and so need not be considered in selecting the SPW. The SPW discounting factor, .1486, was selected from table A.2 in appendix A for 20 years and 10 percent.

Third, after selecting discount factors, the data in worksheet 4.2 should be transferred to either worksheet 4.3 (for costs rising at the same rate as inflation) or to worksheet 4.4 (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.

Worksheet 4.3 *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*	
	$	x		=	$	$ *2.21*
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 4.2, part A.

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 (Proposed − Original)	x	UPW*	=	Discounted Value
	($ *20* − $ *10*)	x	*9.8919*	=	$ *98.92*
	($ ____ − $ ____)	x	____	=	$ ____

[a] Amount, SPW, and UPW* are from worksheet 4.2, part B.

[b] $(1+e)^t = (1 + -.05)^{20} = .3585$, where the rate of differential price rise "e" and year of impact "t" are from worksheet 4.2, part B. This factor adjusts for cost changes <u>after</u> the construction year.

4.3 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.

Code enforcement

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

To determine the effects of a code change on enforcement costs, one might ask the following questions: Will a new concept or technology (such as solar energy systems) require training or hiring of additional building officials? 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. They should be calculated per building or other unit of analysis so that they can be added to other impacts calculated on a similar basis.

Information on State and local costs related to adoption and enforcement of building codes may be found in the testimony prepared for Federal Trade commission hearings by Arthur Young and Company. The data sources included the State budget and State Controller reports.[1] A survey of California building departments provides information on departmental budgets and fees.[2]

Worksheet 4.5 illustrates how to estimate government costs for the hypothetical FSF requirement in terms of costs per dwelling unit.

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[1] Arthur Young and Company, Testimony Before the Federal Trade Commission on the Proposed Rule for Standards and Certification, pp. 22-25.

[2] California Building Officials, A Critical Evaluation and Commentary, July 1979.

Worksheet 4.5 *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		=	$	$ *10*
Original Requirement	*Plan check, inspection*	*Constr. year*	-$ *20*	x	*1*	=	-$ *20*	
			-$	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 A.2 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 A.3, appendix A, for assumed discount rate and building analysis period.

4.4 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 some of the worksheets in this report may be adapted for this purpose.

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

First, 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 4.1, 4.3 and 4.4, possibly with adjustments for tax effects.

It is possible to estimate effects on suppliers of various construction products by breaking down construction costs into their components -- e.g., estimating the change in the value of lumber purchased, the change in electrician's labor, etc.

For example, the economic analysis of the proposed Energy Performance Standards for New Buildings[1] estimated effects of proposed energy conservation standards on shipments of eight industries, including lumber, insulation, and heating, venting and air-conditioning equipment suppliers. The approach is to determine what additional materials and equipment are needed to comply with a code change and which products are displaced. Then, physical quantities and values can be estimated per building and aggregated to find total effects on the industry.

Similarly, labor required or displaced as a result of compliance with a code change can be estimated per building and in the aggregate, by type of labor.

Fire department and other government costs paid for out of government funds can be estimated from worksheet 4.5.

Second, how are impacts on building costs shifted from those directly affected to others? This information is necessary in order to determine accurately who ultimately gains or loses from a code change.

Ideally, estimates of effects on particular groups should reflect the extent to which builders pass on construction cost changes to building purchasers, landlords pass through energy costs to tenants, businesses pass through building costs to their customers, hospitals raise prices, or the government alters fees and taxes to reflect a change in enforcement or fire protection costs.

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[1] U.S. Department of Energy, Office of Conservation and Solar Energy and Office of Buildings and Community Systems, Economic Analysis: Energy Performance Standards for New Buildings, November 1979.

In practice, however, 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 decisionmakers understand who ultimately pays for, and gains from, code changes.

To estimate accurately effects on particular groups, it may be necessary to consider tax effects. Several past building economics studies are useful as examples of how to calculate effects on particular groups. For example, a report by Arthur D. Little, Inc., analyzes effects of energy conservation requirements on suppliers of various building products and on builders, engineers, and code authorities.[1] A Department of Energy report also estimates effects of proposed energy conservation requirements in particular groups.[2] Two NBS economists, Marshall and Ruegg, describe ways of dealing with tax effects on building owners.[3]

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[1] Arthur D. Little, An Impact Assessment of ASHRAE Standard 90-75.

[2] U.S. Department of Energy, Economic Analysis: Energy Performance Standards for New Buildings.

[3] Marshall, Harold E. and Ruegg, Rosalie T. Energy Conservation in Buildings: An Economic Guidebook for Investment Decisions, National Bureau of Standards Handbook 132 (Washington, D.C.: Government Printing Office, 1980), p. 38.

5. IMPACTS ON BUILDING SAFETY AND PERFORMANCE

This chapter explains how to estimate the effects of a code change on building safety and performance.

Building codes can affect property damages, lives lost, and injuries due to building accidents. A code requirement can also affect the performance or usefulness of a building. These and other effects of a proposed code change should be measured against the existing code requirement as a baseline.

The term "building quality" is used here to refer to both the safety and usefulness of a building. Some changes in building quality may be impossible to quantify in dollar terms. However, many other effects can be quantified, at least approximately.

5.1 BUILDING SAFETY

One of the most difficult problems facing code officials is determining the economic effects of a code change on safety. Frequently, the cause-and-effect relationship between a particular building feature and an accident is poorly understood. If the physical impacts of a code change on safety are not known, then it will not be possible to calculate accurate dollar values for safety impacts. However, even when the data are poor, economic analysis can still be helpful in identifying which information is most needed for the analysis. This is accomplished by performing a sensitivity analysis (discussed in chapter 9).

Effects of the code revision on property losses should be estimated in dollars. However, in determining life safety effects, there are two possible approaches.

One approach is to assess 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. This approach is described in section 5.2.

Another approach is to estimate the dollar value of 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. However, following this approach requires assigning a dollar value to lives saved and injuries prevented. This raises a number of practical, theoretical, and philosophical questions, some of which are discussed in the next chapter. The approach itself is described in section 5.3.

5.2 SIMPLIFIED APPROACH

This section presents a simplified approach to estimating safety impacts. It emphasizes presenting life-safety impacts in physical terms. The analysis should be done for each representative case identified in worksheet 2.2.[1] The eight steps in the analysis, which use worksheets 5.1 and 5.2, are described below.

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 5.1 and 5.2.

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 5.1 and 5.2.

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 5.1, 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 5.1 and 5.2 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.

Some sources of accident and loss information are published data bases, technical reports, insurance company figures, and the opinions of experts. 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. Section D.4 in appendix D lists a few sources of information about building accidents and losses.[2]

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[1] This approach is also described in a simplified version of this report: Rawie, Estimating Benefits and Costs of Building Regulations.

[2] Three reports briefly described in appendix C show how researchers estimated losses related to fires, mobil home hazards, and electric shocks.

Worksheet 5.1 *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 A.3, appendix A, for assumed discount rate and building analysis period or life of required feature.

Sometimes the direct impact of a code provision may be to increase safety, but -- paradoxically -- because of market effects, there may be indirect negative impacts on safety. For example, if code requirements increase housing costs significantly, some people may choose to stay in old housing to save money -- possibly reducing safety for these people. This report concentrates on direct effects of accidents; it is beyond the scope of this paper to describe ways of rigorously estimating safety and other effects that occur through the market. However, information on code-caused increases in building costs may help those involved in changing codes to consider possible indirect effects on safety.

3. Determine the dollar value of property losses from each type of accident. Property losses due to fire, earthquake, snow, winds, etc. include not only the actual damage to the building and its contents, but also the less obvious costs such as costs due to disruption of a company's business. Examples of these costs are listed in table 5.1. Fill in the information on worksheet 5.1.

4. Multiply the average cost per accident by the change in the probability that the particular accident will occur. Do this for each type of accident and add these figures to get the total change in annual expected dollar loss. Fill in this information on worksheet 5.1.

5. Multiply the annual dollar loss by a Uniform Present Worth (UPW) discounting factor. This will give the discounted expected value of property losses over the building analysis period (or over the effective life of the required feature, if this is less than the building analysis period).[1] The UPW is found in table A.3 in appendix A. Fill in this information on worksheet 5.1.

6. Estimate the number of fatalities and/or injuries resulting from each type of accident or other event. Fill in this information on worksheet 5.2. Sources of loss information are included in appendix D. A report by Helzer, Buchbinder, and Offensend, described in appendix C, shows how one group of researchers estimated the losses associated with various types of fires.

7. Multiply the value which was estimated in step 6 by the change in probability estimated in step 2 that the particular type of accident 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 5.2.

In some cases the nature of available hazards data will make it easier to estimate directly the number of deaths and injuries associated with various types of accidents, rather than first estimating the numbers of accidents. If so, there may be no need to fill out the second and third column in worksheet 5.2; instead, the analyst could skip to the last three columns and directly fill in the expected change in deaths and injuries.

---

[1] The "expected value" is a way of accounting for uncertainty; it shows the average impact per building. For example, if one building in a thousand suffers a $50,000 fire loss, the expected value of fire losses for a single building is $50.

Worksheet 5.2 *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
			.005 (deaths)	=	*+.00001*		
Confined fire	*+.002*	x	*.05* (major inj.)	=		*+.0001*	
			.5 (minor inj.)	=			*+.001*
			.02 (deaths)	=	*-.00002*		
Room fire	*-.001*	x	*.1* (major inj.)	=		*-.0001*	
			1.0 (minor inj.)	=			*-.001*
			.1 (deaths)	=	*-.0001*		
Building fire	*-.001*	x	*.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 5.1.

8. Multiply the fatalities or injuries prevented annually by the number of years in the building analysis period or the life of the repaired feature, whichever is less. This will show the expected life safety impacts over time. Fill in this information on worksheet 5.2.

Table 5.1 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.

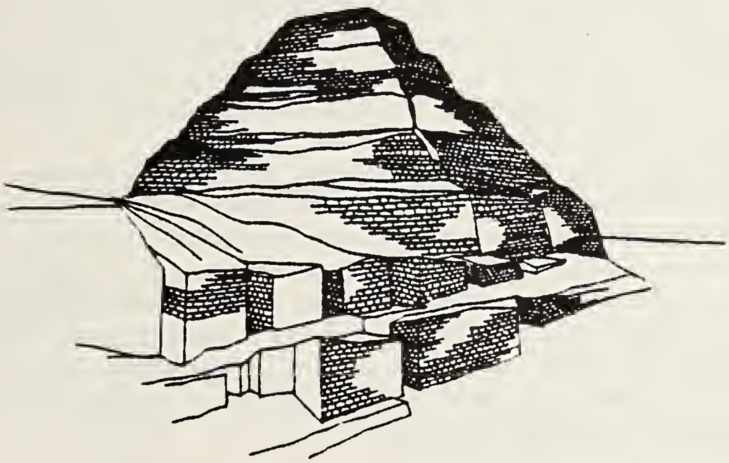
* Costs of insurance administration. Legal fees and administrative costs should be counted, but not claims payments, which are already counted in estimating damages.

* 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 costs of the accident.



5.3 DETAILED APPROACH

The simplified method described in section 5.2 may be the best approach if the resources for doing the analysis are limited. However, it does not provide a rigorous method for estimating changes in the probability of an accident and it does not allow for impacts to vary over the building analysis period. Therefore, this report also presents a detailed approach to estimating safety effects. (The two approaches are compared in the appendix to this chapter.) The detailed approach has seven steps, described below:

1. Determine what types of building accidents or resulting outcomes might be affected by the code change. See the discussion of Step One in section 5.2.

2. Estimate how the code change would affect the probability that a specific type of accident will occur. This can be done using the following procedure.

a. Specify sets of events leading to accidents. To follow this detailed approach, it is necessary to specify the conditions that lead to accidents. These conditions can be set forth as alternative chains-of-events. A probability tree such as the one in figure 5.1 for a hypothetical Fire Safety Feature (FSF) is useful in depicting possible sets of events.

b. Estimate probabilities of various steps in the scenarios. Ultimately, the analyst needs to know the probabilities that various chains of events leading to accidents will occur in the reference building in a given year, and how these probabilities are altered by a code change. This requires estimating the probabilities of various conditions, or steps. This is illustrated in figure 5.1. The numbers on each segment are the probabilities that the event will occur in a single building (or other unit of analysis such as dwelling unit or per square foot) within a year, providing that the preceding events occurred.[1]

   For example, in figure 5.1 the heavy line corresponds to one chain of events. In that chain of events, the probability of an ignition is .0001.[2] The probability that some one will be home if there is an ignition is .95. The probability that there will be a FSF is .10. The probability that the fire will be confined to its origin, if someone is home and there is a FSF, is .8.

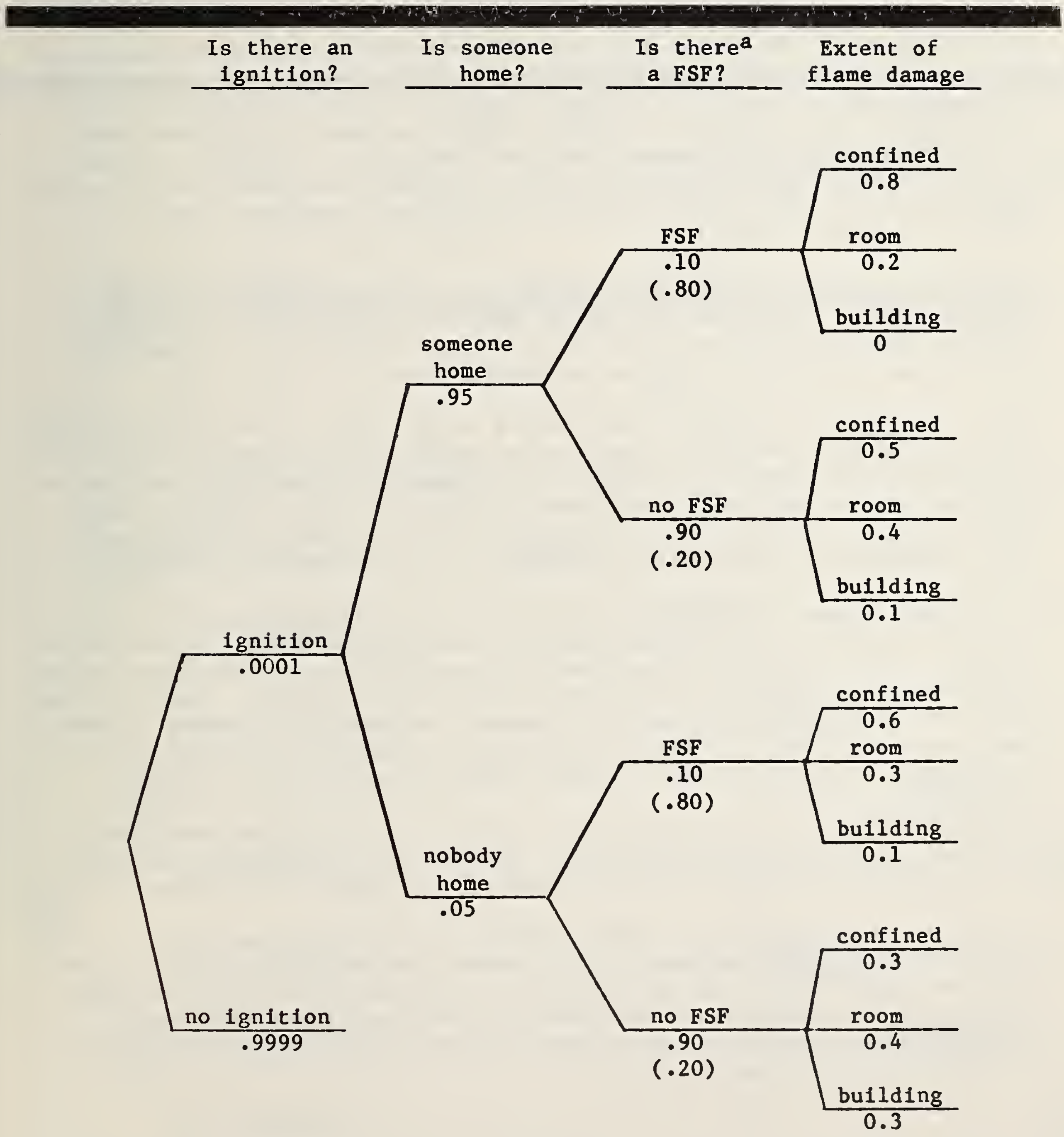
   Revised probabilities are needed to reflect a code change. In the example, the probability of there being a FSF is set at the higher figure in parentheses, (.80), to reflect the code change requiring FSFs.

---

[1] Sources of accident data are listed in appendix D. However, "expert judgment" will also be needed to estimate these probabilities. For an example of how such probabilities have been estimated, see Helzer et al, Decision Analysis of Strategies for Reducing Upholstered Furniture Fire Losses.

[2] That is, an ignition will occur each year in one out of 10,000 dwelling units.

Figure 5.1 EVENTS LEADING TO FIRE: (HYPOTHETICAL EXAMPLE)



[a] Numbers in parentheses are for after the code change.

c. Specify situations which include accident types and key conditions. In the simplified approach, losses were assigned to each type of accident without regard to other conditions such as whether someone is home. In reality, losses depend not only on the accident type, but also on other factors. Thus, the analyst should identify key elements that determine the amount of loss. In the FSF example, two key elements determining the extent of loss are the type of fire (e.g., confined, room, or building) and whether someone is home. Thus, the six "modified" situations that will be used later in the analysis are: 1) someone home/confined fire; 2) someone home/room fire; 3) someone home/building fire; 4) nobody home/confined fire; 5) nobody home/room fire; and 6) nobody home/building fire. These are shown in separate columns in figure 5.2.

d. Estimate the change in probabilities of the situations listed in 2c due to the code change. The next step is to compute the probabilities of each situation occurring and to calculate how these probabilities change with a code change. A way to do this is explained below.

First, multiply the probabilities along a single path in the probability tree to find the probability that the particular chain of events described by the path will occur. For example, the probability that there will be an ignition, someone will be home, there will be a FSF, and a confined fire will result, is .0001 x .95 x .10 x .8 = .0000076. "Path probabilities" can be computed for each chain of events, as is illustrated in figure 5.2.

