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An Economic Analysis of Building Code Impacts: A Suggested Approach

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U.S. DEPARTMENT OF COMMERCE
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PREFACE

This research was sponsored by the Building Economics and Regulatory Technology Divison of the Center for Building Technology. This study examines the economic impact of building codes and develops an assessment methodology to evaluate the benefits and costs of specific building code provisions.

Dr. Harold E. Marshall, Chief of the Applied Economics Program, Robert E. Chapman, and Stephen R. Petersen of the Applied Economics Program offered invaluable help by reading, discussing and commenting on earlier drafts of the report. The author also wishes to acknowledge the useful comments and suggestions from other Bureau reviewers of the report, including William J. Meese, James H. Pielert, Dr. Stephen F. Weber, and Dr. Carol Chapman.

ABSTRACT

This report suggests an evaluation approach which can be used by building officials and legislative bodies faced with making building code decisions. A method to evaluate many of the potential benefit and cost impacts of specific building code provisions is developed. The report also defines and categorizes the economic impacts of building codes. While no approach to classifying building code impacts will be fully appropriate for all uses, the definitions and categories proposed may help to clarify or reconcile some of the differing opinions concerning the impact of building codes. Finally, the report illustrates the suggested approach by evaluating the 1975 National Electrical Code requirement for the use of Ground Fault Circuit Interrupters (GFCIs) in residences. Based on sensitivity analysis, estimates are made of how much it costs society in order to save one life through the GFCI code provision. This case study conclude that the estimated cost to save a life is nearly $4 million. A lower bound estimate of the cost to save a life is about $2.5 to $3.5 million.

Keywords: Benefit-cost analysis; benefit-risk analysis; building codes and standards; building regulations; building safety; economic analysis; economics of safety; ground fault circuit interrupters.

SI CONVERSION UNITS

The conversion factors and units contained in this report are in accordance with the International System of Units (abbreviated SI for Systeme International d'Unites). The SI was defined and given official status by the 11th General Conference on Weights and Measures which met in Paris, France in October 1960. For assistance in converting U.S. customary units to SI units, see ASTM E 380, ASTM Standard Metric Practice Guide, available from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA. 19103. The conversion factors for the units found in this Standard are as follows:

Length

1 in = 0.0254* meter

1 ft = 0.3048* meter

1 mil = 0.001* in

1 yd = 0.9144* meter

Area

1 in^2 = 6.4516* x 10^{-4} $meter^2$

1 ft^2 = 0.0929 $meter^2$

1 yd^2 = 0.836 $meter^2$

Volume

1 in^3 = 1.639 x 10^{-5} $meter^3$

1 liter = 1.00* x 10^{-3} $meter^3$

1 gallon = 3.785 liters

Temperature

°C = 5/9 (Temperature °F -32)

* Exactly

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1.0 INTRODUCTION

1.1 PURPOSE

The major purpose of this report is to suggest an approach to evaluating building code provisions which can be used by building officials, legislators, and other decision makers. It describes a way to measure and evaluate many of the potential benefit and cost impacts of a specific building code provision. The approach uses a model which shows how to organize information in a form which can be of greater use to decision makers. Although some benefit or cost information is incomplete or uncertain, so that exact estimates cannot be made it is hoped that more complete information developed by the approach will lead to better public decisions. In an area as complex as building regulations, however, no claim is made that this approach can be applied to every code provision nor that all concerned parties will use it to reach the same decision once an evaluation is made. But each step is explicit and assumptions are clearly spelled out. Moreover, the use of sensitivity analysis, which is a method to examine uncertain assumptions or information, can help identify key assumptions and research/information needs.

Another purpose of this report is to develop a classification system (or taxonomy) which defines and categorizes the different types of building code impacts. There are conflicting opinions concerning the magnitude and importance of building code impacts. A taxonomy is useful because it provides a framework for understanding and investigating these impacts. Building codes and other related building regulations are believed by many to promote inefficiency, increase costs, or impede innovative building technology. Other experts believe the impact of building codes on efficiency and costs is small. With respect to safety, some observers contend that building codes set unreasonably high safety requirements while others, pointing to losses from fire, accidents, natural disasters, or other hazards call for additional code protection. Controversy over the impact of building codes exists for several reasons. One reason is the lack of a consistent language or set of specific definitions concerning building codes and their impacts. Another reason for conflicting opinions is that different members of the building community have different perspectives, and they are concerned about different types of impacts. Finally, building codes are only one of a large number of interrelated factors which influence performance in the construction sector[1]. The relationship between building codes

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[1]Other strong influences include cyclical and seasonal fluctuations, regional shifts in demand and in composition of output, sensitivity to monetary policy, changes in the construction material supplying industries, and institutional factors (such as other building regulations, zoning and land use regulations, union influence, the organization of contracting/subcontracting systems, and the separation of design from construction).

and these other factors is difficult to assess due to the complexity of the sector, the heterogeneity of the output, and poor construction statistics. While no single set of definitions or approaches to classifying building code impacts will be fully appropriate for all uses, the definitions and categories proposed in this report may help to clarify and reconcile some of the differing opinions concerning the impact of building codes.