To find the probability that a particular situation described in 2c will occur in the reference building, add the "path probabilities" for all paths leading to the situation in question. For example, the someone home/confined fire situation encompasses two paths on the tree: one where someone is home, there is a FSF, and a confined fire results; and one where someone is home, there is no FSF, and a confined fire results. Adding the two path probabilities gives a probability of a someone home/confined fire of .0000503.

Probabilities should be calculated for each of the situations specified in 2c. They should be calculated twice, once for the original code provision, and once for the revised code requirement, as illustrated in figure 5.2.

By subtracting probabilities computed with a code change from the probabilities computed without a code change, the analyst can determine how the code change alters the probabilities of various situations. For example, figure 5.2 illustrates that imposing a code requiring a FSF would increase the probability of a confined fire occurring when someone is home by +.00002 per building per year.

Figure 5.2 PROBABILITIES OF FIRE SITUATIONS (HYPOTHETICAL EXAMPLE)[a]

Ignition	Occupancy	Fire safety feature	Outcome	Path Probability	Someone Home: Confined	Someone Home: Room	Someone Home: Building	Nobody Home: Confined	Nobody Home: Room	Nobody Home: Building
ign. .0001	home .95	FSF .10 (.80)	C 0.8	.0000076 (.0000608)	.0000076 (.0000608)					
			R 0.2	.0000019 (.0000152)		.0000019 (.0000152)				
			B 0	0 (0)			0 (0)			
		no FSF .90 (.20)	C 0.5	.0000427 (.0000095)	.0000427 (.0000095)					
			R 0.4	.0000342 (.0000076)		.0000342 (.0000076)				
			B 0.1	.0000085 (.0000019)			.0000085 (.0000019)			
	not home .05	FSF .10 (.80)	C 0.6	.0000003 (.0000024)				.0000003 (.0000024)		
			R 0.3	.00000015 (.0000012)					.00000015 (.0000012)	
			B 0.1	.00000005 (.0000004)						.00000005 (.0000004)
		no FSF .90 (.20)	C 0.3	.00000135 (.0000003)				.00000135 (.0000003)		
			R 0.4	.0000018 (.0000004)					.0000018 (.0000004)	
			B 0.3	.00000135 (.0000003)						.00000135 (.0000003)
Accide t Probabilities - Original					.0000503	.0000361	.0000085	.00000165	.00000195	.00000140
- Revised					.0000703	.0000228	.0000019	.0000027	.0000016	.0000007
Change					+.00002	-.0000133	-.0000066	+.00000105	-.00000035	-.0000007

[a] Figures in parentheses are for after the code change.

3. Assign dollar values to life safety impacts and determine dollar value of property losses associated with each situation. The next step is to determine what losses result from each situation described in 2c. The starting point for determining these losses is historical hazards data. However, since losses may depend on factors not reflected in the available data, the analyst may have to make loss estimates to account for various conditions surrounding the accident. For example, suppose the historical data suggested that the probability of major injury in a room fire is 0.1.[1] Since an injury is more likely to happen if someone is home when the fire starts, this figure might need to be adjusted up to 0.2 for fire with someone home and down to .01 for fires with nobody home.

   Losses assigned to various accident types for the hypothetical example are shown in figure 5.3. For example, the probability that there will be a death due to a confined fire when someone is home is estimated at .005 in the hypothetical example;[1] the property losses from such a fire are estimated at $2500. (These would be average figures. Some buildings would have above-average losses and other would have below-average losses.)

   In the simplified approach, deaths and injuries were presented in physical terms, without assigning a dollar value. However, in the detailed approach, life safety impacts will be converted to dollars. The dollar figure represents the amount society is willing to pay (or require individuals to pay) to prevent a "statistical" death or injury. Methods of arriving at these dollar values are discussed in chapter 6.

   For purposes of illustration in the example, we have assumed the following dollar values for preventing death, major injury, and minor injury: death - $300,000; major injury - $50,000; and minor injury - $1,000. It should be emphasized that these values were selected arbitrarily and are used for illustration only.

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[1] That is, a major injury would occur in one out of every ten room fires.

Figure 5.3 EXPECTED LOSSES DUE TO ACCIDENTS (HYPOTHETICAL EXAMPLE)

			Loss Type			
			Death	Major Injury	Minor Injury	Property Loss
Ignition	Someone Home	Confined	.005	.05	.5	$ 2,500
		Room	.02	.2	2	$10,000
		Building	.2	.7	3	$50,000
	No one Home	Confined	0	0	0	$ 2,500
		Room	.02	.05	1	$10,000
		Building	.05	.3	1	$50,000

Once the deaths, injuries, and property losses associated with each situation are known, and dollar values are assigned, it is possible to calculate expected dollar losses for each situation. The average number of deaths or injuries from an accident are multiplied by the appropriate value and summed, together with property losses, to find the expected loss if an accident of that type occurs. For example, in the hypothetical case in table 5.2, a confined fire that occurs when someone is home results in an average of .005 deaths. Multiplying this by the $300,000 assumed value per deaths gives an expected loss of $1,500 due to fatalities if that particular type of fire occurs. Adding this to losses due to property damages and injuries gives an expected cost of $7,000 if a confined fire occurs when someone is home. (As noted before, this is an average loss. In some confined fires the losses would be greater, and in others they would be less.)

Table 5.2

DOLLAR LOSSES DUE TO ACCIDENTS (HYPOTHETICAL EXAMPLE)

Accident Type	Average No. of Deaths or Injuries[a]	x	$ Value of Deaths or Injuries[b]	=	Average Loss if Accident Occurs Subtotals	Totals
1. Someone home/ confined fire						
Death	.005		$300,000		$ 1,500	
Major Injury	.05		50,000		2,500	
Minor Injury	.5		1,000		500	
Property Loss					2,500	$ 7,000
2. Someone home/ room fire						
Death	.02		$300,000		$ 6,000	
Major Injury	.2		50,000		10,000	
Minor Injury	2		1,000		2,000	
Property Loss					10,000	$ 28,000
3. Someone home/ building fire						
Death	.2		$300,000		$60,000	
Major injury	.7		50,000		35,000	
Minor injury	3		1,000		3,000	
Property loss					50,000	$148,000
4. No one home/ confined fire						
Death	0		$300,000		$ 0	
Major Injury	0		50,000		0	
Minor Injury	0		1,000		0	
Property Loss					2,500	$ 2,500
5. No one home/ room fire						
Death	.02		$300,000		$ 6,000	
Major Injury	.05		50,000		2,500	
Minor Injury	1		1,000		1,000	
Property Loss					10,000	$ 19,500
6. No one home/ building fire						
Death	.05		$300,000		$15,000	
Major Injury	.3		50,000		15,000	
Minor Injury	1		1,000		1,000	
Property Loss					50,000	$ 81,000

[a] From figure 5.3. [b] Assumed.

4. <u>Calculate per-unit property and life safety impacts for each year in the building analysis period</u>. The next step is to compute expected losses by multiplying the loss associated with each situation by the change in probability of that accident occurring, and summing. This gives a weighted average which represents the change in loss that is statistically expected for a single building (or other unit of analysis) in a given year. This should be done for each year of the building analysis period, unless impacts are expected to be the same each year.

In the hypothetical example in table 5.3, the code change decreases the probability of a room fire occurring when someone is home by .0000133. The average loss if a fire occurs is $28,000. Multiplying the decreased probability by the loss if the fire occurs shows that the dollar losses statistically expected per building, in a given year, due to this particular accident type, will decline by about 37¢. Summing the changes shows that the hypothetical code change would cause expected dollar life safety and property losses per building in a given year to decline by $1.28. (With this very slight impact on safety, the code change would only be cost-effective if compliance and enforcement costs were also extremely low.)

Table 5.3

CHANGE IN EXPECTED LIFE SAFETY AND PROPERTY DOLLAR LOSSES IN A SINGLE YEAR (HYPOTHETICAL EXAMPLE)

Accident Type	Change in Probability of Accident[a]	x	Loss if Accident Occurs[a]	=	Change in Expected Loss
1. Someone home/ confined fire	+ .00002		$ 7,000		+ $0.14
2. Someone home/ room fire	- .0000133		$ 28,000		- $ .3724
3. Someone home/ building fire	- .0000066		$148,000		- $ .9768
4. No one home/ confined fire	+ .00000105		$ 2,500		+ $ .002625
5. No one home/ room fire	- .00000035		$ 19,500		- $ .006825
6. No one home/ building fire	- .0000007		$ 81,000		- $ .0567
			Change in Expected Loss		- $1.2701

[a] From figure 5.2

5. <u>Calculate per-unit impact over the building analysis period by summing annual impacts</u>. If the change in annual expected losses is likely to be the same each year, then the change need only be calculated one time. The present dollar value of expected life safety and property losses over time can be estimated using a Uniform Present Worth factor (UPW), as was done in Step 5 of the simplified approach.

   But if the change in expected losses is likely to vary unevenly over the life of the building, the calculations will have to be repeated for each year of the building analysis period. This variation may occur, for example, if a code feature loses its effectiveness as the building ages. Or, the variation may occur because of changes in the dollar losses connected with a particular accident. For example, an increase in the cost of medical care may increase the cost of an injury.

   The example in table 5.4 illustrates how to calculate the change in losses over time. First, each loss for a given year must be discounted to the construction year by multiplying the loss by a Single Present Worth factor selected for the appropriate year in the building analysis period. The discounted values are then summed to find the change in the discounted value losses due to the code change, -$6.82 in the example.[1]

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[1] It may also be useful to calculate the effect on the number of deaths and injuries in physical terms. This can be done by multiplying the average number of deaths (or injuries) of an accident by the changed probability of that accident as a result of the code change. Then, life safety impacts over time can be calculated by summing impacts in each year of the building analysis period. In presenting these results, you should make clear that life safety effects were also included in dollar losses and you should explain the timing of life safety effects.

Table 5.4

CHANGE IN LIFE SAFETY AND PROPERTY DOLLAR LOSSES
OVER BUILDING ANALYSIS PERIOD
(HYPOTHETICAL EXAMPLE)

Year in Building Analysis Period	SPW (10%)	x	Change in Expected Losses[a]	=	Discounted Value of Change in Expected Losses
1	.9091	x	(-$1.27)	=	-$1.15
2	.8264	x	(- 1.27)	=	- 1.05
3	.7513	x	(- 1.27)	=	- .95
4	.6830	x	(- 1.27)	=	- .87
5	.6209	x	(- 1.27)	=	- .79
6	.5645	x	(- 1)	=	- .56
7	.5132	x	(- 1)	=	- .51
8	.4665	x	(- 1)	=	- .47
9	.4241	x	(- .50)	=	- .21
10	.3855	x	(- .50)	=	- .19
11	.3505	x	(- .10)	=	- .04
12	.3186	x	(- .10)	=	- .03
13	.2897	x	(- 0)	=	0
14	.2633	x	(- 0)	=	0
15	.2394	x	(- 0)	=	0
16	.2176	x	(- 0)	=	0
17	.1978	x	(- 0)	=	0
18	.1799	x	(- 0)	=	0
19	.1635	x	(- 0)	=	0
20	.1486	x	(- 0)	=	0
TOTAL					-$6.82

[a] These hypothetical figures reflect declining effectiveness of a FSF over time. The figure for year one is from table 5.3.

5.4 BUILDING PERFORMANCE

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.

Usable space

Building code requirements may reduce the amount of building space available. For example, 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 5.3 illustrates a method of calculating the costs of space foregone, using rentals as a measure of the value of lost space. Effects are calculated for the building analysis period and discounted to the construction year.

Valuing space. 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. However, if the change in space is large relative to the size of the market, rentals may go up or down, and a figure lower than current rentals may be needed to value space. This is explained further in the appendix to this chapter.

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 additional benefits of the foregone 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.

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. Impacts of codes on rehabilitation are discussed in Berry[1] and Gross, Pielert, and Cooke.[2]

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[1] Berry, Proceedings of the National Conference on Regulatory Aspects of Building Rehabilitation.

[2] Gross, Pielert, and Cooke, Impact of Building Regulations on Rehabilitation.

Worksheet 5.3 *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 A.3, appendix A, for assumed discount rate and building analysis period.

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, 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.[1] On the other hand, a requirement for a fire extinguisher may interfere with the aesthetic quality of a historic building. Or mandatory double-glazing might cause builders to use fewer windows -- sacrificing the psychological and emergency exit benefits of the omitted windows.

One measure of lost benefits may be the effect on the rent that can be charged or the selling price of a building. Lost value may also be estimated 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 dollar impacts of a change in efficiency or amenities cannot be estimated, these impacts can still be described qualitatively so that they will not be overlooked completely in making code change decisions.

Residual value

The feature required by a code change may have some residual value after the assumed building analysis period. For example, if the true lifetime of a building is 40 years, a sprinkler system may still provide protection beyond an assumed 25-year building analysis period. Also, after its useful life, there may be a salvage value for that component.

Estimating the discounted residual value of the code-required feature may be a difficult task. However, for a long building analysis period, an error in estimating residual value may not be very important 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. Thus, even a rough approximation of residual value may be sufficient. In some cases residual value may be so small that it can be neglected altogether. Worksheet 5.4 may be used to calculate the impacts on discounted residual value.

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[1] MacFadyen, David J. "A Case History of the Integrity of the National Electrical Code," in Cooke, Patrick W., Ed., Proceedings of the Third Annual NBS/NCSBCS Joint Conference, National Bureau of Standards Special Publication 552 (Washington, D.C.: Government Printing Office, 1979), pp. 58, 59.

Unintended effects

A code change may result in unintended impacts on building amenities and usefulness. For example, consider the case of a code provision that is aimed at protecting against fire deaths. That provision might also increase the day-to-day convenience of the building by providing more exits and/or it might decrease building security.

Any significant unintended effects on building safety and performance should also be estimated and presented separately for consideration by decisionmakers.

Worksheet 5.4 *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]	=	Changes 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 A.2, appendix A for assumed discount rate and building analysis period.

Table 5.5 COMPARISON OF SIMPLIFIED AND DETAILED APPROACHES FOR ESTIMATING SAFETY IMPACTS

Simplified Approach	Detailed Approach
1. Determine accident types or other outcomes.	1. Determine accident types or other outcomes.
2. Estimate how the code change would affect the probability of the accident occurring.	2. Estimate how the code change would affect the probability that a specific type of accident will occur, using the following procedure:
3. Determine property losses associated with each accident type.	a. Specify events leading to accidents.
4. Calculate annual per-unit property impact.	b. Estimate probabilities of various events.
5. Calculate per-unit impact over the building analysis period using UPW factor.	c. Specify situations which include accident types and key conditions.
6. Determine fatalities and injuries from each type of accident.	d. Estimate change in probability of the situations listed in 2c due to code change.
7. Determine expected annual fatalities and injuries by multiplying per-accident impacts by change in probability of accident.	3. Assign dollar values to life safety impacts, and determine dollar value of property and life safety losses associated with each accident type under certain key conditions.
8. Calculate life safety impacts over time by multiplying annual impacts by number of years in building analysis period.	4. Calculate per-unit property and life safety impacts for each year in the building analysis period.
	5. Calculate per-unit impact over the building analysis period by summing annual impacts. (Determination of fatalities and injuries is included in step 3.)
	6. Determine expected fatalities and injuries in a given year by multiplying per-accident impacts by the change in probability of accident.
	7. Calculate life safety impacts over time by summing impacts in each year of the building analysis period.

CALCULATING THE VALUE OF LOST SPACE

This section describes a method for calculating costs of lost space if a code change leads to reduced construction.

Usually a single code change has little effect on building space, so that the loss of building space can be neglected in calculating costs of code changes. However, if there is a large effect on building space, as in the present example, the loss of space may be a significant cost of the code change and should be computed. If it is not possible to compute this cost quantitatively, it should at least be described so that decisionmakers will consider it when they approve code revisions.

Demand curve for building space

The demand curve (DD') for building space in figure 5.4 shows the amounts people are willing to pay for varying amounts of space of a given quality and location in a hypothetical jurisdiction. The height of the curve at a certain point on the x-axis shows how much the "marginal" renter is willing to pay per square foot.[1]

For example, if 9,000,000 square feet are available, the marginal renters are willing to pay up to $14 per square foot. If only 5,000 square feet are available, the marginal renters would be willing to pay up to $20 per square foot. (Naturally, they will try to rent space for less, but will pay $20 if necessary.)

The rent they would be willing to pay is a measure of the value of the space to them.

Before the code change

Suppose that before a code change, 10,000,000 square feet of space are available. To rent all this space, landlords must charge no more than $10 per square foot; otherwise some space will remain vacant. This means a renter who would be willing to pay as much as $14 per square foot need only pay $10. This renter gets a "consumer surplus" of $4 per square foot. Renters willing to pay other maximum amounts get surpluses of different sizes.

The total consumer surplus is equal to the area of the triangle DCG under the demand curve.

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[1] It is convenient to treat all space as rented, but the same principles apply to purchased space.

After the code change

Now, suppose a code change reduces the amount of space available so that the price goes up to \$14 per square foot. Some renters--those willing to pay less than \$14 per square foot--are priced out of the market and there is a loss of consumer surplus equal to the striped triangle, EFC.[1] This is a net loss to society.

In the example in figure 5.4, the demand curve is a straight line, so that the lost benefits to the community are one-half of EF x FC, or $1/2\ (\$14/ft^2 - \$10/ft^2) \times (10M\ ft^2 - 9M\ ft^2) = \$2,000,000/year$.

We did not provide a worksheet for making this type of calculation and, unlike other effects discussed in this report, it is not calculated on a per unit basis. It should be added to aggregate impacts with appropriate discounting. (See chapter 8.)

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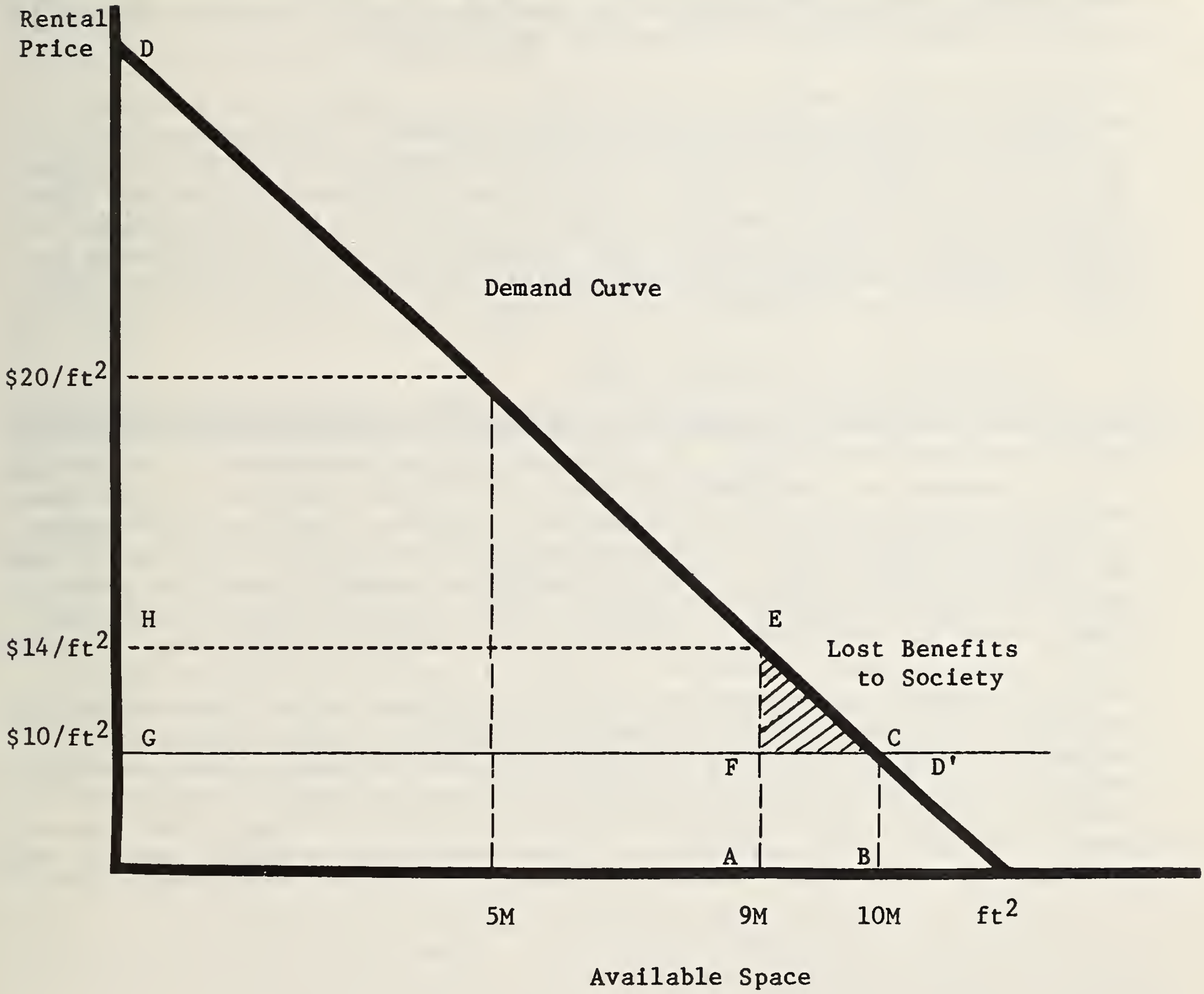
[1] There is also a loss of consumer surplus equal to the rectangle EFGH. However, this share of the renters' loss is the building owners' gain, rather then being a net loss to the community. It is true that some of this payment may compensate for higher costs to the building owner due to the code change; but these higher costs are included elsewhere in the analysis and need not be counted here.

Figure 5.4 EFFECTS OF CODE CHANGE ON CONSUMER SURPLUS



6. ECONOMIC VALUE OF LIFE SAFETY

This chapter concerns the dollar value of life safety. There is no generally accepted approach for imputing a dollar value to death and injury. Therefore, this chapter discusses factors to be considered, but it does not attempt to provide a definitive way to value life safety impacts.[1]

Assigning a dollar value to the prevention of a death or injury raises philosophical, theoretical, and practical problems. It may require an exercise of judgment which the analyst is not prepared to make. Even so, it is still useful for the analyst to collect and present information about the economic aspects of death and injury in order to aid decisionmakers in imputing values to life safety. The discussion in this chapter should be helpful whether the analyst assigns dollar values to life safety or leaves this burden to those who make code decisions.

6.1 CONTROVERSIES OVER VALUING SAFETY

The notion of putting a dollar value on safety is controversial, especially where lives are in question. At the heart of the controversy is the feeling that it cheapens or dehumanizes life to put a dollar value on it. In examining this issue, however, it is important to remember that the dollar value is not assigned as a measure of human worth; it is assigned in order to make the unavoidable decision: How much should the community spend (or require building owners and others to spend) to reduce building risks? Assigning a higher value for purposes of evaluating code change decisions does not necessarily make life more sacrosanct. Rather, it may mean that code changes will be passed which provide greater protection against building hazards at the expense of other aspects of safety or quality of life. For example, assigning a high dollar value to life safety in making decisions concerning hospital fire protection might mean that a large portion of health care spending would go into hospital construction to meet stringent code requirements and would not be available for other needs such as better nursing care.

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[1] One of the best works on this subject is a book by M. W. Jones-Lee, The Value of Life: An Economic Analysis, (Chicago: University of Chicago Press, 1976). See also: Anderson, Lee G. and Settle, Russel F., Benefit-Cost Analsis: A Practical Guide (Lexington, MA.: Lexington Books, 1978); Walters, Jeffrey, L. Economic Benefit-Cost and Risk Analysis of Results of Mobile Home Safety Research: Wind Safety Analysis (Washington, D.C.: U.S. Department of Housing and Urban Development, 1979); Cornell, M. et al, Survey of Methods for Estimating the Cost of a Human Life (prepared for the U.S. Coast Guard, 1976); Faigin, B. M., 1975 Societal Costs of Motor Vehicle Accidents (Washington, D.C.: U.S. Department of Transportation, 1976); and Technology + Economics, Inc., The Consumer Product Safety Commission Injury Cost Model: Complete Documentation, 1980.

Statistical life

Another objection to assigning a dollar value to life safety rests on the idea that, to the person involved, life has value limited only by how much that person could pay to preserve it. This objection can be met by introducing the concept of a "statistical life."

In considering a code change, the decisionmaker is not contemplating the certainty of death to a few identifiable individuals, but rather a small change in risk to a large number of people. The lives saved as a result of a code requirement are "statistical lives," since those who otherwise would have been victims could not have been identified in advance. The distinction between certain death versus a risk of death means that the relevant question is not "How much should be spent to prevent certain death?" but rather, "How much should be spent to reduce risk?" This concept is illustrated in example 6.1.

Example 6.1: FINDING THE VALUE OF A STATISTICAL LIFE

Problem: In a community of 1,000, each individual is willing to pay up to $400 to prevent a .002 risk of death due to fire. What is the value implicitly put on a "statistical life" by this community, when contemplating a fire protection code change which would reduce the probability of death by .002 for each citizen?

Solution: If the risk of death is reduced by .002, this will save .002 x 1,000 = 2 statistical lives. The community is willing to pay $400 x 1,000 = $400,000 to save these two lives, or $200,000 per life. Thus $200,000 is the value that the community implicitly puts on a statistical life.

People routinely make decisions concerning how much to spend to reduce individual risk by a small amount. For example, homeowners must decide how much to spend on smoke detectors. Cities and counties must determine how much to spend on fire protection, knowing that failure to increase the fire protection budget increases risk slightly to many individuals and may result in additional lives lost. Thus, the need to assign a value to saving a statistical life is not an unusual one.

6.2 VALUES USED PREVIOUSLY

One method of determining what value to assign to a statistical life is to use values that have been assigned in previous analyses of government safety and health regulation, or values which are implied in public policy decisions. However, using such numbers may have serious drawbacks.

First, some past studies have estimated only monetary costs of accidents, neglecting the intrinsic value of life and health. For example, a study for the National Highway Traffic Safety Administration covers only the monetary impacts of accidents.[1] Second, even the monetary estimates may be based on a methodology which is unacceptable to those who make code change decisions. Third, even if the monetary values were properly computed, they may have been estimated for populations and types of accidents significantly different from those affected by building codes. For example, a study on the economic costs of accidents for the Coast Guard may be relevant only to the boating population and boating accidents, but not to building accidents.[2]

The values estimated in previous studies may have other problems as well, such as inadequate data to support them. Moreover, the values implied in public policy decisions may reflect tradition or political considerations rather than the ideal balance between cost and safety. Thus, using the values for life safety previously estimated for policy purposes or implied in policy decisions may be politically convenient, but it may perpetuate use of inappropriate numbers. Agencies interviewed in one study suggested that the specific number used to value life safety is not important so long as a consistent figure is used for various policy decisions.[3] This may be true from a political point of view, but it does not necessarily promote efficiency or fairness: it may be better to be occasionally right than consistently wrong.

6.3 ESTIMATING COST COMPONENTS

There are three types of losses due to death or injury which should be considered in assigning values to life safety: (1) direct monetary costs such as medical bills; (2) indirect monetary costs because the victim no longer works; and (3) non-monetary costs due to pain and suffering and loss of the intrinsic value of life. These losses will be discussed in the following sections. However, before beginning that discussion, there are several points to keep in mind.

First, it may be feasible to calculate monetary costs of accidents, but not nonmonetary costs such as pain and suffering. Even though the monetary costs represent only a fraction of overall costs of death and injury, they are still worth estimating because they set a lower boundary on what should be spent to protect life safety.

Second, costs of death and injury accrue not only to the victim, but also to the victim's family and friends, insurance companies, government agencies, employers, and others. Costs to all of these groups should be considered.

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[1] Faigin, 1975 Societal Costs of Motor Vehicle Accidents.

[2] Cornell, Survey of Methods for Estimating the Cost of a Human Life.

[3] Ibid, pp. 3-2, 3-3.

Direct Costs of Death and Injury

Direct costs of accidents which should be considered include medical expenses such as hospital bills (including those paid by insurance companies); costs of medical supplies such as drugs, prosthetics, and wheelchairs; costs of home nursing care; and psychiatric counseling. The level of medical expenses depends both on the number of days of care and the type of care needed. For example, costs of treating burn victims are higher than costs of treating many other kinds of injuries. Some data on medical costs of burns are given in Stacey and Smith.[1]

Accidental death and injury also create a host of other direct costs, such as legal costs, funeral costs, and costs of administering health-related insurance. (The insurance claims payments are counted under medical expenses.)

Indirect monetary costs

Most economists would agree that the value of a potential victim's productive labor should be considered in assigning values to life safety. However, there is some disagreement as to how labor should be valued.

A death or injury deprives society of the victim's productive labor. It may impose additional costs of retraining new employees. Even the portion of earnings that was paid in taxes is a loss to society, since the government foregoes tax revenues.

Foregone earnings are the before-tax amounts that would have been earned -- over the lifetime in case of death, or over the period of recovery from an injury -- discounted to their present value. A value is imputed to unpaid productive labor such as housework and volunteer work. It may also include income foregone by family members who have to stay home to care for a sick person.

If an accident results in injury, the gross amount of foregone earnings are a good measure of indirect monetary costs. However, when an accident results in a fatality, economists disagree on whether to measure indirect monetary costs by: (1) gross value of earnings; (2) net earnings, after subtracting out the value of consumption; or (3) some other measure related to earnings. The approach taken may vary depending on who is to pay for a code change and the level of risk involved.

The value of life from society's point of view is the value to the victim plus the value to others. The author believes that where fatalities are involved, earnings net of consumption are relevant when considering the value of a life to those other than the potential victim, since earnings net of consumption deter-

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[1] Stacey, Gary S. and Smith, Kathy S., "Methodology for Estimating Costs of Injuries and Property Losses," Fire Technology, August 1979, pp. 195-209.

[2] Technology + Economics, Injury Cost Model.

mine the individual's net monetary contribution to others. From the victim's point of view, foregone earnings are not a direct measure of monetary costs.[1] However, earnings are one of several factors affecting wealth and borrowing ability which, in turn, affect willingness and ability to pay to preserve life, discussed in the next section. Readers who wish to pursue this difficult but intriguing subject should see the works cited in the footnote.[2]

Pain and suffering, and the intrinsic value of life

The prevention of injury and death has an intrinsic value apart from the gain of an individual's productive labor or the savings in medical costs. Most people would probably agree that pain and suffering and the loss of the intrinsic value of life should be counted in assigning values to life safety. However, because of the great difficulty in measuring these effects, they are sometimes omitted from estimates of the value of life safety.

It is difficult to set values on freedom from pain and suffering and preservation of life for its own sake. These benefits do not have established market values. One approach might be to value these aspects of life safety at what a person is willing to pay to avoid risk over and above the purely monetary costs of accidents. However, it is difficult to distinguish between what a person would pay to avoid non-monetary consequences and what he or she would pay to avoid monetary consequences. Therefore, the willingness-to-pay approach is best used to estimate overall costs to the victim rather than only non-monetary costs.

Another approach which has been used to estimate costs of these intangibles is jury awards for injury and death in negligence cases. Data concerning jury awards, together with a discussion of the drawbacks of this measure of the cost of pain and suffering, are presented in the Consumer Product Safety Commission Injury Cost Model.[3]

6.4 ESTIMATING WILLINGNESS TO PAY

In the "willingness to pay" approach, the value of reducing risk is based on what people would be willing to pay to reduce risks. It may be an alternative to the approach described earlier of simply adding up costs of accidents, or it may be a tool for inferring values of cost items which are difficult to quantify, such as pain and suffering.

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[1] If someone loses their life, the marginal utility of money becomes zero and the added cost from loss of income is zero, i.e., you can't take it with you.

[2] Jones-Lee, The Value of Life, p.46; Walters, Wind Safety Analysis, p. 48; Dardis, Rachel and Thompson, Ruth, "Strategies for Reducing Residential, Fire Losses," Journal of Consumer Product Flammability, June 1979, pp. 136-151; Faigin, 1975 Societal Costs of Motor Vehicle Accidents, p. 3; and Technology + Economics, Injury Cost Model, p. 3-55 through 3-86.

[3] Technology + Economics, Injury Cost Model, pp. 3-39 through 3-51.

Policy-makers must decide whether to assign values to life safety which reflect what people are willing to pay for safety, or whether to assign values which reflect what people "ought to" pay in light of costs of accidents such as those discussed above.

The willingness to pay approach, as described here, focuses on what people would pay to avoid a small increase in risk, not what they would pay to avoid a certainty of death or injury. This is because code changes normally cause small changes in risk to individuals, and the amount someone would spend on safety is not necessarily proportional to the risk.

For example, if someone would pay $500,000 to prevent certain death, we might expect them to be willing to pay 1/10,000 x $500,000 or $50 to avoid a one-in-a-ten-thousand risk of death. But people do not necessarily behave this way. People who believe "it can't happen to me" may be willing to pay less to avoid an accident than the expected cost savings. People who believe "it very well could happen to me" may be willing to pay more. Thus, a risk-taking person might be willing to pay only $10 to avoid a one-in-ten-thousand risk of death, even if they would pay $500,000 to prevent certain death.

One method of determining what a person would spend to reduce risk is to look at market behavior, e.g., the wage premium received by people in hazardous occupations,[1,2] how much more people pay for safer products, or how much they pay for safety features.[3] This approach is objective, but it has drawbacks: (1) people may be ignorant of the true risks; (2) people who work in hazardous jobs may put a relatively low value on safety compared to the average person; those who pay extra for safety features may put a relatively high value on safety; and (3) it may be difficult to determine to what extent a wage or price difference is due to difference in safety as opposed to other factors.

Another approach is to survey people to find out what they would pay to avoid risk. This method has the disadvantage that people may not know what they would pay (or may not be willing to reveal it).

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[1] Melinek, Stanley J., "A Method of Evaluating Human Life for Economic Purposes," Accident Analysis and Prevention, October 1974, pp. 103-114.

[2] Thaler, R. and Rosen, S., "The Value of Saving a Life: Evidence from the Labor Market," in Nestor E. Terleckyj, ed., Household Production and Consumption (New York: Columbia University Press, 1976), pp. 265-297.

[3] Dardis, Rachel, "The Value of Life: New Evidence from the Market Place," American Economic Review, December 1980, pp. 1077-1082.

Whether to use consistent values for life

Some methods of valuing lives result in higher values for some groups of people than for others. For example, approaches which emphasize lifetime earnings as a measure place a higher value on lives of males over females, of adults in their working years over the elderly, and of the rich over the poor.[1] Using such figures in making building code decisions can create a bias toward providing greater protection to some groups, such as adult males.

If this bias is considered undesirable, the differences may be reduced by altering the estimating approach or by assigning a value to life safety that represents an average of various populations, regardless of sex, age, or wealth.

In some cases, however, using different values for life safety may be desirable. Where occupants of a building bear the costs of providing greater protection, using the same dollar value regardless of who is affected may result in code requirements that are excessively high for lower-income people and insufficient for upper-income people. For example, elderly people living on fixed incomes might be forced to spend high amounts for fire protection in situations where they would be better off spending more on other items.

Some people may feel that deaths and injuries due to hazards that the building occupant is not likely to perceive, or which affect children or people who cannot easily avoid exposure to the risk, are not the same as those affecting adults who knowingly and voluntarily take risks. The reasoning may be that more should be spent to protect life safety in some situations than in others. This point can be accommodated by assigning a higher value to life safety in certain situations, e.g., if the hazard in question is not voluntarily and knowingly risked by responsible adults.

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[1] See, for example, Walters, Wind Safety Analysis, p. 51.

7. THE BENEFIT-COST RELATIONSHIP

This chapter discusses ways of comparing benefits and costs and shows how to calculate Net Monetary Benefits for the hypothetical Fire Safety Feature.