A third purpose of this report is to illustrate the evaluation approach developed herein. The 1975 National Electrical Code requirement for the use of Ground Fault Circuit Interrupters (GFCI) in residences is analyzed.

1.2 BACKGROUND AND PERSPECTIVE

Building codes are one of the more important types of building regulation. From the Code of Hammurabi, (about 1700 B.C.) to the present, such codes have sought to ensure safe buildings. However, building codes are believed by many to unduly increase the cost of buildings. Modern critics might still agree with a 1920 Senate Committee report which concluded:

> The building codes of the country have not been developed upon scientific data, but rather on compromises; they are not uniform in principle and in many instances involve an additional cost of construction without assuring most useful or more durable buildings.[1]

Criticism has been growing in recent years. In the late 1960's, three national commissions, the Advisory Commission on Intergovernmental Relations (ACIR), the National Commission on Urban Problems (the Douglas Commission) and the President's Committee on Urban Housing (the Kaiser Committee) identified building codes as important factors affecting the efficient production of housing.[2]

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1 See the Advisory Commission on Intergovernmental Relations (ACIR) report, Building Codes, A Program for Intergovernmental Reform, Washington, D.C., 1966, for a review of the early criticism of building codes.

2 The ACIR Report, Building Codes, A Program for Intergovernmental Reform; the report of the National Commission on Urban Problems (the Douglas Commission Report); Building the American City, Washington, D.C., 1968, and the report of the President's Committee on Urban Housing (the Kaiser Committee), A Decent Home, Washington, D.C., 1968.

A recent book, The Building Code Burden, contends that "Misuse of regulatory powers has resulted in higher than necessary housing costs, obstruction of new building technologies, inefficient use of scarce national resources, and discrimination against lower income families."[1] A recent Ford Foundation study identifies building codes as one of the significant institutional barriers to the introduction of new energy technologies for buildings.[2]

Most observers, including members of the building community, would probably agree that building code regulations and the entire regulatory process can be improved, and a number of reforms have been initiated following the ACIR, Douglas Commission, and Kaiser Committee reports. These reforms include: (1) efforts by the Federal government to promote performance rather than specification standards, most recently through the establishment of the National Institute of Building Sciences (NIBS), (2) a move by State governments to increase their enactment of state-wide building codes, (3) the formation of the National Conference of States on Building Codes and Standards (NCSBCS) for the purpose of improving uniformity and reciprocity of codes between States, and (4) increasing cooperation between the model code associations through CABO -- The Council of American Building Officials. This organization was formed to promote uniformity in building codes and has sponsored a single-and two-family dwelling code.[3]

But at the same time that reforms have been initiated to reduce the adverse impact of building codes, the use of building codes and other building regulations has increased dramatically. One reason is the growth of building innovation. Some innovation has involved substitution of one building material or skill for another induced by changes in supply prices of labor or materials (such as the rapid increase in the price of building materials in the late 1960's and early 1970's) or by occasional shortages of a particular material or skilled labor input. Government has also encouraged building innovations in programs such as Operation Breakthrough. The number of building code provisions grow as new building innovations increase the diversity of products, designs, and building techniques. A second reason is that new building code provisions and regulations have also been introduced to satisfy

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1 Field, Charles G., Rivkin, Steven R., The Building Code Burden, Lexington Books, Lexington, Mass., 1975, p. 129.

2 Schoen, Richard, Hirshberg, Alan, and Weingart, Jerome, New Energy Technologies for Buildings: Institutional Problems and Solutions, Ballinger Publishing Company, Cambridge, Mass., 1975.

3 Schoen, Richard, Hirshberg, Alan, and Weingart, Jerome, New Energy Technologies for Buildings: Institutional Problems and Solutions. See Appendix C for a thoughtful summary of building code reform proposals and programs.

a broader definition of public welfare. State and national energy conservation regulations are the most prominent example. Regulations to accommodate needs of the physically handicapped and provisions requiring more secure doors, locks, and windows are others.

1.3 SCOPE AND ORGANIZATION

Section 2 develops a taxonomy to define and categorize building code impacts. A taxonomy is a systematic method of classification which can provide a framework for examining problems. Three major categories of building code impacts are described: (1) building code system impacts, (2) income distribution impacts, and (3) benefit-cost impacts. Only the third category, benefit-cost impacts, are treated in depth by this report. Section 3 suggests an assessment methodology based upon benefit cost analysis to measure, organize, and evaluate the potential benefits and costs of specific code provisions.

To illustrate the assessment methodology, Section 4 summarizes the results of a case study which examines the 1975 National Electrical Code requirement for the use of Ground Fault Circuit Interrupters (GFCIs) in new residences. GFCIs are devices designed to protect occupants against electric shock. Using sensitivity analysis, a range of estimates are made of how much the GFCI code provision costs society per life saved.

The report concludes in Section 5 with a discussion of the limitations of the approach, recommendations for implementing the assessment methodology, a summary of findings, and recommendations for future research.