Two methods for comparing benefits and costs are: (1) net benefits (benefits minus costs), and (2) the benefit/cost or savings-to-investment ratio (SIR). There are also variations of these methods which can be used when some of the code change impacts are not quantified in economic terms.

This report emphasizes using the net benefits measure because it is the most useful in comparing alternative versions of a code requirement. Other methods will also be discussed here because some of these may be useful under certain circumstances.[1]

Before describing how to compute these measures, two adjustments are needed. These are explained in the next section.

Net monetary benefits are the portion of net benefits which can be quantified in monetary terms. A method for calculating net monetary benefits is explained below and illustrated for the hypothetical Fire Safety Feature introduced earlier.

7.1 ADJUSTMENTS

In previous worksheets 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 3 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

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[1]The various methods are discussed in Grant, Eugene L. and Ireson, W. Grant, Principles of Engineering Economy, 5th edition (New York: Ronald Press, 1970); Smith, Gerald W., Engineering Economy: Analysis of Capital Expenditures, 2nd edition (Ames, Iowa: The Iowa State University Press, 1973); and 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.: Government Printing Office, 1979). Additional methods of comparing benefits and costs, such as the discounted payback and internal rate of return methods, are discussed in these works.

Another calculation 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 4.2, 4.3, and 4.4 to worksheet 7.1. 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 7.1 for the hypothetical code change. Adjusted O&M costs are $201.07.

Discount to present value

At this point, all monetary impacts have been discounted to the future construction year. For example, in the illustration, impacts occurring after 1985 were discounted to 1985. Now it is necessary to further discount to find the present values.

To do this, first, enter the values of changes in building performance on worksheet 7.2 (see page 67). Where building performance improves, use a positive number. Otherwise, use a negative number. These values are taken from worksheets 5.3, 5.4, and other worksheets you may have devised to estimate changes in performance.

Second, enter the changes in building costs and property losses on worksheet 7.2. Use positive numbers for cost or loss increases and negative numbers for cost or loss reductions. The cost changes are taken from worksheets 4.1, 4.5, and 7.1. Property loss changes are from worksheet 5.1.

Third, select a Single Present Worth factor from table A.2 in appendix A for the assumed discount rate and the number of years before the building is constructed, and enter it on worksheet 7.2.

Fourth, multiply the SPW factor by the values discounted to the construction year to find the present value of each impact.

7.2 NET BENEFITS

The net benefits method involves summing the benefits and costs of a proposed code change, where impacts are measured relative to effects of the current provision and discounted to the present value.[1] An expression for net benefits (benefits minus costs) is:

$$NB = \Delta Q - \Delta C - \Delta G, \tag{7.1}$$

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[1] Net benefits and the other measures described in this chapter can be calculated per unit (e.g., per building) or on an aggregate basis. Aggregating is also discussed in chapter 8.

Worksheet 7.1 *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 4.2)	Change in O&M Costs (Worksheet 4.4)	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 4.3				+	$ *92.98*
TOTAL O&M COSTS ADJUSTED FOR DIFFERENTIAL COST CHANGES, DISCOUNTED TO CONSTRUCTION YEAR					$ *201.07*

[a]Based on construction date in worksheet 2.2.

[b]The cost change factor, $(1 + e)^t$, adjusts for the rate of differential cost change, e, listed above and in worksheet 4.2; "t" is the number of years before the building is constructed.

Calculations for first line in the table: $(1 + e)^t = (1 + .01)^5 = 1.051$.

Calculations for second line in the table: $(1 + e)^t = (1 - .05)^5 = .774$.

where:

NB = net benefits of the code change,

ΔQ = the dollar value of the change in building quality (safety and performance) due to the code change,

ΔC = the change in building costs due to the code change, and

ΔG = the change in government costs due to the code change.

All amounts are discounted to present value and may be either per unit or aggregate, depending on whether net benefits were calculated per unit or in the aggregate.

Worksheet 7.2 illustrates a method of comparing benefits and costs. After carrying out the calculations described in section 7.1, sum the first group of values in the worksheet to find the total effect on building performance, and sum the second group to find the total effect on building cost plus property loss.

Next, 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 7.2 shows only <u>monetary</u> effects; there are also life safety impacts not shown in worksheet 7.2. Therefore, we cannot determine just by looking at worksheet 7.2 whether the code change would be cost effective for Representative Case I.

The Net Monetary Benefits on worksheet 7.2 are given only for a single unit, such as a dwelling unit or building, and they refer only to one representative case. Worksheet 7.2 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.

<u>How to use the net benefits measure</u>

Net benefits is a very useful measure of the impact of alternative versions of a code requirement.[1] If there are two competing proposed code changes, and if both proposals have benefits which exceed their costs, the best code provision would be the one with the greatest net benefits. (This assumes that there is no ceiling on any cost element, such as construction costs.)

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[1] Net benefits may be calculated on a per unit basis, as in the example here. Alternatively, they may be calculated on an aggregate basis, either by summing individual net benefits (as is shown in chapter 8) or by summing individual costs and benefits by type from worksheet 7.2, and then computing aggregate net benefits.

Worksheet 7.2 *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
5.3	Building Space	$ *-127.08*	X	*.6209*	=	$ *-78.90*
5.4	Residual Value	$ *1.85*	X	*.6209*	=	$ *1.15*
	(Other Impact)	$	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
4.1	Initial Costs	$ *100.00*	X	*.6209*	=	$ *62.09*
4.5	Government Costs	$ *10.00*	X	*.6209*	=	$ *6.21*
7.1	O&M Costs	$ *201.07*	X	*.6209*	=	$ *124.84*
5.1	Property Loss	$ *- 99.85*	X	*.6209*	=	$ *-62.00*
	(Other cost or loss)[c]	$	X		=	$
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. Use a positive number for increases in value, cost, or loss. Use a negative number for decreases.

[b] From table A.2, appendix A, for assumed discount rate and number of years before building is constructed.

[c] If life safety impacts are quantified in dollars, they should be included here.

For example, the net benefits approach could be used to determine what R-value should be required for insulation. Two methods for doing this are explained below for a code requirement affecting insulation. The methods are illustrated in figures 7.2 and 7.3 in the appendix to this chapter.

Method 1: One method is to calculate the net energy savings and net costs (compared with the current code requirement) of a number of alternative levels of insulation in order to find the insulation level with the greatest net benefits. In the example in table 7.1, the increase to R-30 insulation provides the greatest net benefits.

Method 2: A second method is to calculate only the added benefits and the added costs of each increase in insulation. For example, starting with R-0, calculate the marginal benefits of having one more increment of insulation, calculate the marginal cost of this increase, and compare the two. In the example in table 7.1, moving from R-11 to R-19 increases the cost by $80. The added savings, $184, exceeds added costs by a considerable amount. Moving to R-30 increases the cost by an additional $110, which is only slightly less than the added savings of $119.

If the marginal benefit is greater than the marginal cost, the added insulation is cost-effective. Repeating these calculations for further increases in insulation, one can find the point at which the marginal benefits of another increment of insulation no longer exceed the marginal cost. This is the ideal level for the code requirement.[1] Beyond this point, added costs are greater than added benefits. In the example, this point occurs at close to R-30 insulation.

Possible disadvantages of the net benefits approach

The main disadvantages of using the net benefits approach exclusively are that it requires effects to be quantifiable in dollar terms and a simple net benefit figure may not provide decisionmakers with enough information. Some effects, such as those related to life safety, are very difficult to quantify in dollar terms, and, in any case, people making code changes are likely to want more information about impacts than is given by a simple dollar figure. Therefore, it is often useful to make up a table which gives both the net benefits figure and individual benefits and costs.

In addition, the net benefits approach may not always be the simplest way to find the most cost-effective code change. This is true when people involved in the code change process have in mind a "regulatory budget" -- the maximum

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[1] While this statement is true for insulation, in other cases there may be some exceptions to this general statement. One difficulty might be that the indicated "optimal" level is better than any other levels close to the apparent optimum, but that there is some other level which is very different from, and better than, the apparent optimum. In other words, the marginal analysis might select a "local" optimum and overlook the "global" optimum. Also, if the marginal benefits curve crosses the marginal cost curve from below, the marginal benefits will equal marginal costs at the least optimal level.

Table 7.1

HYPOTHETICAL IMPACTS OF INCREASED ATTIC INSULATION[a]

Method 1: Greatest Net Benefits

Incremental Increase	Cost	Savings	Net Savings (Savings - Cost)
From R-0 to R-11	$180	$1,051	$871
From R-11 to R-19	260	1,235	975
From R-19 to R-30	370	1,354	984 (greatest net benefits)
From R-30 to R-38	450	1,401	951

Method 2: Marginal Benefit = Marginal Cost

	Change in Cost	Change in Savings
From R-0 to R-11	$180	$1,051
From R-11 to R-19	80	184
From R-19 to R-30	110	119 (marginal benefit closest to marginal cost)
From R-30 to R-38	80	47

[a] Numbers are based on a hypothetical example used in Department of Energy/National Bureau of Standards Federal LCC Workshop for Energy Conservation and Solar Energy in Federal Facilities, 1979, p. 95. (workshop notebook, unpublished).

added construction cost they are willing to impose through code changes made in a particular year. For example, the aim might be to keep construction costs from rising more than a certain amount because of energy conservation cost changes, regardless of the eventual benefits of the code change. This requires a way to choose the most beneficial combination of code changes which still stays within the "budget." It may take a good deal of calculation to solve this problem through the net benefits approach, as is illustrated in example 7.1. Often, it is simpler to solve the problem by calculating benefit/cost ratios, described in the next section.

7.3 BENEFIT/COST OR SAVINGS-TO-INVESTMENT (SIR) RATIO

Another way of relating benefits and costs is the benefit/cost or savings-to-investment (SIR) ratio (benefits divided by costs). This ratio is useful if one cost item is subject to a constraint. For example, it is useful if there is a ceiling on construction costs. Here we assume that there is a constraint on construction costs, I. Therefore the benefit/cost ratio used here has only construction costs in the denominator; all other effects are in the numerator, i.e.:[1]

$$B/C = \frac{\Delta Q - \Delta O\&M - \Delta G}{\Delta I}, \qquad (7.2)$$

where:

- B/C = Benefit/cost ratio,
- ΔQ = Change in the dollar value of building quality due to the code change,
- $\Delta O\&M$ = Change in operation and maintenance costs due to the code change,
- ΔG = Change in government costs due to the code change, and
- ΔI = Increase in initial costs due to the code change.

All amounts are discounted to present value.[2]

How to use the benefit/cost ratio

The benefit/cost ratio shows whether benefits exceed costs. This ratio may be useful in ranking code changes in order to select the set of code changes which will provide the greatest protection for a given increase in a constrained item.

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[1] In general, the cost item(s) subject to a constraint goes into the denominator; other costs and benefits go into the numerator.

[2] The benefit/cost ratio can be computed per unit or on an aggregate basis. To compute the aggregate ratio, first calculate the aggregate amount of the constrained cost item (from worksheet 7.2); this is the "C" of the "B/C" ratio. Then calculate the aggregate amounts of all other impacts; these are the "B" of the ratio.

Example 7.1: SELECTING THE BEST "PACKAGE" OF CODE CHANGES: NET BENEFITS APPROACH (HYPOTHETICAL EXAMPLE)

Problem: Five code changes have been proposed. Each of the five is cost-effective. However, collectively they would raise construction costs by $320 per house. The present values of their costs, gross benefits, and net benefits are shown in the table below. Those making the code change decision do not want construction costs to increase by more than $100. Which combination of code changes would give the greatest net benefits while not exceeding the $100 ceiling on construction costs increases?

Code Change	Gross Benefits	Added Construction Cost	Net Benefits
A	$180	$ 30	$150
B	100	20	80
C	200	50	150
D	60	20	40
E	400	200	200

Solution: Code change "E" is immediately eliminated from consideration because its construction cost increase of $200 exceeds the $100 ceiling. (This is true even though "E" would have the greatest net benefits of any of the proposals.) Various combinations of the remaining proposals, A, B, C, and D, are evaluated for their impact on present value construction costs and net benefits, as shown below.

Alternative Packages of Code Changes	Construction Cost	Net Benefits
A	$ 30	$150
A+B	50	230
A+B+C	100	380
A+B+C+D	120	420
B	$ 20	80
B+C	70	230
B+C+D	90	270
C	50	150
C+D	70	190
D	20	40

The table shows that the combination with the greatest net benefits is A + B + C + D. However, this combination would raise construction costs by $120, which exceeds the $100 ceiling. Therefore, this is rejected in favor of the next most beneficial combination, A + B + C, which only raises construction costs by $100.

As noted earlier in this chapter, those involved in the decisionmaking process might sometimes decide to set a ceiling on how much construction costs might be increased as a result of a set of code changes. In these situations, the self-imposed "budget" keeps them from making all the code changes which might have net benefits. Instead, they must select the package of code changes that delivers the greatest net benefits for a specified maximum increase in construction costs. (This is analogous to the situation of an investor who has a limited budget to invest to make the greatest profits.)

The method of selecting this package is illustrated in example 7.3 on the facing page. It is the same problem as example 7.1 and results in the same solution, but it involves less computation.

The package is selected by first calculating benefit/cost ratios for the various possible code changes. To maximize the net benefits subject to a constraint on construction costs, the change in construction costs (the cost which is limited by the budget constraint) is included in the denominator and all the other costs and benefits are included in the numerator.

Next, code changes are selected in order of their benefit/cost ratios. The code change with the highest ratio would be selected first, then the change with the next highest ratio, and so on, until the "budget" is used up. This gives the package of code changes which provides the greatest net benefits within the "budget" restriction.

A modified approach may be needed if approval of one code provision affects the benefits and costs of other proposals.[1]

Example 7.2: NET BENEFITS VS. BENEFIT/COST RATIO

Problem: There is no "ceiling" on allowable construction costs, and two mutually exclusive alternative code changes have the following costs and benefits. Which code change is more desirable?

	Code Change A	Code Change B
Benefits	$1,000	$10
Costs	$ 200	$ 1
Benefit/cost ratios	5:1	10:1

Solution: The benefit/cost ratios are 5:1 for code change A and 10:1 for code change B. However, the net benefits for code change A are $800 compared with only $9 for code change B. Therefore, code change A yields the greatest net gain to society. While both are cost effective, if only one code change can be selected, code change A is more desirable.

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[1] McConnaughey, An Economic Analysis of Building Code Impacts, p. 16, describes a method of calculating the benefit/cost ratio in such cases.

Disadvantages of the benefit/cost approach

The benefit/cost ratio can be misleading. If only one code requirement can be approved from among several alternatives, it is tempting to think that the code requirement with the highest benefit/cost ratio is the best choice. This is not necessarily the case. A minor change might have smaller net benefits but a higher benefit/cost ratio than a more major code change. Generally, the best code provision is the one with the highest net benefits, regardless of whether it has a higher or lower benefit/cost ratio than some other version. Example 7.2 on the facing page illustrates this point.

Example 7.3: SELECTING THE BEST PACKAGE OF CODE CHANGES: BENEFIT/COST RATIO (HYPOTHETICAL EXAMPLE)

Problem: Each of five proposed code changes is cost-effective, but collectively they raise construction costs by $320 per house. Their impacts are shown below. Those making the code change decision do not want construction costs to increase by more than $100. Which combination of code changes would give the greatest net benefits while not exceeding the $100 ceiling on construction costs increases?

Code Change	Gross Benefits	Added Construction Cost	Net Benefits
A	$180	$ 30	$150
B	100	20	80
C	200	50	150
D	60	20	40
E	400	200	200

Solution: As is shown in the table below, the benefit/cost ratios are computed for each proposed code change and the proposals are ranked according to their B/C ratio. Then, the cumulative increase in construction costs is calculated as each proposal is added to the "package," starting with the highest ranked change, "A". After "C" is selected, the cumulative increase in construction costs would just equal the $100 ceiling. Thus, "D" and "E" are not included in the package. This is depicted graphically in Figure 7.4 in the appendix to this chapter. (Note that this gives exactly the same solution as computing net benefits, but requires less calculation.)

Code Change	Gross Benefits	Increase in Construction Costs	Cumulative Increase in Constr. Costs	B/C
A	$180	$ 30	$ 30	6
B	100	20	50	5
C	200	50	100	4
D	60	20	120	3
E	400	200	320	2

In addition, there is one situation in which the benefit/cost method may not work for choosing the best package of code changes within a limited "budget." This occurs when the "last" code change selected does not leave enough "budget" to include the code change with the next highest benefit/cost ratio. In such cases, a code change with a lower benefit/cost ratio might have to be added to the package instead of one or more of the code changes with higher benefit/cost ratios, so as to use up the remaining budget in a way that maximizes net benefits. Figure 7.1 illustrates this situation, which forces the analyst to use the net benefits approach to find the best package. In the example, the "budget" is assumed to be $70, so that code change "C" cannot be selected, since it exceeds the budget. Code change "D" must be selected instead.

Cost/Effectiveness Ratio

It may be useful to find the ratio of the dollar cost for a non-monetary benefit such as lives saved. Decisionmakers can use this ratio to decide whether it is worth spending the indicated amount to save a life, prevent an injury, or obtain some other non-monetary benefit.

However, this measure should be used with caution. If several mutually exclusive proposals are all cost-effective, this ratio would not necessarily indicate which proposal is best. For example, a code provision costing $100 for each life saved is not necessarily more desirable than an alternative requirement which costs $1,000 for each life saved. If the $1,000/life alternative saves 10 lives (at a total cost of $10,000) and the $100/life alternative saves only one life, the higher priced alternative would be the more desirable code change, unless a budget constraint prevents the $1000/life alternative from being chosen. (We assume that lives are valued at more than $1000 each.)

Figure 7.1 ILLUSTRATION OF POTENTIAL PROBLEMS IN USING BENEFIT/COST RATIO TO RANK CODE CHANGES

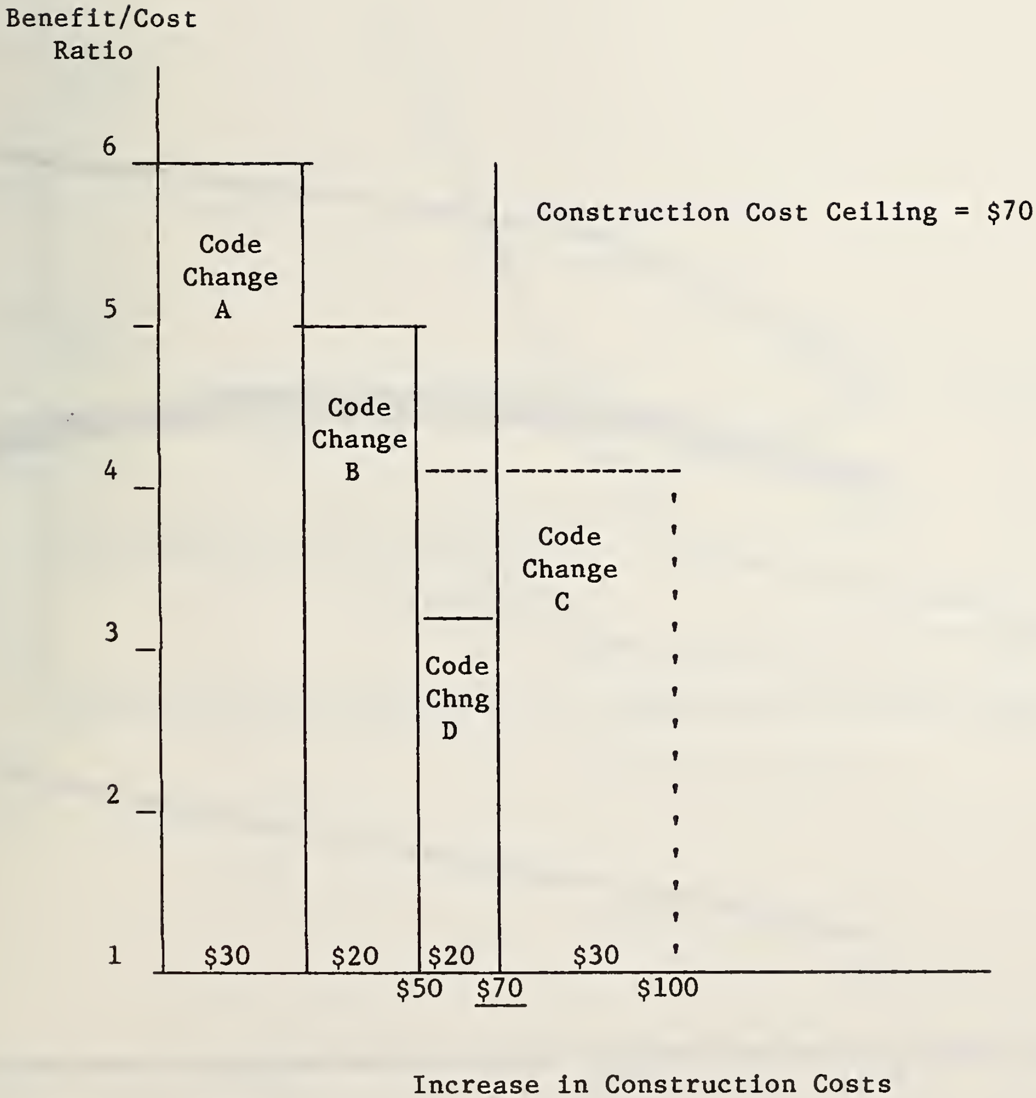
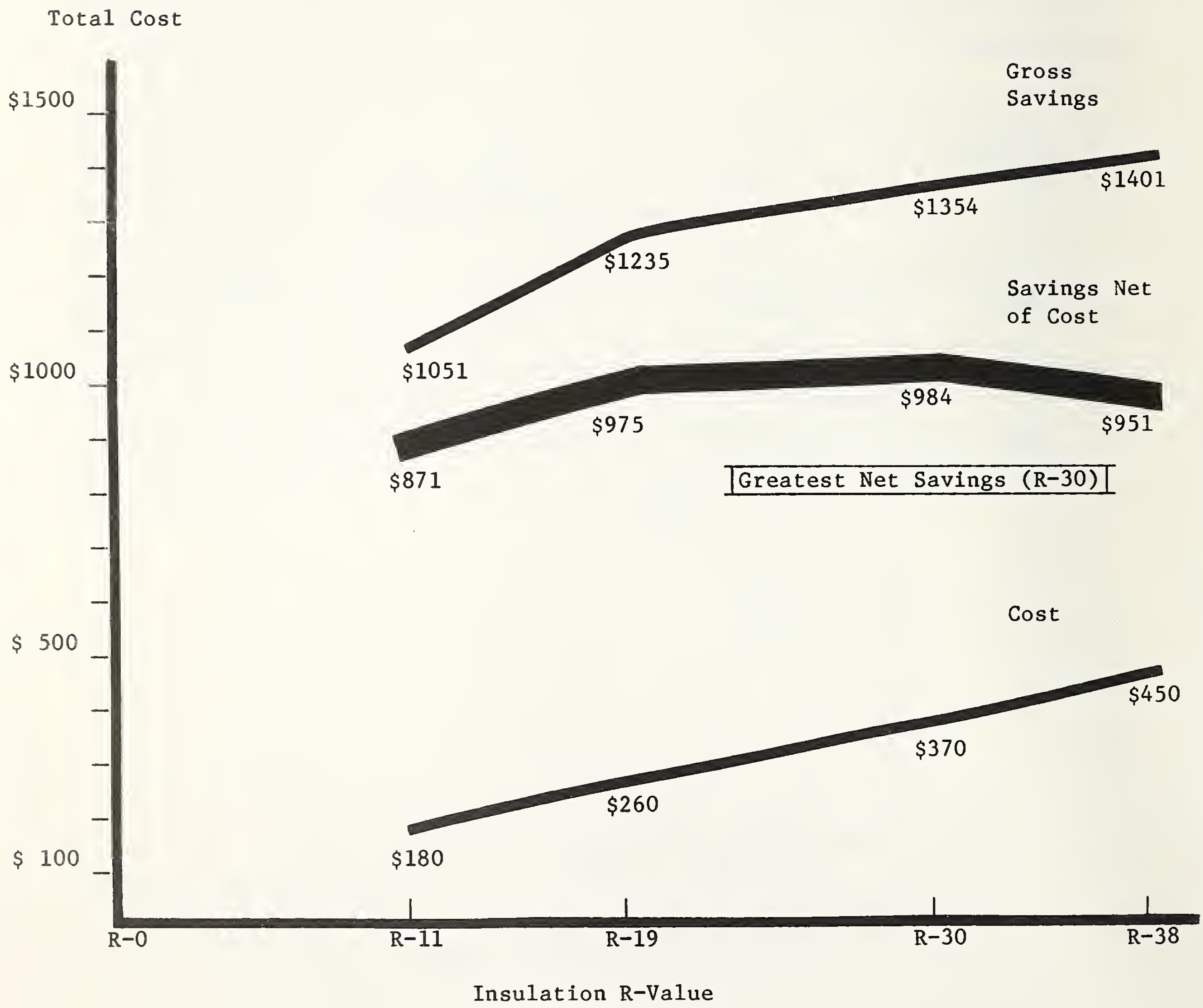
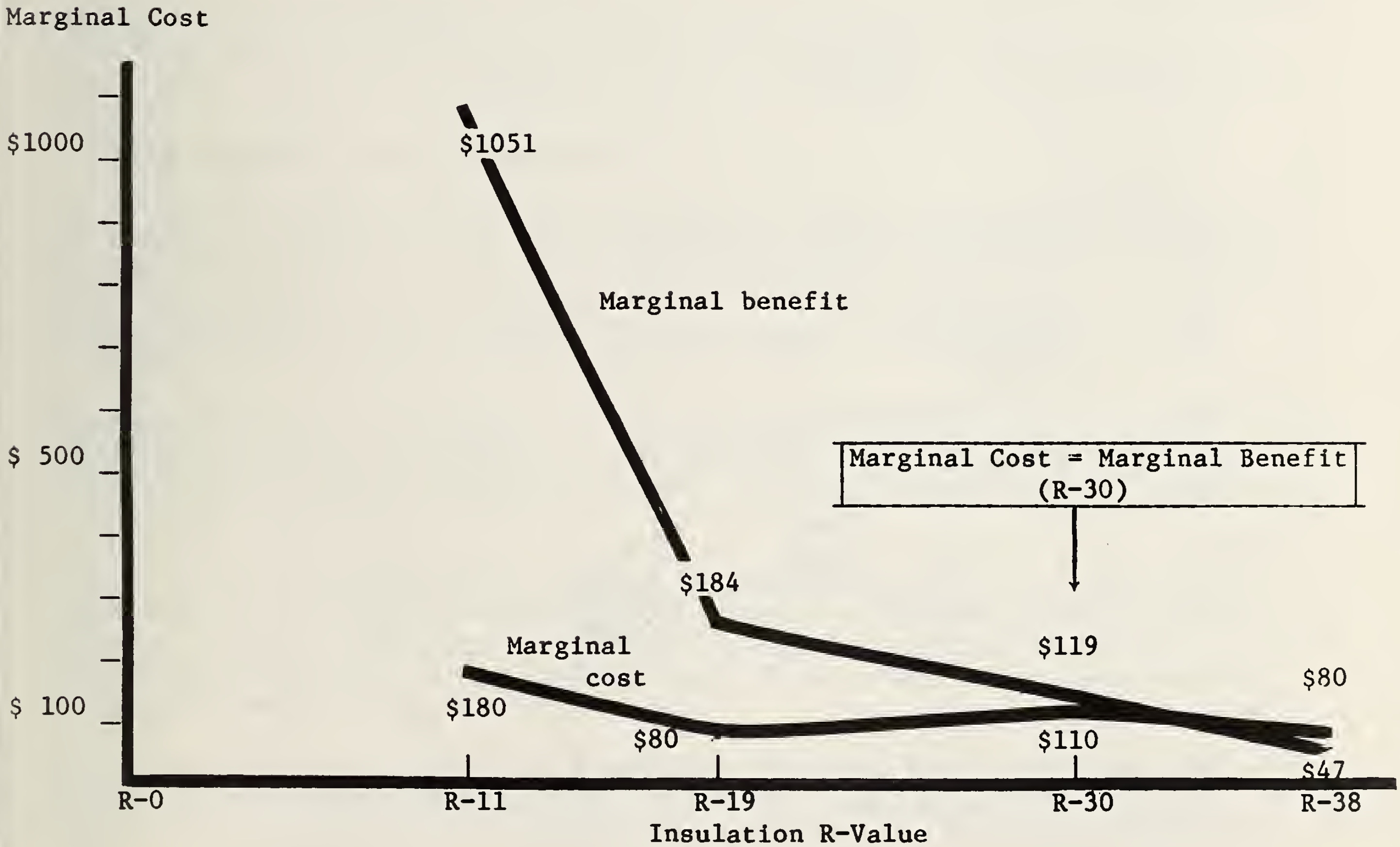


Figure 7.2 CHOOSING AMONG ALTERNATE LEVELS OF INSULATION
METHOD 1: GREATEST NET BENEFITS[a]



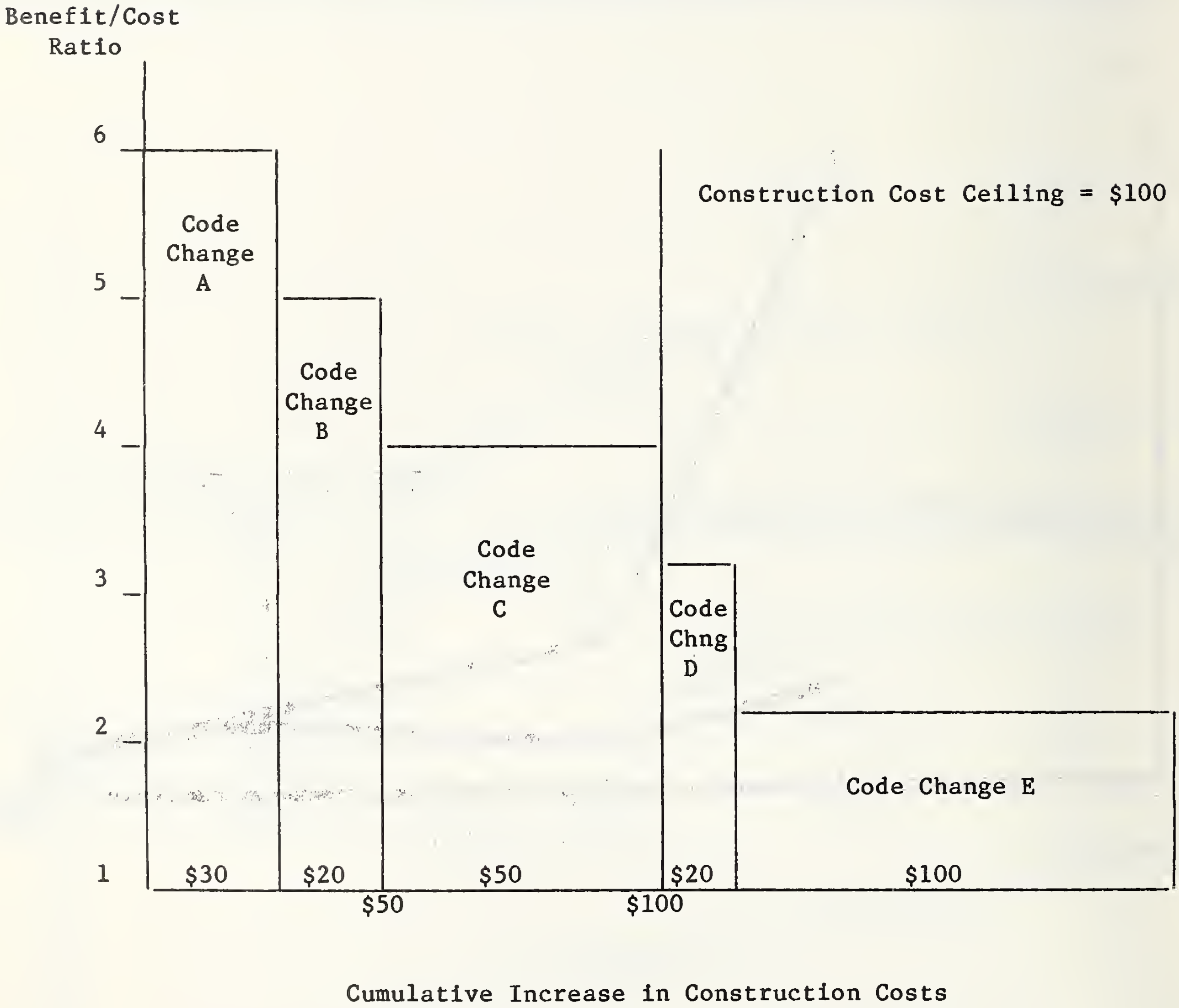
[a] See footnote "a" to table 7.1.

Figure 7.3 CHOOSING AMONG ALTERNATIVE LEVELS OF INSULATION
METHOD 2: MARGINAL BENEFITS = MARGINAL COSTS[a]



[a] See footnote "a" to table 7.1.

Figure 7.4 SELECTING THE BEST PACKAGE OF CODE CHANGES WITH "BUDGET" CONSTRAINT



8. CALCULATING AGGREGATE IMPACTS

So far, this report has focused on calculating the 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 aggregate the effects on many buildings into one number.

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."

Steps in the calculations

Worksheets 8.1a and 8.1b illustrate the procedure for calculating aggregate impacts of a code change for the hypothetical FSF example used earlier in this report. The figures on the number of affected dwelling units are taken from example 2.2 in chapter 2. The example and discussion assume that the analyst is following the net benefits approach described earlier. There are two steps.

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.[1]

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.[2]

Buildings should not be counted if they 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. An alternative is to assume that there is 100 percent use of the code-mandated feature in the jurisdictions adopting the code change. However, this assumption might introduce some error, since it overstates the impacts of the code change and does not allow for the softening effects of waivers, which may be granted if the code change is <u>not</u> cost effective and if safety and health can be protected through other measures.

For a model code change, the analyst will also need to determine which jurisdictions follow the code. This may involve reducing the estimate of the number of affected buildings to allow for lags in adopting the model or state code.[3]

Also, some jurisdictions may have adopted the requirement even without a model code change; if the aim is to determine impacts of changing the model code, buildings in these jurisdictions should not be counted in aggregating. Thus, the analyst should estimate how many jurisdictions will adopt the requirement as a result of the model code change. One approach is to use a table such as the following to describe the adoption of a code change over time:

---

[1] A simplified approach to estimating numbers of buildings is to assume that there is no long-term growth in construction over the code analysis period. For example, McConnaughy[1] assumed that annual new construction would equal the average of new construction over the past five years. This approach does not account for either long-term growth in the building stock or changes in the composition of new construction. However, it allows the analyst to use data from past years rather than having to seek out, or make, forecasts.) See McConnaughey, <u>An Economic Analysis of Building Code Impacts</u>, p. 36.

[2] Some information on delays is given in Field and Rivkin, the <u>Building Code Burden</u>.

[3] Cooke, Patrick W. and Eisenhard, Robert M., <u>A Preliminary Examination of Building Regulations Adopted by the States and Major Cities</u>, NBSIR 77-1390 (Washington, D.C.: National Bureau of Standards, 1977).

Worksheet 8.1a *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 5.2 (life safety) or 7.2 (monetary impacts).

* *Underlying calculations for Case I are shown in worksheets 4.1 through 7.2 in this guide. The underlying calculations for Cases II, III, and IV, using similar worksheets, are not shown due to limited space.*

Year	Jurisdictions Adopting Model Code Change (% of buildings)
1980 (year of code change)	0
1981	5%
1982	10%
1983	40%
1984	60%
1985	70%

In the example on worksheet 8.1a and 8.1b, the number of dwelling units for each case was determined from the information in example 2.2 in chapter 2 and entered onto the worksheets. 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 on worksheet 8.1a and 8.1b, and sum the products.[1]

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.