2.0 TAXONOMY OF BUILDING CODE IMPACTS

The purpose of this section is to develop definitions and a taxonomy which can be used as a framework for understanding and investigating building code impacts.

2.1 THE NEED FOR A TAXONOMY

The impact of building codes can be examined from many perspectives. Homebuilders may be most concerned about the inconvenience and higher cost associated with compliance. Building code officials may stress technical or safety characteristics. Labor unions or building material producers may be most concerned about the impact of a particular code provision on them - that is upon employment or sales. Other members of the building community (architects, industrialized builders, subcontractors, national policy makers) have somewhat different concerns. Impacts may be local, regional, or national. Although some impacts are direct and relatively easy to assess, many are hidden, indirect, or closely interrelated with other building regulations. As the introduction indicated, reports by national commissions such as the Douglas Commission and other studies have identified many of these different types of impact. However, there is a wide range of opinion concerning the seriousness and magnitude of the problem.

Many of the recent reform efforts have been additive to the system -- that is, new organizations with new concerns or responsibilities have been added (they have not replaced existing organizations) to the existing system. The increase in the use of building codes to achieve new welfare objectives such as energy conservation or provision for the handicapped is also additive to the system. Thus, the need for a taxonomy is becoming more important as efforts to reform and improve the regulatory process have increased.

2.2 DEFINITIONS AND BASIC CONCEPTS

It is assumed that most readers are familiar with the building industry. Nevertheless, it is necessary to define some terms and concepts before the taxonomy of impacts can be examined in detail. A building code is a set of provisions regulating construction of buildings to protect the public health, safety and general welfare which become legal documents when adopted by Federal or State statutes or administrative regulation, or by local ordinances. For the purposes of this analysis, a building code is intended to include the broad definition providing for all building related elements such as structural, mechanical, plumbing, and electrical materials and systems.

The term building code system refers to the group of institutions which have evolved in the United States to regulate building construction through building codes. In addition to local and State building codes, major elements of the building code system are model codes, voluntary standards which are referenced in codes, and the public and private testing, certifying, research, or coordinating organizations which are specifically concerned with building codes and standards. Examples of such organizations are the National Conference of States on Building Codes and Standards (NCSBCS), the American National Standards Institute (ANSI), the American Society for Testing Materials (ASTM), Underwriters' Laboratories (UL), the National Institute of Building Science (NIBS), and the National Bureau of Standards (NBS).

The building code system is a major subset of the building regulatory system. Major elements of this system include other State and local statutes or ordinances such as health codes, architectural codes, housing codes, environmental regulations, and zoning or subdivision regulations[1]. In addition to State and local regulations, other major elements are Federal government actions which affect construction. These include: (1) Federal regulations issued by agencies, such as the Mobile Home Construction and Safety Standards issued by the Department of Housing and Urban Development (HUD), (2) Federal Conditions of Participation such as the HUD Minimum Property Standards (MPS), and (3) Federal procurement or construction criteria by agencies such as the General Services Administration (GSA).[2]

Building code impacts are the effects or consequences of building codes (a single building code provision, a building code, or of the building code system as a whole). A distinction between local, regional and national impacts is important because the type and magnitude of impacts can vary within each of these areas. Moreover, different types of decision problems and types of building code reforms may be necessary for each of these areas. Local impacts concern effects or consequences within a single code jurisdiction. The single code jurisdiction area may be a city, a county, or a State. Regional impacts concern effects of building codes in different code jurisdictions within a construction market area. The construction market area can vary in size and may extend to more than one State. For conventional housing construction the market is often confined to a large metropolitan area. Specialized types of building construction or manufactured housing may have somewhat larger market areas. National impacts concern effects or consequences of building codes for areas larger than the regional construction market area. These different types of "area" impacts are discussed in greater detail in the next subsection, which classifies building

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[1] For a recent description of other building regulations which affect housing see Seidel, Stephen R., Housing Costs and Government Regulations: Confronting the Regulatory Maze, The Center for Urban Policy Research, New Brunswick, New Jersey, 1978.

[2] I wish to thank Robert Kapsch of the National Bureau of Standards, Center for Building Technology, for suggesting this break-down of Federal actions which affect construction.

code impacts into three major categories, based primarily upon the economic characteristics of the impacts.

2.3 TYPES OF IMPACTS

2.3.1 Building Code System Impacts

Building code system impacts concern impacts which are due to the institutional system which has evolved to regulate building construction through building codes. Building code system impacts primarily stem from the non-uniformity and diversity of building codes between jurisdictions, and from the product acceptance process. The impacts can be roughly divided into three subcategories: (1) duplication impacts, (2) building innovation impacts, and (3) production organization impacts.

Examples of duplication impacts are added administrative, compliance marketing or testing costs incurred by private firms, and added administrative costs by public agencies. At the regional level these impacts primarily affect builders and local building departments. Added costs may occur, for example, when local review of building plans is required for identical plans already approved in a neighboring jurisdiction. This not only adds additional direct time and monetary costs to the builder, but indirectly may also increase the fees paid by the builder to the local jurisdiction if the added administrative costs by the local building department are passed on through higher fees. At the national level building material producers and suppliers are primarily affected by the added marketing, testing, certification, and listing costs associated with getting their product accepted by model, State, large city, and local code authorities. One indirect effect of these added costs is to increase prices.[1]

Building innovation impacts refer to a second, and perhaps more important effect -- delay in the diffusion of new building innovations. If the building code system acts as a barrier which delays the diffusion of new building innovations, the effects can be substantial at the national level. This can be true even when the effects of building innovation upon a particular building are small. An example of this type of impact is provided by a recent study which examined the potential cost saving in single-family houses from reduced sized venting (RSV), an innovative plumbing technology.[2] The study estimates that RSV offers a potential savings of $46 to $125 per single family house, depending upon regional model code requirements and plumbing system design. Over an eleven-year period from 1975 to 1985 the estimated savings to the

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1 The degree to which such costs are passed on as higher prices depends upon the particular market conditions of the product in question.

2 Marshall, Harold E., Ruegg, Rosalie, T., and Wyly, Robert S., "Cost Savings from Reduced-Sized Venting," Plumbing Engineer, July-August 1977.

nation as a whole from the use of RSV was $106.5 million. This estimate was based on a diffusion rate assumption which allowed for an increasing (but not complete) acceptance of RSV over the period. When half the basic diffusion rate was assumed, the estimated savings declined to $58 million. When one-and-one-half the basic diffusion rate was assumed, the estimated saving increased to $149 million.

One type of delay in the diffusion of an innovation occurs when local jurisdictions are slow in revising their code.[1] This type of delay might be reduced if some type of national product acceptance system such as the European Agrement System were instituted.[2] An Agrement System would not eliminate other types of delay however since building innovations can also be delayed by safety considerations which require investigation during the standards development process. A well known example of delay resulting from the standards development process concerns the automatic flue gas damper. The automatic flue gas damper is a potentially energy conserving device which was first marketed in the United States in the mid 1960's. Fuel savings in excess of 20 percent were claimed in certain circumstances. However, concerns regarding the safety of the devices have been difficult to resolve, so that a standard for these dampers has taken over ten years to develop.[3]

The third subcategory of building code system impacts is production organization impacts. Production organization impacts refer to the effects of building codes upon the structure of the building industry. One example of this type of impact concerns the way in which the design professions are organized. The non-uniformity of codes reinforce the

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[1] For a description and analysis of the many factors which affect the diffusion of building innovations see Chapter 6 of, Ventre, Francis T., Social Control of Technological Innovation: The Regulation of Building Construction, Unpublished PhD dissertation, Department of Urban Studies and Planning, Massachusetts Institute of Technology, 1973.

[2] A description of the Agrement system may be found in Appendix C of New Energy Technologies for Building: Institutional Problems and Solutions.

[3] Delay in the development of a flue gas damper standard and problems associated with certifying flue gas dampers were first brought to public attention in an article by Jack Anderson in October 1972. The CBS television program, "Sixty Minutes" also contained a segment on flue gas dampers in December 1976. The Senate Subcommittee on Antitrust and Monopoly conducted Hearings in March 1976 on Voluntary Industrial Standards. This hearing focused upon flue gas dampers and described the complex circumstances surrounding the delay.

local nature of the construction industry.[1] Perhaps the most well known production organization impact is that non-uniform codes are one factor which may prevent cost reductions in buildings constructed using industrialized building systems. Cost reduction may be prevented in several ways. An industrialized builder may choose to produce all buildings to the most stringent code provision requirements in the market area in order to achieve economies of scale in production. One estimate, by the Douglas Commission, placed the added direct construction costs as high as 15 percent for a manufactured home builder wanting to market his product in a 20 State area.[2] Alternatively, a manufacturer could limit his market by only producing for those less stringent jurisdictions within the market area. Or, the manufacturer could adjust the production process to produce individual buildings which meet the requirements of each jurisdiction within the market area.[3]

To summarize, three subcategories of building code system impacts have been briefly described. The types of impacts described are well known in the literature, and efforts to reform the building code system to reduce these impacts have been a central concern of the ACIR, Douglas Commission, and Kaiser Committee reports. While examples were given to illustrate how building code system impacts increase costs, no attempt was made to quantify the magnitude of these impacts. Building code system impacts are especially difficult to isolate from other equally important factors which affect the performance of the construction sector. For example, it is clear that building code constraints are only one factor which can inhibit industrialized system building. Other technical, institutional, and economic factors appear to be more important barriers. Thus, even though it is possible to show that production organization

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[1] For example, local A & E firms are typically hired by larger outside A & E firms due to their familiarity with the local code requirements, their contact with local code officials, and their knowledge of other local conditions.

[2] Building the American City, p. 262.