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[1] If there are some buildings which do not seem to fit in any category represented by a reference buiding, then the impacts will have to be separately estimated for these buildings. One approach would be to assume that impacts for the "other" category are a certain percent of impacts for a category containing a reference building. See for example Arthur D. Little, Inc., Energy Conservation in New Building Design: An Impact Assessment of ASHRAE Standard 90-75 (Washington, D.C.: Federal Energy Administration, 1976), p. 97. Such estimates are rough, since they are made without a benefit-cost analysis, but presumably they are better than completely ignoring impacts on "other" buildings.

Worksheet 8.1 *b* *hypothetical example*

AGGREGATE IMPACTS[a]

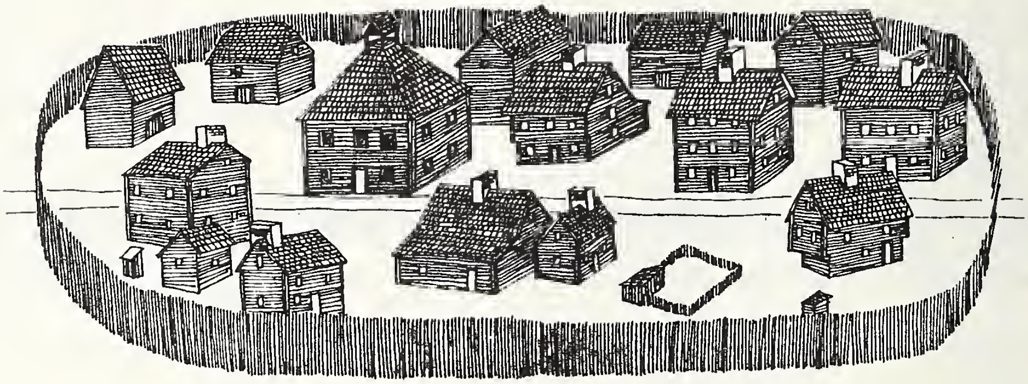
Type impact(s) *Lives Saved* Unit of analysis *Dwelling unit*

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 5.2 (life safety) or 7.2 (monetary impacts).



9. SENSITIVITY ANALYSIS AND PRESENTING RESULTS

The final steps in a benefit-cost analysis are to conduct a sensitivity analysis and to present the results in a format that will be useful to those who must make code change decisions.

9.1 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? Table 9.1 gives examples of parameters that may be altered as part of a sensitivity analysis.[1]

Table 9.1 EXAMPLES OF PARAMETERS THAT MAY BE ALTERED 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

[1] Another method for dealing with uncertainty is probability analysis. This involves estimating the probability that an event will occur (e.g., that a smoke detector will fail) and multiplying that probability by the impact if the event occurs. This gives an "expected value". However, estimating the probabilities is itself a difficult and uncertain task. See Ruegg, Rosalie T., Solar Heating and Cooling in Buildings: Methods of Economic Evaluation, NBSIR 75-712 (Washington, D.C.: National Bureau of Standards, 1975), p. 33.

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 the estimate.

Another reason for doing a sensitivity analysis is to aid decisionmakers who will use the results of the benefit-cost analysis. It shows whether disagreeing with assumptions or underlying data is sufficient reason to reject the results of an analysis. For example, suppose the basic analysis uses a discount rate of 10 percent, but a code official believes that 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 results of the analysis. If it does not, then both parties might still accept the general conclusions.

How to do a sensitivity analysis

This section describes how to do sensitivity analysis. The method is illustrated on worksheet 5.3 redone for the sensitivity analysis, and on worksheets 9.1 and 9.2, 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 9.1, along with the value used in the original analysis. 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 is 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, one 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, one may recompute Net Benefits for an "optimistic case" and "pessimistic case," varying a number of factors each time. In the example, several factors are varied at once.

Worksheet 9.1 *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 2.2.

[b]Values in the basic analysis are from worksheets 4.1 through 5.4, and 8.1.

[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.

3. <u>Determine values to use in the sensitivity analysis</u>. Select values which might occur under some plausible set of circumstances. Record these values on the top half of worksheet 9.2.

4. <u>Recompute worksheets 4.1 through 7.2</u>. It is necessary to repeat the calculations on most worksheets using the altered values. For the hypothetical example, it was necessary to recalculate most worksheets, but only the recalculation of worksheet 5.3 is shown in this guide.

5. <u>Record the results on worksheet 9.2</u>. 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 9.2 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 (i.e., net monetary costs increased) from -$209 to -$291. Life safety benefits also declined.

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

7. <u>Compute new aggregate values</u>. Worksheet 8.1 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.

Worksheet 9.2 *hypothetical example*

SENSITIVITY ANALYSIS[a]

Representative case *I*

Variable	Values in Basic Analysis	Values in 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 2.2.

[b]From worksheet 7.2 calculated using original and altered values.

[c]From worksheet 5.2 calculated using original and altered values.

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 A.3, appendix A, for assumed discount rate and building analysis period.

Breakeven Analysis

Breakeven analysis is a type of sensitivity analysis which can be used if all impacts are given in monetary terms. It does not require determining a possible range of values for key parameters. The breakeven value is the value a parameter must take for benefits to just equal costs (i.e., for net benefits to be zero). This type of analysis is illustrated in example 9.1

Example 9.1: BREAKEVEN ANALYSIS

Problem: An energy conservation code change would require double glazing on windows. Aggregate net benefits of the code change are related to the price of heating oil as follows:

Oil Price ($/gallon)	Net Benefits of Code Change
$.50	- $ 200,000
.75	- 100,000
1.00	0
1.25	+ 50,000
1.50	+ 75,000

What is the breakeven price of heating oil?

Solution: The breakeven price for heating oil is $1.00/gallon. At this price, the costs of double glazing are just offset by benefits from energy conservation. At any price greater than $1.00/gallon the code change would be cost-effective.

9.2 PRESENTING RESULTS

A single number representing net benefits usually would not give decisionmakers enough information about the economic impacts of a proposed code change. It may not be possible to represent the effects of a code change in a single number and some effects may not be quantifiable at all. Therefore, it is useful to present the results of the analysis in a table of benefits and costs which includes both numbers and verbal descriptions of code impacts.[1]

Such a table summarizes a variety of information in a simple format. It should highlight the most important effects of the code change -- even if these effects are not quantified. This will assure that important qualitative effects are not overlooked by those making code change decisions.

Worksheet 9.3 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 report.

A 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 was the building analysis period? The code analysis period? What other possible important or controversial assumptions were made?

Quantitative impacts. List quantitative information which may be useful, such as overall Net Monetary Benefits, initial construction cost impacts, and the number of fatalities and injuries prevented.

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

Uncertainty. State the areas of uncertainty in the results. To summarize these, present results of the sensitivity analysis and/or verbally qualify the results. For example, the table might state: "Safety effects are highly uncertain due to lack of good fire incidence data."

Concisely presented results of an economic analysis will assist decisionmakers in identifying the building code changes which will more efficiently achieve building safety, energy conservation, and other goals.

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[1] See for example, Hendrickson, Paul L.; McDonald, Craig L.; and Schilling, A. Henry, Review of Decision Methodologies for Evaluating Regulatory Actions Affecting Public Health and Safety (prepared by Battelle Pacific Northwest Laboratories, Richland, Washington, for the U.S. Nuclear Regulatory Commission, Washington, D.C., 1976), p. 53

Worksheet 9.3 *hypothetical example*

RESULTS OF THE BENEFIT-COST ANALYSIS

Code change *Fire Safety Feature requirement*

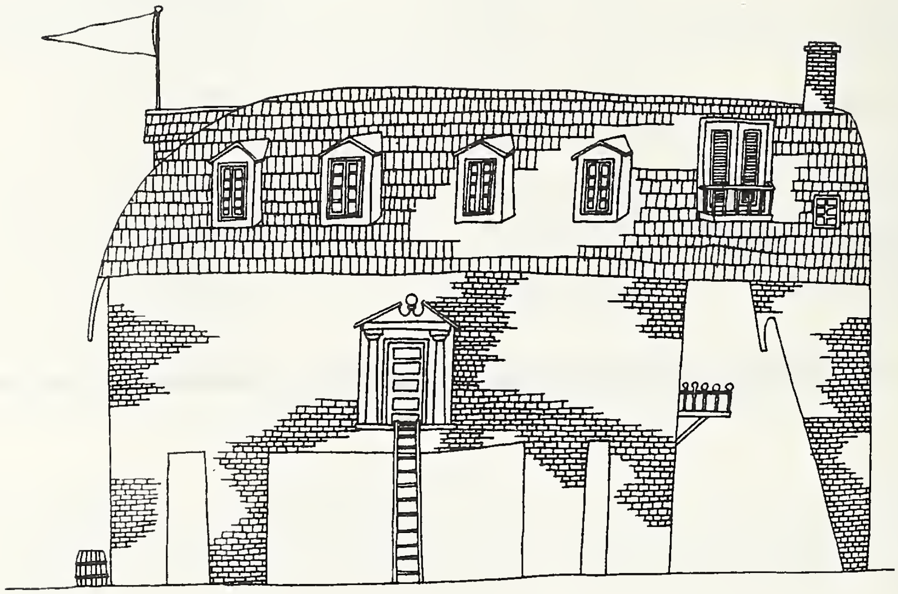
SELECTED ASSUMPTIONS

Subject	Value Used in Basic Analysis	Values Used in Sensitivity Analysis
Unit of analysis	*Dwelling unit*	*Dwelling unit*
Discount rate	*10%*	*8%*
Building analysis period	*25 years*	*25 years*
Code analysis period	*10 years*	*10 years*
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 8.1. [b]From worksheet 8.1 recomputed for sensitivity analysis.



10. CONCLUSIONS

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 code revisions which will afford the greatest protection for the construction dollar. The purpose of this report is to describe a method of using benefit-cost analysis to identify such code revisions. If the needed data are available, frequently economic analysis can help identify less costly ways to achieve the desired level of building safety. It can also help find the right balance between dollars spent on building safety and dollars spent on other needs. This is because money spent on building safety competes with other types of spending.

For example, a school district with a limited budget may have to choose between improving buildings or increasing teachers' salaries; a hospital may have to choose between increased fire safety or better nursing care, and so on. Should quality-of-life goals be achieved through better buildings or through other ways of spending the money? Economic analysis can be very helpful in striking this balance.

A formal benefit-cost analysis is not feasible for many code changes, and it is not justified for minor, noncontroversial changes. This report describes how to conduct an economic analysis of those building code changes for which economic analysis is appropriate. This method involves defining representative cases to analyze; estimating the discounted impacts on building cost, safety, and performance, and on government costs; calculating net benefits by subtracting costs from benefits; aggregating over the various representative cases to find overall impacts in a code jurisdiction; conducting a sensitivity analysis; and writing up the results, including both monetary and nonmonetary effects.

To illustrate the method, sample worksheets have been completed for a hypothetical problem. However, no one method and no one set of worksheets would be suitable for the many types of code changes that come before standards committees, model code organizations, and government bodies each year. Thus, to conduct a benefit-cost analysis, it will probably be necessary for the individual analyst to devise his or her own set of worksheets, using the blank worksheets found in appendix F as a starting point.

10.1 RESEARCH NEEDS

More data

Decisions are being made which affect costs of buildings throughout the country. Yet, often they must be made with only a general notion of the ultimate impacts of the code requirements on building safety and/or performance. The lack of data concerning engineering and safety effects of building features makes it impossible in many cases to carry out a useful benefit-cost analysis.

The many gaps in data concerning impacts of building features have been pointed out a number of times. For example, a 1980 article in Fire Journal assessed the quantity of research concerning automatic sprinkler systems as "little" and the quality as only "fair," and suggested that further research to determine costs and effectiveness should have very high priority. Research on smoke detectors was also considered insufficient.[1] A 1978 U.S. Fire Administration study of fire detectors encountered serious problems with the quality of fire incidence reports.[2] There are similar data problems in other areas.

One reason for these gaps in data is that information is expensive to collect and organize and costly engineering studies may be needed to provide it. But this expense must be balanced against the cost of inappropriate building requirements due to inadequate information. Even a modest effect on the cost of millions of buildings adds up to a staggering national total. As a preliminary step, areas should be identified where the lack of good information concerning the impacts of building features is imposing the greatest costs.

Value of life safety

Numbers have been developed to reflect the "value of life" or "value of injury" for use in public policy decisions. However, these are usually tailored to problems other than building code decisions, and a value developed for one purpose is not likely to be appropriate for other kinds of decisions.

An ambitious but useful research project would be to develop information that would help decisionmakers determine how much money should be spent to reduce accident risks. It is probably more efficient to develop such information in a research project which concentrates on this question than for analysts to tackle this difficult issue as part of each individual analysis of code change impacts.[3] A study tailored to building problems would provide information on various costs of building-related accidents and what individuals or society might be willing to spend (or require to be spent) to prevent them, including information on:

* Factors which may warrant spending more, or less, on building protection -- e.g., whether a risk is hidden or obvious, the age group protected, and whether the community or the occupants ultimately pay for the protection.

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[1] Swersey, Arthur J., and Ignall, Edward, "What Does Fire Research Have to Do with Fire Protection," Fire Journal, January 1980, pp. 63-74.

[2] Waterman, T. E., Mniszewski, K. R., and Spadoni, D. J., Cost/Benefit of Fire Detectors, (prepared by the IIT Research Institute, Chicago, for the National Fire Data Center, U.S. Fire Administration, Washington, D.C., 1978).

[3] Such a study has been done for product safety. See Technology + Economics, Injury Cost Model.

* What building occupants are willing to pay to reduce their personal risks, for various types of risk and occupants.

* What communities are willing to pay to preserve life safety through fire department or police protection.

* What health care facilities normally spend to reduce patient risks.

* Medical costs resulting from fatalities and injuries related to fire, tornadoes, earthquakes, and other building-related hazards.

* Other monetary costs of life safety hazards in buildings.

* Characteristics of the populations which are at risk for various types of building hazards.

Case studies

There is a need for economic analysis of proposed or existing code requirements which impose significant costs that may not be justified by the level of benefits. Case studies would contribute directly to improving building code decisions and would help in developing methods of analysis that could be used in later studies.

It would be useful to further test and refine the worksheets in this report and to develop new worksheets which are specific to particular types of code change decisions.

An important question is how the methodology described in this report can be made simpler and yet still be useful. For example, which factors are likely to be relatively unimportant in most analyses so that they do not need precise estimates, and which factors are likely to be crucial and need careful estimates? Such information would assist analysts to know in advance where to direct their greatest efforts in estimating code change impacts.

Appendix A: TABLES OF DISCOUNT FACTORS[1]

A.1 Discounting Formulas

A.2 Single Present Worth Factors (SPW)

A.3 Uniform Present Worth Factors (UPW)

A.4 Modified Uniform Present Worth Factors for Discount Rate of 8% (UPW*)

A.5 Modified Uniform Present Worth Factors for Discount Rate of 10% (UPW*)

A.6 Modified Uniform Present Worth Factors for Discount Rate of 12% (UPW*)

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[1] Other tables of discount factors can be found in many building economics texts, such as Marshall, H. E., and Ruegg, R. T., Energy Conservation in Buildings, National Bureau of Standards Handbook 132 (Washington, D.C.: Government Printing Office, 1980); or in investment analysis texts.

Table A.1 Discounting Formulas

Nomenclature	Abbreviation	Use When	Algebraic Form
Single Present Value Formula	SPW	Given F; to find P	$P = F \frac{1}{(1+i)^N}$
Uniform Present Value Formula	UPW	Given A; to find P	$P = A \frac{(1+i)^N - 1}{i(1+i)^N}$
Modified Uniform Present Value Formula	UPW*	Given A; escalating at rate e; to find P	$P = A \cdot \sum_{j=1}^{N} \left(\frac{1+e}{1+i}\right)^j = \left(\frac{1+e}{i-e}\right)\left[1 - \left(\frac{1+e}{1+i}\right)^N\right] A$

Where:

P = a present sum of money
F = a future sum of money
i = an interest rate
N = number of interest periods
A = an end-of-period payment (or receipt) in a uniform series of payments (or receipts), usually annually
e = annual rate of increase of annual payment (or receipt)

Source: Gerald W. Smith, Engineering Economy: Principles of Capital Expenditures, 2nd Ed. (Ames, Iowa: The Iowa State University Press, 1973), p. 47.

Table A.2

SINGLE PRESENT WORTH FACTORS[a]

(SPW)

P ← F $\qquad$ P = (SPW) x (F)

Present Value $\qquad$ Future Amount

	Real Discount Rate										
Year	6%	8%	10%	12%	15%	Year	6%	8%	10%	12%	15%
1	.9434	.9259	.9091	.8929	.8696	26	.2198	.1352	.0839	.0525	.0264
2	.8900	.8573	.8264	.7972	.7561	27	.2074	.1252	.0763	.0469	.0230
3	.8396	.7938	.7513	.7118	.6575	28	.1956	.1159	.0693	.0419	.0200
4	.7921	.7350	.6830	.6355	.5718	29	.1846	.1073	.0630	.0374	.0174
5	.7473	.6806	.6209	.5674	.4972	30	.1741	.0994	.0573	.0334	.0151
6	.7050	.6302	.5645	.5066	.4323	31	.1643	.0920	.0521	.0298	.0131
7	.6641	.5835	.5132	.4523	.3759	32	.1550	.0852	.0474	.0266	.0114
8	.6274	.5403	.4665	.4039	.3269	33	.1462	.0789	.0431	.0238	.0099
9	.5919	.5002	.4241	.3606	.2843	34	.1379	.0730	.0391	.0212	.0086
10	.5584	.4632	.3855	.3220	.2472	35	.1301	.0676	.0356	.0189	.0075
11	.5268	.4289	.3505	.2875	.2149	40	.0972	.0460	.0221	.0107	.0037
12	.4970	.3971	.3186	.2567	.1869	45	.0727	.0313	.0137	.0061	.0019
13	.4688	.3677	.2897	.2292	.1625	50	.0543	.0213	.0085	.0035	.0009
14	.4423	.3405	.2633	.2046	.1413						
15	.4173	.3152	.2394	.1827	.1229						
16	.3936	.2919	.2176	.1631	.1069						
17	.3714	.2703	.1978	.1456	.0929						
18	.3503	.2502	.1799	.1300	.0808						
19	.3305	.2317	.1635	.1161	.0703						
20	.3118	.2145	.1486	.1037	.0611						
21	.2942	.1987	.1351	.0926	.0531						
22	.2775	.1839	.1228	.0826	.0462						
23	.2618	.1703	.1117	.0738	.0402						
24	.2470	.1577	.1015	.0659	.0349						
25	.2330	.1460	.0923	.0588	.0304						

[a] Formula for P is given in table A.1.