[3] See Field, Charles G., and Rivkin, Steven R., The Building Code Burden, Chapters 2 through 4 for an indictment of the adverse effects of building codes upon industrialized housing.

impacts prevent cost reduction by industrialized builders, there is little convincing evidence that if these barriers were removed industrialized system building would become significantly more competitive with conventionally constructed buildings of the same quality.[1]

2.3.2 Income Distribution Impacts

Income distribution impacts concern the way in which building codes affect the economic welfare of specific groups in the economy. Generally, any change in a building code, a code provision, or in the building code system will make some groups better off and other groups worse off. Income distribution impacts are divided into two subcategories on the basis of the type of group affected. Producer impacts concern the effects upon those trade/contractor/labor groups supplying inputs to construction. Consumer impacts concern the effects upon building purchasers and users.

Producer Impacts

Building codes confer substantial benefits or impose costs on specific producer groups. Thus, there is strong incentive for particular groups to seek to influence code decisions. An underlying assumption of this discussion is that the affected groups compete with each other to influence building code decisions in order to maximize their incomes.[2] Influence can be exerted in several ways: by political lobbying of legislative bodies, by participation in voluntary standard or model code groups, or by providing advice or technical information to building code decision makers.

The most extensive information available concerning the influence of interest groups at the local level comes from a survey by Field and

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[1] Industrialized building systems have only been partially successful in Europe (where building regulations are more uniform than in the U.S.) under a set of special conditions which favored their adoption. For a description of the many problems associated with industrialized systems see: Terner, I.D., and Turner, F. C., Industrialized Housing: The Opportunity and the Problem in Developing Areas, U.S. Department of Housing and Urban Development, Washington, D.C., 1972.

[2] This assumption forms the basis of one economic theory of regulation. A description of this theory is contained in: Posner, R. A., "Theories of Economic Regulation, "Bell Journal of Economics and Management Science, Vol. 5, No. 2, Autumn 1974, pp. 335-358.

Ventre of local building departments.[1] The data from the survey have been analyzed by Ventre, and by Field and Rivken.[2] Field and Rivkin stress the influence of local interests relative to outside interests. They contend that local building interests use building codes to restrict the introduction and diffusion of innovations into the local market.[3] They argue that this use of building codes is analagous to the national use of tariffs and quotas to restrict foreign competition. Ventre however, argues that this tariff analogy generalization cannot be carried far, and that it may only apply in a limited way to the marketing of manufactured housing.[4] Ventre emphasizes that:

> Analysis of the participation of industry elements in the decision to modernize the local building code reveals that not only does "everyone want to get into the act" but that the extent and nature of that participation of most of the actors alternate from high to low, pro to con, varying with the specific technology under review.[5]

Ventre's analysis supports the conclusion that although unions generally act to restrict the introduction of new, more progressive building code provisions, local building firms generally act to support such provisions. He also finds that the degree of support or resistance to change by each type of interest group varies by the type of change being considered. The competition between interest groups is characterized by shifting coalitions and a fragmentation of power. No one

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[1] Field, Charles G., and Ventre, Francis T., "Local Regulation of Building Agencies, Codes, and Politics," Municipal Yearbook 1971, Washington, D.C., International City Management Association.

[2] Ventre, Francis T., Social Control of Technological Innovations: The Regulation of Building Construction; Ventre, Francis T., "Decision-Aiding Communications in the Regulatory Agency: The Partisan Uses of Technical Information" in Research and Innovation in the Building Regulatory Process: National Bureau of Standards Special Publication 473, Washington, D.C., 1977; Field, Charles G. and Rivkin, Steven R., The Building Code Burden.

[3] This is one of the major themes of Field and Rivkin's The Building Code Burden. Chapter 4 develops this theme.

[4] Ventre, Francis T., Social Control of Technological Innovation: The Regulation of Building Construction, pp. 219-224.

[5] Ibid., p. 353.

interest group appears to be uniformly successful in influencing code decisions in their favor.[1]

Ventre's findings that unions generally act to restrict while local building firms act to support more progressive local building code decisions is confirmed by an econometric study by Oster and Quigley.[2] All of the studies described above find other factors (such as the education level of the chief building official, the region, the type of jurisdiction, and the degree of professional contact with other professionals and with model code associations) to be important in the local building code decision-making process.

Less information is available concerning the influence of interest groups at the national level. The information available suggests that trade associations are very active at this level. A study for the Douglas Commission by Mahaffey gives one example of this type of activity:

> During the 1967 convention of the International Conference of Building Officials (ICBO), 161 proposed code changes were considered. Of this number, 68 were proposed by code enforcement officials, 50 were instigated by the trade associations and 43 came from professional groups. Thirty-four model code changes (out of 161 proposed) were approved by the voting membership. Sixteen of the changes approved were instigated by code officials, 17 were originated by trade associations and only one of those approved came from the professional groups.[3]

Trade associations were particularly successful in this example. Although they submitted only 31 percent of the proposals, half of the proposals approved were originated by trade associations.

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1 Ventre's general conclusions are developed in some detail, especially in Chapters 4 and 6 of Social Control of Technological Innovation: The Regulation of Building Construction.

2 Oster, Sharon M. and Quigley, John M., "Regulatory Barriers to the Diffusion of Innovation: Some Evidence from Building Codes," The Bell Journal of Economics, Vol. 8, No. 2, Autumn 1977, pp. 361-377. The study uses data from the Field and Ventre Survey as well as independent data on the degree of unionization and on local building firm size.

3 Mahaffey, C. T., A Special Study on Building Codes, Background Paper No. 18 for the National Commission on Urban Problems, Washington, D.C., 1968, pp. 3-7.

Trade associations are also very active on the standard committees of the voluntary standards organization. These standards are referenced in building codes. Critics of the voluntary standards system contend that dominance by trade or industry groups may lead to anticompetitive practices, or to standards which are not set at the optimal level.[1]

Consumer Impacts

This subcategory of Income distribution impact concerns the impact on building purchasers and renters of the increase in construction costs due to building codes. A building code sets one level of protection, but this level may be "too high" for low-income families on limited budgets to purchase new housing. If building codes increase the price of new housing then the long run impact is to reduce the supply of new housing. This leads to a complex set of indirect effects and substitutions which may occur both within and outside of the housing market. In some housing markets the very poor may compete with higher-income families for existing houses, or may be housed in unsafe or unhealthy units which might otherwise be abandoned. Some low/middle-income families may no longer be able to purchase new houses, or may do so by leaving less of their budget available for other goods and services.

If strong emphasis is placed on building safety fewer resources are available for other goods and services, including investment in other safety programs. Several researchers have suggested that more lives could probably be saved by investing the same resources in areas other than building codes or regulations.[2] For example, one researcher roughly computes that traveling is 14 times as dangerous per person hour as occupying buildings, and that a person is about 200 times more likely to die of disease than from a building accident. Another study roughly estimated that strict enforcement in existing hospitals of the Life Safety Code of the National Fire Protection Association would cost $12.7 to $63.5 million for each potential

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1 Very little research concerning the voluntary standards system has been accomplished. The only major economic study is David Hemenway's Industrywide Voluntary Product Standards, Ballinger Publishing Co., Cambridge, Mass, 1975. See his Appendix B and C for a critical evaluation of the membership of two specific standards committees, and Chapter 9 for a summary of his major findings.

2 O'Hare M., "Structural Inadequacies in Urban Environmental Management," Regional and Urban Economics, Vol. 3, No. 1, 1973, pp. 63-82.

year of life saved. In contrast, kidney dialysis was estimated to cost about $20,000 per potential year of life saved.[1]

2.3.3 Benefit-Cost Impacts

Benefit-cost impacts concern the positive and negative effects of a building code or a code provision on society as a whole. Benefits are defined as the positive impacts while costs are defined as the negative impacts of a code or a code provision. It is important to make the distinction between benefits and costs clear, because the classification of a particular impact as a benefit or as a cost is a definitional question. For example, where a code provision is proposed to give additional protection against a building hazard, a primary benefit (positive impact) is the reduction in the risk of loss from that hazard. A primary cost (negative impact) is the added resources (primarily construction costs) needed to comply with the code provision. In contrast, when a code provision is proposed to allow new or innovative building technology, the primary benefit intended may be an increase in quality or a reduction in construction costs. However this expected benefit may be only obtainable by increasing the risk of loss from a building hazard (a cost). Thus, a change in risk or a change in construction cost can be either a benefit or a cost. A _decrease_ in risk or construction cost is treated here as a benefit. An _increase_ in risk or construction cost is treated here as a cost.

It is important to understand that this category concerns social benefits and costs. That is, the concern is for the positive or negative impacts upon society (the nation) as a whole. This contrasts with the income distribution impact category concern for the impact on groups smaller than the nation as a whole such as trade associations, local unions, subcontractors, contractors, or building material producers. Further description of benefit-cost impacts is deferred to section 3, which proposes an assessment approach to evaluate the benefit-cost impacts of single code provisions.

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[1] Feeley, Rich, Chapman, Diana, and Fielding, Jonathan F., "Structural Codes and Patient Safety: Does Strict Compliance Make Sense?," _American Journal of Law and Medicine_, Vol. 3, No. 4., Winter 1977-78, pp 447-454.

3.0 ASSESSING BENEFIT-COST IMPACTS

This Section presents an approach to evaluate the potential benefit and cost impacts of specific building code provisions. The approach is a systematic technique which may be useful to building officials, legislators, or other members of the building community concerned with building code decisions. Its purpose is to aid decision makers by providing a framework to assemble and organize available or easily obtainable information. The approach can be used to estimate some of the potential benefit or cost outcomes of a building code decision, but it recognizes that information is often uncertain so that exact estimates cannot be made.

No claim is made that the methodology described in this chapter can be applied to every code provision, nor that, once an evaluation is made, all concerned parties will reach the same conclusion. It is not a substitute for the need to make judgments or achieve consensus in the decision process. However, the approach can contribute to this decision process by helping to define objectives and alternatives, by focusing on key issues, and by reducing uncertainty. Each step is explicit and its assumptions are clearly spelled out.