Table A.3

UNIFORM PRESENT WORTH FACTORS[a]

(UPW)

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

Present Value   Annually Recurring Future Amounts

Real Discount Rate

Year	6%	8%	10%	12%	15%	Year	6%	8%	10%	12%	15%
1	0.943	0.926	0.909	0.893	0.870	26	13.003	10.810	9.161	7.896	6.491
2	1.833	1.783	1.736	1.690	1.626	27	13.211	10.935	9.237	7.943	6.514
3	2.673	2.577	2.487	2.402	2.283	28	13.406	11.051	9.307	7.984	6.534
4	3.465	3.312	3.170	3.037	2.855	29	13.591	11.158	9.370	8.022	6.551
5	4.212	3.993	3.791	3.605	3.352	30	13.765	11.258	9.427	8.055	6.566
6	4.917	4.623	4.355	4.111	3.784	31	13.929	11.350	9.479	8.085	6.579
7	5.582	5.206	4.868	4.564	4.160	32	14.084	11.435	9.526	8.112	6.591
8	6.210	5.747	5.335	4.968	4.487	33	14.230	11.514	9.569	8.135	6.600
9	6.802	6.247	5.759	5.328	4.772	34	14.368	11.587	9.609	8.157	6.609
10	7.360	6.710	6.144	5.650	5.019	35	14.498	11.655	9.644	8.176	6.617
11	7.887	7.139	6.495	5.938	5.234	40	15.046	11.925	9.779	8.244	6.642
12	8.384	7.536	6.814	6.194	5.421	45	15.456	12.108	9.863	8.283	6.654
13	8.853	7.904	7.103	6.424	5.583	50	15.762	12.233	9.915	8.305	6.661
14	9.295	8.244	7.367	6.628	5.724						
15	9.712	8.559	7.606	6.811	5.847						
16	10.106	8.851	7.824	6.974	5.954						
17	10.477	9.122	8.022	7.120	6.047						
18	10.828	9.372	8.201	7.250	6.128						
19	11.158	9.604	8.365	7.366	6.198						
20	11.470	9.818	8.514	7.469	6.259						
21	11.764	10.017	8.649	7.562	6.312						
22	12.042	10.201	8.772	7.645	6.359						
23	12.303	10.371	8.883	7.718	6.399						
24	12.550	10.529	8.985	7.784	6.434						
25	12.783	10.675	9.077	7.843	6.464						

[a] Formula for P is given in table A.1.

Table A.4

MODIFIED UNIFORM PRESENT WORTH FACTORS
FOR DISCOUNT RATE OF 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] See table A.1 for formula for P.

Table A.5

MODIFIED UNIFORM PRESENT WORTH FACTORS FOR DISCOUNT RATE OF 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 table A.1 for formula for P.

Table A.6

MODIFIED UNIFORM PRESENT WORTH FACTORS
FOR DISCOUNT RATE OF 12%[a]

(UPW*)

P? ← A (1+e) + $(1+e)^2$ + . . . 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 table A.1 for formula for P.

Appendix B: GLOSSARY OF ECONOMIC TERMS[1]

AGGREGATE IMPACTS - Impacts on all affected buildings within 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 the absence of a code change.

BENEFIT-COST ANALYSIS - A method of evaluating an alternative by comparing the discounted value of expected benefits with the discounted value of expected costs.

BENEFIT-COST RATIO - Discounted benefits divided by discounted costs; the ratio must be greater than one for a code change to represent an economic improvement.

BREAKEVEN ANALYSIS - A method of finding that value of a variable for which discounted 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.

DIFFERENTIAL PRICE ESCALATION RATE - The difference between a general rate of inflation and the rate of increase assumed for a given cost item, such as energy.

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

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[1] Definitions are based on Ruegg, R. T.; Petersen, S. R., and Marshall, H. E., Recommended Practice for Measuring Life-Cycle Costs of Buildings and Building Systems, NBSIR 80-2040 (Washington, D.C.: National Bureau of Standards, 1980); Marshall, H. E. and Ruegg, R. T., Simplified Energy Design Economics, National Bureau of Standards Special Publication 544 (Washington, D.C.: U.S. Government Printing Office, 1980); and comments by various reviewers. For further definitions of economic terms, see the Recommended Practice cited above.

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.

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 discounted benefits and discounted costs.

NONMONETARY IMPACTS - Impacts, such as changes in life safety, for which it is not feasible to assign dollar values.

PRESENT VALUE - The value of a benefit or cost at the present time (i.e., as of the base period), found by discounting future cash flows to the present.

REAL DISCOUNT RATE - The rate of interest reflecting the real earning power of money over time. This is the discount rate to use in discount formulas or to select discount factors when future benefits and costs are expressed in constant dollars.

REAL PRICE RISE - The rise in a price in constant dollars, i.e., the price rise after allowing for the overall level of inflation.

REAL RATE OF INTEREST - A rate of interest calculated based on 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 building analysis period, or when it is no longer to be used.

SENSITIVITY ANALYSIS - Testing the outcome of an evaluation by altering the value of one or more parameters from the initially assumed values(s).

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.

Appendix C: THREE STUDIES OF SAFETY IMPACT

This appendix gives examples, drawn from three studies, of how researchers have estimated safety effects of code changes. The descriptions below are not intended to be comprehensive summaries. Rather, they are intended to give the reader a feel for how data can be obtained and used in estimating safety impacts.

Ground Fault Circuit Interrupters. In a 1978 report, economist John McConnaughey assessed effects of a code requirement for Ground Fault Circuit Interrupters (GFCI's), which protect against electric shocks.[1] 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 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.

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 to be .0000007. This is the figure that would be entered on worksheet 5.2 under the "Total Change in Annual Expected Loss."

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[1] McConnaughey, An Economic Analysis of Building Code Impacts.

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.[1]

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 of 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.[2] 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 fire, 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.

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[1] Walters, Jeffrey L., Economic Benefit-Cost and Risk Analysis of Results of Mobile Home Safety Research: Wind Safety Analysis (prepared for U.S. Department of Housing and Urban Development, March 1979).

[2] Helzer, Susan Godby; Offensend, Fred L.; and Buchbinder, Benjamin, Decision Analysis of Strategies for Reducing Upholstered Furniture Fire Losses, NBS Technical Note 1101 (Washington, D.C.: National Bureau of Standards, 1979).

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.

Appendix D: SOURCES OF DATA

D.1 SOURCES OF DATA ON CHARACTERISTICS AND GROWTH OF THE BUILDING STOCK[1]

Housing data (general)	U.S. Department of Housing and Urban Development, Statistical Yearbook, U.S. Government Printing Office, Washington, D.C.
Construction authorized and put in place	Construction Review, U.S. Department of Commerce, Bureau of Domestic Business Development, Industry and Trade Administration, Washington, D.C.
Housing forecasts	Marcin, Thomas. The Effects of Declining Population Growth on the Demand for Housing, U.S. Department of Agriculture, General Technical Report, NC-11, 1974.
Housing characteristics and defects in housing	U.S. Bureau of the Census, Annual Housing Survey: 1977, United States and Regions, Series H-150-77, U.S. Government Printing Office, Washington, D.C., 1979. Part A: General Housing Characteristics, and Part B: Indicators of Housing and Neighborhood Quality.
Housing characteristics, e.g., type structure; location; number of bathrooms and bedrooms; external wall material; type foundation; heating fuel; parking facilities; number of stories; floor space	New One-Family Houses Sold and for Sale, Series C25, U.S. Bureau of the Census, Washington, D.C. (monthly publication).
Housing characteristics	Characteristics of New and Existing Single-Family Detached and Multi-Family Low-Rise Dwelling Units by Region, NAHB Research Foundaion, Rockville, Md., 1976.

[1] For more detail concerning data in Census publications, see U.S. Bureau of Census, Catalog, U.S. Government Printing Office, Washington, D.C.; or Construction Statistics Data Finder, U.S. Bureau of the Census, Washington, D.C.

D.1 SOURCES OF DATA ON CHARACTERISTICS AND GROWTH OF THE BUILDING STOCK - (Continued)

Characteristics of apartments completed	U.S. Bureau of the Census, _Characteristics of Apartments Completed: 1978_, Series H-131A, U.S. Government Printing Office, Washington, D.C.
Number of low-income and elderly housing units, by state	U.S. Department of Housing and Urban Development, _1977 Statistical Yearbook_, U.S. Government Printing Office, Washington, D.C.
Family characteristics	_Social and Economic Characteristics of the Metropolitan and Nonmetropolitan Population_, U.S. Department of Commerce, Bureau of the Census, Washington, D.C., 1974 and 1970.
Building features; common materials or designs	Trade journals, interviews with contractors or architects in HUD regional offices; or collect through original building survey.
Climate data	Environmental Design Service, _Climatic Atlas of the United States_, U.S. Department of Commerce, Washington, D.C. 1968, 1974.

D.2 SOURCES OF CONSTRUCTION COST DATA

Construction costs	Building Construction Cost Data, Robert Snow Means Company, Inc., Duxbury, Mass. (published annually).
Construction costs	Mechanical and Electrical Cost Data, Robert Snow Means Company, Inc., Duxbury, Mass., 1979.
Construction costs	Building Cost File, Van Nostrand Reinhold Co., New York (published annually).
Overall unit costs of building components	Design Cost File, Van Nostrand Reinhold Co., New York, 1979.
Construction costs; includes remodeling/ renovation costs	Dodge Manual for Building Construction Pricing and Scheduling, McGraw-Hill Information Systems Company, New York (published annually).
Construction costs	Dodge Building Cost and Specification Digest, McGraw-Hill, New York (subscription service - updated semi-annually).
Construction costs	Engelsman, Coert, Engelsman's General Construction Cost Guide, Van Nostrand Reinhold Co., New York, 1979.
Construction costs	National Construction Estimator, Craftsman Book Co., Solana Beach, California, 1980.
Construction costs	General Construction Estimating Standards, Volume I (sitework, piling and concrete); Volume II (masonry, metals, doors, finishes, windows, specialities); and Volume III (mechanical and electrical systems) Richardson Engineering Services, Inc., Solana Beach, California (annual publication).
Costs of selected building components: foundations and floors; exterior wall framing and sheathing; windows and doors; furrings; insulation; heating and cooling systems	Selected Cost Data on Residential Construction (prepared for the National Bureau of Standards), NAHB Research Foundation, Inc., Rockville, Md., December 1977.

D.2 SOURCES OF CONSTRUCTION COST DATA - (Continued)

Wage rates for construction trades by geographical area; building materials prices; cost indices (rate of inflation for construction costs)	Engineering News Record, McGraw-Hill, New York (various issues).
Union hourly wages in building trades	Department of Labor; Bureau of Labor Statistics.
Construction cost indices	Construction Review, U.S. Department of Commerce, Bureau of Domestic Business Development, Industry and Trade Administration, Washington, D.C. (monthly publication).
Construction cost indices	Value of New Construction Put in Place, Series C30, U.S. Bureau of the Census, Washington, D.C. (monthly publication).
Insulation costs	Masonry Advisory Council, "1978 Masonry Cost Guide," Park Ridge, Ill., 1978.
Housing weatherization costs	Weber, S. F.; Boehm, M. J.; and Lippiatt, B. C., Weatherization Investment Costs for Low-Income Housing, National Bureau of Standards NBSIR 80-2167, U.S. Government Printing Office, Washington, D.C., 1980.
Lead paint abatement costs	Chapman, Robert and Kowalski, Joseph. Guidelines for Cost-Effective Lead Paint Abatement, Technical Note 971, National Bureau of Standards, U.S. Government Printing Office, Washington, D.C., 1979.
Selling expenses, taxes, profits	Mobile Home Manufacturers' Cost and Profile Survey, published by Mobile-Modular Housing Dealer Magazine, Chicago, Ill., 1977.
Fire protection systems	Various issues of the Fire Journal, published monthly by National Fire Protection Association, Boston.

D.2 <u>SOURCES OF CONSTRUCTION COST DATA</u> - (Continued)

Construction costs; materials, component, and system list prices	Individual builders; state and local home builders associations; trade associations; building materials and equipment suppliers.
Wholesale prices of construction materials	U.S. Department of Labor, Bureau of Labor Statistics, <u>Producer Prices and Price Indexes</u>, U.S. Government Printing Office, Washington, D.C. (monthly publication).

D.3 SOURCES OF DATA ON OPERATION AND MAINTENANCE COSTS

Expenditures for residential maintenance and alterations	Residential Alterations and Repairs, Series C50, U.S. Bureau of the Census, Washington, D.C. (quarterly publication).
Apartment building operation and maintenance (O&M) data: by building location, age, and type of ownership	Income/Expense Analysis: Apartments, Condominiums and Cooperatives, Institute of Real Estate Management, Chicago, Ill. (annual publication).
Shopping center O&M data; e.g. maintenance, utilities, by size of shopping center	Dollars and Cents of Shopping Centers, Urban Land Institute, Washington, D.C., 1978.
Office building O&M data: data by age, height, size and location	Office Building Experience Exchange Report, Building Owners and Managers Association International, Washington, D.C.
Hospital operations data	American Hospital Association, Hospital Administrative Services Division. Chicago, Ill., (published twice a year).
Income and costs for suburban office buildings	Institute of Real Estate Management, Chicago, Ill.
Obsolescence (product life) information	Manufacturer, industry associations.
Price indices to be used to convert current dollars to constant dollars	Monthly Labor Review, U.S. Department of Labor, Bureau of Labor Statistics, Washington, D.C.
Energy Use	
Energy price forecasts	Department of Energy, Energy Information Administration (See 45 Federal Register 5620, January 23, 1980).
Energy use	End Use Energy Consumption Data Base: Series 1 Tables, 1974, U.S. Department of Energy, Energy Information Administration, Washington, D.C., June 1978.

D.3 SOURCES OF DATA ON OPERATION AND MAINTENANCE COSTS - (Continued)

Energy use	Residential and Commercial Energy Use Patterns, 1970-1990, Report to the Council on Environmental Quality and the Federal Energy Administration, Arthur D. Little, Inc., Cambridge, Mass., November 1974.
Energy consumption annually for 1960 through 1978, by state, fuel, type, and major end use sector	State Energy Data Report, Statistical Tables and Technical Documentation, 1960 through 1978, Department of Energy, Energy Information Administration, Washington, D.C., April 1980.
Conservation activities performed by households, January 1977 to December 1978; status of households with respect to insulation, storm windows, etc.	Residential Energy Consumption Survey: Conservation, Department of Energy, Energy Information Administration, Washington, D.C., February 1980.
Tabulations of fuel oil used by single-family households	Single-Family Households: Fuel Oil Inventories and Expenditures, Department of Energy, Energy Information Administration, Washington, D.C., December 1979.

D.4 SOURCES OF DATA ON BUILDING HAZARDS AND PROPERTY LOSSES

Data from the National Electronic Injury Surveillance System on injuries related to consumer products including appliances, building parts such as glazing and stairs, home furnishings and fixtures such as bathtubs and carpets	NEISS Data Highlights, U.S. Consumer Product Safety Commission, Washington, D.C. (published quarterly).
Causes of deaths in fires	Vital Statistics of the United States: Mortality, Volume II, Parts A and B, U.S. Department of Health, Education and Welfare, National Center for Health Statistics, Washington, D.C.
Test reports and supporting statements submitted with proposed standards and changes in model codes concerning hazards and effects of code changes in reducing hazards	Model building code organizations; standards, committees, and testing laboratories.
Loss data, indirect costs of accidents	Insurance companies.
Includes abstracts of publications containing data on building accidents	National Technical Information Service, Building Industry Technology (abstracts of reports and other publications), NTIS, Springfield, VA 22161 (weekly publication).

Fire Hazards

Summaries of data on fire deaths from various sources, descriptions of sources of data on fire incidents, fire deaths, and property losses	Fristrom, Geraldine, Fire Deaths in the United States: Review of Data Sources and Range of Estimates, National Fire Data Center, U.S. Fire Administration, Washington D.C., 1977.
Fire incident reports (computerized system)	National Fire Incident Reporting System, U.S. Fire Administration, Washington, D.C.
Fire deaths, incidents, dollar losses; by cause, occupancy	"Fire and Fire Losses Classified," Fire Journal, National Fire Protection Association, Boston, Mass. (published annually).

D.4 SOURCES OF DATA ON BUILDING HAZARDS AND PROPERTY LOSSES - (Continued)

Fire Hazards - (Continued)

Cumulative fire experience: fatalities, age, time of day, other factors	Fire Protection Handbook, National Fire Protection Association, Boston Mass., (published every six or seven years).
Fire injury costs	Stacey, Gary S. and Smith, Kathy S., "Methodology for Estimating Costs of Injuries and Property Losses," Fire Technology, August 1979, pp. 195-209.
Major fire incident reports (computerized system)	Fire Incident Data Organization (FIDO), National Fire Protection Association, Boston, Mass.
Local fire problems	State Fire Marshall reports (e.g., Michigan and California).
Fire frequency (including unreported fires)	Highlights of the National Household Survey, U.S. Fire Administration, Washington, D.C., 1976.
Fire loss data	1977 Fire Losses in Ontario, Province of Ontario, Office of the Fire Marshall.
Data on building fires, costs of accidents	Accident Facts, National Safety Council, Chicago, Ill. (annual publication).
Data on deaths, injuries, dollar losses and incidents	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., Dec. 1978.
Fire injury costs	Barancik, J. I. and Shapiro, M. A., Pittsburgh Burn Study, Graduate School of Public Health, University of Pittsburgh, May 1972.
Indirect costs of residential fires	Munson, M.J. and Ohls, J.C., "Indirect Costs of Residential Fires," Fire Journal, January 1979, pp. 42-48.