The assessment approach involves six general steps. They are:

- Define the problem and clarify the objectives
- Identify alternatives
- Identify the benefits and costs to be considered in the analysis
- Estimate the annual benefits and costs
- Peform the analysis
- Assess the results

The assessment approach based upon these steps is designed to be used primarily to evaluate a proposed code provision change to assess whether it is desirable to accept or reject the proposed change. It can also be used to evaluate "how much" (i.e., the level or scope of application) of a particular type of code protection is desirable. For example, it could be used to evaluate the expected outcomes of requiring one, two, or three smoke detectors for a given area to be protected. Finally, if a number of different proposed code changes are evaluated, the approach can be used to rank the desirability of the different proposed changes. An example of the "ranking" type of decision might be whether to accept a proposed change concerning fire safety such as a sprinkler requirement or accept a proposed change concerning safety from electric shock such as a grounding requirement.

The approach is also helpful for evaluating code decisions which involve significant interdependencies. Interdependencies occur if the approval of one code provision will affect the benefit or cost impacts of other code provision changes being considered. For example both smoke detector requirements and flame spread requirements would be expected to reduce fire deaths. However, approval of one requirement will affect the number of lives which might be saved by the other. When there are only a few interdependent code provision changes being considered, each provision can be first evaluated independently of the others and ranked. If the highest ranked provision is approved, then the remaining provisions can be reevaluated to account for changes in benefits and costs.

The specific assessment approach presented here is not intended for use in evaluating energy conservation codes. Detailed treatment of factors particular to energy conservation is beyond the scope of this study, but is available from other research.[1]

The remainder of this section describes in turn each of the six steps in the assessment approach. Section 4 presents a case study to illustrate how the approach can be applied in practice.

3.1 DEFINING THE PROBLEM AND CLARIFYING THE OBJECTIVE

It is easy to define the general objective of building codes as the protection of public health, safety and general welfare. It is often more difficult to relate a code provision to a particular health, safety, or general welfare problem. An initial requirement then, is defining the specific objectives of the code provision. Ideally, the code language should be as precise, complete, and unambiguous as possible. Requiring precise language does not imply a rigid prescriptive code. Rather, the code provision should be worded in such a way that its meaning, intent, and application is clear. A clear understanding of what is to be analyzed is essential. The assessment process, which identifies and measures the potential benefits and costs, can help to define the specific objectives of the code provision.

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[1] See Petersen, Stephen R., The Role of Economic Analysis in the Development of Energy Standards for New Buildings. National Bureau of Standards Interagency Report 78-1471, May 1978 for an economic analysis approach to develop a national energy conservation standard. See Ruegg, Rosalie T., McConnaughey, John S., Sav, G. Thomas, and Hockenbery, Kimberly, Life-Cycle Costing: A Guide for Selected Energy Conservation Projects for Public Buildings National Bureau of Standards Building Science Series 113, June 1978 for an approach to evaluate specific energy conservation measures in buildings.

Once the proposed code provision change is defined, it is necessary to find a common base for evaluation. The effect of a code provision depends on the specific design used to comply with the provision. Therefore to assess its impact, it is necessary to choose a typical design which incorporates the proposed code provision change. When the code provision applies to more than one building type or allows more than one method to meet the requirement, additional designs are needed. For a performance based code, typical designs could be based upon a manual of accepted practice.

3.2 IDENTIFYING THE ALTERNATIVES

Normally, many alternatives to a code provision can be identified. Selection of the alternatives to be considered should depend upon the level at which the decision is being made, and upon the range of feasible alternatives.

To illustrate the problem of selecting alternatives, consider fire safety. Many alternatives other than building codes can protect the public from building fires. At the national level, sponsoring fire research, providing subsidies for local fire protection services, regulating or reducing consumption of cigarettes, or establishing a fabric flammability standard are some of the alternatives to building code provisions. However these alternatives are often outside the range of feasible alternatives for building code decision makers. At the local level, purchasing better fire equipment, building more fire stations, increasing the resources available for inspection and enforcement of existing regulations, or conducting a public education campaign are some of the alternatives to building code provisions. They are often within the range of feasible alternatives to local decision makers.

The purpose of raising this issue is not to propose that building code decision makers compare the benefit and cost impacts of each building code provision with all other types of action which society might take to save a life, avert an injury, reduce illness, or prevent property damage. The specific assessment approach developed in this study is generally not appropriate for evaluating non-building code alternatives. The issue is raised to alert building code decision makers to be aware of non-building code actions which may be effective alternatives to building codes. When these actions are within the feasible range of alternatives, an assessment of these alternatives may also be appropriate.

The choice of alternatives for evaluating proposed building code provision changes depends upon how the assessment approach is used. When the assessment approach is used to evaluate whether a change should be accepted or rejected, the only alternative considered is the existing building practice. Typical designs which incorporate the proposed change are compared to typical designs without the proposed change. When the assessment approach is used to evaluate "how much" of a particular code provision is desirable, the alternative levels of protection are specified. Typical designs for each level are developed and compared against each other, and with typical designs for the existing building practice.