D.4 SOURCES OF DATA ON BUILDING HAZARDS AND PROPERTY LOSSES - (Continued)

Fire Hazards - (Continued)

Social and economic effects of residential fires	Rapkin, Chester, ed., The Social and Economic Consequences of Residential Fires, (forthcoming; editor is at Princeton University).
Assessments of smoke detectors, remote alarm system, automatic suppression system	Assessment of the Potential Impact of Fire Protection Systems on Actual Fire Incidents, Applied Physics Lab, Johns Hopkins University, Laurel, Md., October 1978.
Safety impacts of retrofit features for health care facilities (as rated by a panel of experts)	Nelson, H. E. and Shibe, A. J., A System for Fire Safety Evaluation of Health Care Facilities, NBSIR 78-1555, National Bureau of Standards, Washington, D.C., November, 1978. Available through NTIS.
Smoke detector effectiveness	Gratz, D. V. and Hawkins, R. E, Evaluation of Smoke Detectors in Homes, International Association of Fire Chiefs, Foundation, Washington, D.C., 1980; available through NTIS.
Smoke detector effectiveness	Smoke Detectors in Ontario Housing Corporation Dwellings, Ministry of Housing, 4th floor, Queen's Park Toronto, M7A2K5, Canada, 1978.
Smoke detector cost effectiveness	Potter, J. J.; Smith, M. L.; and Panwalke, S. S., Cost Effectiveness of Residential Fire Detection Systems, Texas Tech University, Lubbock, 1976.
Smoke detector sales and installations	Young, J. K. and Feignenbaum, E. L., "Survey and Analysis: Occupant-Installable Smoke Detectors," Aerospace Report ATR-77(2819)-2, September 1977.
Performance of fire protection and control equipment	Independent testing laboratories (e.g., Factory Mutual); product manufacturers; trade associations (e.g., Fire Equipment Manufacturers Association).

Fire Hazards - (Continued)

Flammability of building materials	Trade associations (e.g., Society of the Plastics Industry).
NBS fire research	Jason, Nora H., Fire Research Publications, 1980, NBSIR 81-2272, National Bureau of Standards, Washington, D.C., April 1981.

Natural Disasters

Statistics on deaths and property losses from hurricanes, floods, earthquakes and tornadoes	Sav, G. Thomas, Natural Disasters: Some Empirical and Economic Considerations, NBSIR 74-473, National Bureau of Standards, Washington, D.C., February 1974.
Hurricane, flood and earthquake damages and death	Dacy, Douglas C. and Kunreuther, Howard, The Economics of Natural Disasters, The Free Press, New York, 1969.
Hurricane, flood, earthquake and tornado damages and deaths	Disaster Preparedness, Vol. 3, Executive Office of the President, Office of Emergency Preparedness, Washington, D.C., U.S. Government Printing Office, January 1972.
Hurricane, flood, earthquake and tornado damages and deaths	Annual Summary of Disaster Services Activities, American Red Cross, Washington, D.C.
Hurricane, flood, earthquake and tornado damages and deaths	Highlights of Disaster Relief Services, American Red Cross, Washington, D.C. (annual publication).
Hurricanes, tornados, and floods	Sorkin, Alan L., Economics of Natural Disasters (forthcoming; author is at the Johns Hopkins University and the University of Maryland, Baltimore County).
Hurricane and flood damages and deaths	Climatological Data, National Summary, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, Ashville, N.C.

D.4 <u>SOURCES OF DATA ON BUILDING HAZARDS AND PROPERTY LOSSES</u> - (Continued)

<u>Natural Disasters</u> - (Continued)

Earthquake damages	McClure, F. E., "Studies in Gathering Earthquake Damage Statistics," Coast and Geodetic Survey, U.S. Department of Commerce Washington, D.C., 1967.
Earthquake property losses	<u>A Study of Earthquake Losses in the San Francisco Bay Area</u>, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Research Laboratories; report for the Office of Emergency Preparedness, Boulder, Colo.
Earthquake damages	<u>Studies in Seismicity and Earthquake Damage Statistics, 1969</u>, National Ocean Survey, U.S. Department of Commerce; prepared for Department of Housing and Urban Development, 1969, Rockville, Md.
Tornado incidents and deaths	<u>Tornado Preparedness Planning</u>, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, U.S. Government Printing Office, Washington, D.C., 1970.
Tornado data	<u>General Summary of Tornadoes</u>, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, U.S. Government Printing Office, Washington, D.C.
Economic, safety, and other impacts of natural disasters and unusual climatic conditions	<u>Impact Assessment of Major Climatic and Other Natural Events</u>, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data and Information Service, Washington, D.C. (published monthly).

D.4 SOURCES OF DATA ON BUILDING HAZARDS AND PROPERTY LOSSES - (Continued)

Natural Disasters - (Continued)

Damage due to wind, tornadoes, hurricanes, etc., by state	Storm Data, National Weather Service, National Oceanic and Atmospheric Administration, National Climatic Center, Ashville, N.C. (monthly publication).

Miscellaneous Hazards

Indoor air pollution	Benson, F. B., et al., Indoor - Outdoor Air Pollution Relationships: A Literature Survey, Publication AP-112, Environmental Protection Agency, Washington, D.C., August 1972.
Electric shock fatalities	Newspaper clippings summarized for the National Electric Code Panel, Preprint of the Proposed Amendments to the 1971 NEC, National Fire Protection Association, Boston, Mass.
Lead paint poisoning	Gilsinn, Judith F., Estimates of the Nature and Extent of Lead Paint Poisoning in the United States, NBS Technical Note 746, National Bureau of Standards, Washington, D.C., December 1972.
Housing needs of the handicapped; survey presented in support of proposed model code change	1980 Proposed Changes to the BOCA Basic Codes, Vol. II, Building Officials and Code Administration International, Homewood, Ill., p. 55.
Effects of housing project design on crime	Newmann, Oscar, Defensible Space: Crime Prevention through Urban Design, Macmillan, New York, 1972.
Burglary losses	Crime in the United States: Unified Crime Reports, Federal Bureau of Investigation, U.S. Department of Justice, Washington, D.C. (annual publication).

D.4 SOURCES OF DATA ON BUILDING HAZARDS AND PROPERTY LOSSES - (Continued)

Miscellaneous Hazards - (Continued)

Costs of death and injury	Faigin, B. M., 1975 Societal Costs of Motor Vehicle Accidents, U.S. National Highway Traffic Safety Administration, Washington, D.C., 1976.
Costs of death and injury	Cornell, M., et al, A Survey of Methods for Estimating the Cost Value of a Human Life, U.S. Coast Guard, Washington, D.C., 1976.
Insurance claims records containing information on value of hospital and professional medical services, by age, sex, and type injury for 1976 through 1978.	Civilian Health and Medical Program for the Uniformed Services (CHAMPUS), Department of Defense.
Accident costs	Kurtz, Robert D. and Stone, Robert F., "A Model of Injury Costs," Consumer Product Safety Commission and Technology + Economics, Inc. (paper presented at the Atlantic Economic Conference, October 10, 1980).
Annual per capita earnings by age, sex, race, education, etc.	Statistical Abstract of the United States, U.S. Department of Commerce, Bureau of the Census, U.S. Government Printing Office, Washington, D.C.

Appendix E: ADDITIONAL READING

E.1 BENEFIT-COST ANALYSIS

American Telephone and Telegraph Company, Construction Plans Department. Engineering Economy: A Manager's Guide to Economic Decisionmaking, 3d edition. New York: McGraw-Hill, 1977.	Engineering economics
Anderson, Lee G. and Settle, Russell F. Benefit-Cost Analysis: A Practical Guide. Lexington, Mass.: 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
Ashford, N. A. and Hill, C. T., et al. The Benefits of Environmental, Health, and Safety Regulation, prepared for the U.S. Senate Committee on Governmental Affairs. Washington, D.C.: U.S. Government Printing Office, 1980.	Federal benefit-cost studies
Brown, David B. "Cost/Benefit of Safety Investments Using Fault Tree Analysis," in Journal of Safety Research, Vol. 5., No. 2 (June 1973), pp. 73-81.	Risk analysis
Department of the Navy, Naval Facilities Engineering Command. Economic Analysis Handbook, NAVFAC P-442, July 1980. (Available from Naval Publications and Form Center, 5801 Tabor Ave., Philadelphia 19120, Stock Control No. 0525-LP-0377152.)	Benefit-cost analysis for facilities planning
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
Ruegg, Rosalie T.; Petersen, Stephen R.; and Marshall, Harold E. Recommended Practice for Measuring Life-Cycle Costs of Buildings and Building Systems, NBSIR 80-2040 (Washington, D.C.: National Bureau of Standards, 1980).	Methods of estimating costs of constructing and operating buildings
Smith, Gerald W. Engineering Economy: Analysis of Capital Expenditures, 2nd edition. Ames, Iowa: The Iowa State University Press, 1973.	Investment analysis

E.1 BENEFIT-COST ANALYSIS - (Continued)

U.S. House of Representatives, Subcommittee 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

E.2 BUILDING ECONOMICS IN GENERAL

The American Institute of Architects. Life-Cycle Cost Analysis: A Guide for Architects. Washington, D.C., 1977.	Life-cycle costs
Arthur Young and Co. A Comparative Economic Impact Analysis of the Present and Proposed State Building Standards Process. Prepared for the State of California, State and Consumer Services Agency, October 15, 1978.	Building codes
Banks, W. B. and Kroll, M. E. A Method for Predicting Changes in Building Costs (Princes Risborough, England: Princes Risborough Lab., c1980, available through NTIS).	Construction 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
Rawie, Carol Chapman. Estimating Benefits and Costs of Building Regulations: A Step-by-Step Guide, Washington, D.C., National Bureau of Standards, June 1981.	Building codes
Stone, P. A. Building Economy. New York: Pergammon Press, 1976 (second ed.)	Building economics
Thompson, B. E. and Chapman, R.E. Productivity in Residential Construction: An Annotated Bibliography, NBSIR 80-2150. Washington, D.C.: National Bureau of Standards, February 1981.	Contains sections on construction costs

E.3 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

E.3 FIRE SAFETY - (Continued)

Chapman, Robert E.; Chen, Phillip T.; and Hall, William G. Economic Aspects of Fire Safety in Health Care Facilities: Guidelines for Cost-Effective Retrofits. NBSIR 79-1902. Washington, D.C.: National Bureau of Standards, 1979. Available through NTIS.	Fire safety in hospitals
Comptroller General of the United States. Federal Fire Safety Requirements Do Not Insure Life Safety in Nursing Home Fires: Report to Congress, B-164031(3), Washington, D.C.: General Accounting Office, June 1978.	Sprinklers in nursing homes
Dardis, Rachel and Thompson, Ruth. "Analyzing the Effectiveness of Alternative Fire Protection Strategies," in Fire Journal, September 1979, pp. 27-30.	Upholstered furniture standard; smoke detectors
Dardis, Rachel and Thompson, Ruth. "Strategies for Reducing Residential Fire Losses," in Journal of Consumer Product Flammability, Vol. 6, No. 2, June 1979, pp. 136-151.	Upholstered furniture standard; smoke detectors
Helzer, Susan Godby; Offensend, Fred L.; and Buchbinder, Benjamin. Decision Analysis of Strategies for Reducing Upholstered Furniture Fire Losses, National Bureau of Standards Technical Note 1101, Washington, D.C.: U.S. Government Printing Office, 1979.	Upholstered furniture standard; smoke detectors
Munson, Michael J. and Ohls, James C. "Indirect Costs of Residential Fires," in Fire Journal, January 1979, pp. 42-48.	Fire costs
Stacey, G. S. and Smith, K. S. "Methodology for Estimating in Costs of Burn Injuries and Property Losses," in 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, Ill., Sept. 1978. (Report prepared for the U.S. Fire Administration, Washington, D.C.)	Fire detectors

E.4 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, December 1975.	ASHRAE 90-75

Chapman, Robert E.; Crenshaw, Richard W.; Barnes, Kimberly A.; and Chen, Phillip T. Optimizing Weatherization Investments in Low-Income Housing: Economic Guidelines and Forecasts, NBSIR 79-1948. Washington, D.C.: National Bureau of Standards, February 1980. Available through NTIS. — Weatherization

Lentz, Craig, "ASHRAE Standard 90-75 -- Economic Impact on Selected Industries and the Design Profession," in ASHRAE Journal, Vol. 18, No. 6, June 1976, pp. 33-38. — ASHRAE 90-75

Lentz, Craig, "ASHRAE Standard 90-75 -- Impact on Building Energy Usage and Economics," ASHRAE Journal, Vol. 18, No. 4, April 1976, pp. 23-28. — ASHRAE 90-75

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Appendix F

BLANK WORKSHEETS

Worksheet 2.1

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 2.2

REPRESENTATIVE CASES

Code analysis period_______________ Unit of analysis _______________

	Representative Case			
Characteristics	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				

Worksheet 4.1

IMPACT ON UNIT INITIAL COSTS[a]

Representative case ________ (from worksheet 2.2)

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 4.2

IMPACT ON UNIT OPERATION AND MAINTENANCE COSTS[a]

Representative case _______ Discount rate _______ %

Building analysis period (from worksheet 2.2) _____ 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]
	$				$			
	$				$			
	$				$			

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]
		$				$			
		$				$			

[a]The unit of analysis should be the one listed on worksheet 2.2.

[b]At present prices.

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

[d]From discount factor tables A.2 through A.6 in appendix A for assumed discount rate, timing of impact, and (for UPW*) the rate of differential price change.

Worksheet 4.3

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 4.2, part A.

Worksheet 4.4

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
		$ ________	X	________	X	________	=	$ ________
Proposed Requirement		$ ________	X	________	X	________	=	$ ________
Original Requirement	-	$ ________	X	________	X	________	=	$ ________
	-	$ ________	X	________	X	________	=	$ ________

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

[a]Amount, SPW, and UPW* are from worksheet 4.2, part B.

[b]$(1 + e)^t$ = (___ + ___)__ = __________, where the rate of differential price rise "e" and year of impact "t" are from worksheet 4.2, part B. This factor adjusts for cost changes after the construction year.

Worksheet 4.5

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 A.2 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 A.3, appendix A, for assumed discount rate and building analysis period.

Worksheet 5.1

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 A.3, appendix A, for assumed discount rate and building analysis period or life of required feature.

Worksheet 5.2

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 5.1.

Worksheet 5.3

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 A.3, appendix A, for assumed discount rate and building analysis period.

Worksheet 5.4

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 A.2, appendix A for assumed discount rate and building analysis period.

Worksheet 7.1

ADJUSTING O&M COSTS FOR DIFFERENTIAL COST CHANGES

Representative case ______ Years before building constructed ____ years[a]

Rate of Differential Cost Change (Worksheet 4.2)	Change in O&M Costs (Worksheet 4.4)	X	Cost Change Factor[b]	=	Adjusted O&M Costs
____ %/yr.	$ ________	X	______	=	$ ________
____ %/yr.	$ ________	X	______	=	$ ________
+ O&M costs from worksheet 4.3				+	$ ________
TOTAL O&M COSTS ADJUSTED FOR DIFFERENTIAL COST CHANGE, DISCOUNTED TO CONSTRUCTION YEAR					$ ________

[a] Based on construction date in worksheet 2.2.

[b] The cost change factor, $(1 = e)^t$, adjusts for the rate of differential cost change, e, listed above and in worksheet 4.2; t is the number of years before the building is constructed.

Calculations for first line in table: $(1 + e)^t$ = (1 + ____)__ = _____.

Calculations for second line in table: $(1 + e)^t$ = (1 + ____)__ = _____.

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
5.3	Building Space	$	X		=	$
5.4	Residual Value	$	X		=	$
	(Other Impact)	$	X		=	$
TOTAL EFFECT ON PERFORMANCE		$	X		=	$

Worksheet Number	Type Impact	Change in Building Cost[a]	X	SPW[b]	=	Present Value
4.1	Initial Costs	$	X		=	$
4.5	Government Costs	$	X		=	$
7.1	O&M Costs	$	X		=	$
5.1	Property Loss	$	X		=	$
	(Other Cost or Loss)[c]	$	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. Use a positive number for increases in value, cost, or loss. Use a negative number for decreases.

[b] From table A.2, appendix A, for assumed discount rate and number of years before building is constructed.

[c] If life safety impacts are quantified in dollars, they should be included here.

Worksheet 8.1

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 5.2 (life safety) or 7.2 (monetary impacts).

Worksheet 9.1

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 2.2.

b Values in the basic analysis are from worksheets 4.1 through 5.4, and 8.1.

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 9.2

SENSITIVITY ANALYSIS[a]

Representative case ________

Variable	Values in Basic Analysis	Values in 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 2.2.

[b] From worksheet 7.2 calculated using original and altered values.

[c] From worksheet 5.2 calculated using original and altered values.

Worksheet 9.3

RESULTS OF THE BENEFIT-COST ANALYSIS

Code change ______________________________

SELECTED ASSUMPTIONS

Subject	Value Used in Basic Analysis	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 8.1. [b] From worksheet 8.1 recomputed for sensitivity analysis.

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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 report describes a method for estimating the benefits and costs of proposed changes in building codes. A companion report by the author, Estimating Benefits and Costs of Building Regulations: A Step-by-Step Guide, published by the National Bureau of Standards as NBSIR 81-2223, provides a simplified description of the same basic method.

This report shows the reader how to set up the problem, discount impacts to their present value, estimate code impacts on building costs, estimate effects on building safety, compute aggregate impacts, and conduct a sensitivity analysis. One chapter discusses the problem of assigning a dollar value to life safety. Worksheets and an extensive list of references, including sources of data on building costs and hazards, are included.

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 economics; construction regulation; economics; fire safety codes; regulation.

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