3.3 IDENTIFYING THE BENEFITS AND COSTS

3.3.1 Benefits

Any positive impact of a proposed building code provision is a benefit. Benefits can be divided into primary benefits and secondary benefits. Primary benefits can be thought of as those positive impacts which the provision is intended to produce directly. The most important type of primary benefits concern safety. They are reductions in the loss of life, injury, and property damage from building hazards.

Other benefits such as lowering construction costs or improving the usefulness of the building are also important. Sometimes the benefits are intended for a specific type of building occupant or user such as the handicapped. At other times, code provisions may be proposed to deal with a particular problem such as historic restoration.

Secondary benefits are positive effects which are induced or indirectly generated by a code provision. For example, the secondary benefits of a requirement for a sprinkler or a smoke detector system may be a reduction in the need for fire insurance, or a reduction in the need for fire protection services. A somewhat different example concerns indirect effects in the building supply industries. Occasionally, a code provision may help to create a large new market for a specific product (for example smoke detectors). This large market may in turn induce cost-reducing product development, or economies of scale in production. Even more indirect and elusive are psychological or environmental (quality-of-life) benefits which may accrue to building owners or occupants.

3.3.2 Costs

Any negative impact of a proposed building code provision is a cost. Like benefits, costs can be divided into primary costs and secondary costs. Primary costs are the added labor, equipment, materials, and other compliance costs which directly result from the code provision change. Another important type of primary cost which may occur when new construction cost-reducing technology is proposed, is any added risk to safety which the new technology might introduce.

Secondary costs are negative effects which are induced or indirectly generated by a code provision. They are often subtle, hard-to-measure, indirect costs which result from the code provision's influence on design, human behavior, or industry practice. For example, false alarms by smoke detectors may induce heart attacks or injuries if emergency egress is attempted. False tripping of electric circuits by Ground Fault Circuit Interrupters (GFCI's) or false alarms by smoke detectors may encourage some homeowners to remove the devices themselves, thus exposing them to a shock hazard. A code provision requiring sprinkler systems in high-rise buildings on some occasions may induce owners, designers, or developers to choose to build low-rise rather than high-rise buildings. This may affect safety as well as construction costs (for example by increasing the risk of stair accidents). As a final example consider the egress requirements for travel distance to an exit in hospitals. Since exits take room which might otherwise be used for treatment a difference in the travel distance to exit requirement may induce change in design, say from a two story to a three story hospital. Even if this type of design change were predictable so that the difference in construction cost of the two designs could be estimated, other more subtle cost changes might also occur. For example, the productivity of doctors and nurses might change (one design might require more time to transfer patients, or additional nursing stations might be needed).

3.4 ESTIMATING THE ANNUAL BENEFITS AND COSTS

In practice, it is not possible to measure accurately all the benefits and costs identified with a specific building code provision. Part of this measurement problem is inherent in the very nature of construction, since buildings serving the same function are unique in many characteristics such as design, size, location, or materials used. Another part of this measurement problem is due to imprecise or incomplete code language which allows substantial latitude for interpretation and enforcement in different code jurisdictions. A third reason for this measurement problem is that statistics on building safety are imprecise, not available, or not in a form which can be easily used. Another reason is that some benefit and cost impacts are intangible; that is, although they can be identified, there is no known or accepted method available to measure their magnitude. Finally, assessing code provisions takes resources. Even if it were possible to measure more accurately certain impacts through extensive research, the added degree of precision may not be worth the added time or money expense.

Even though not all benefit and cost impacts are easily measured, useful assessment can still be accomplished. In this assessment approach, potential benefits and costs can be evaluated using information having different levels of reliability and precision. Available information is often the only assessment information needed. The approach assumes that some of the information used to estimate benefits and costs is uncertain.

To estimate annual benefits and costs it is first necessary to establish a base period for the analysis and to determine the number of buildings affected by the code provision.

The base period year is the starting point for the assessment. Usually the base period is one or two years before the code provision change is intended to become effective. For example, a code provision change which is to become effective in 1978 may have a base year of 1977 or 1976, depending upon the availability completeness of the benefit and cost information.

A major element in the assessment approach is determining the number of buildings to be protected relative to the total number of buildings in which the losses occur. Since the building codes are not national in scope and vary from one code jurisdiction to another, a simplifying assumption concerning the number of buildings to be protected is needed. The assumption made is that the code provision is a mandatory requirement for all buildings constructed in the base year[1]. Since building construction is subject to building cycles, an average of at least five years is preferred to a single year estimate of the number of buildings constructed in the base year.

An example can illustrate the use of this approach. Suppose a code provision which applies to all residential construction is to become effective in 1976. Between 1971 and 1975 an average of approximately 1.7 million private single and multi-family units were built.[2] Using 1975 as the base year, assume that 1.7 million residential units were constructed in 1975 which incorporated the proposed code provision. If the total stock of residences in 1975 was about 72 million then the number of buildings protected relative to the total number of buildings is about 2.4 percent (1.7/72 = .0236).

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[1]In this base year approach, only the potential benefits and costs which result from compliance with the code provision in the base year are evaluated. An alternative approach is to estimate the actual number of buildings which are affected by the code provision in each year the provision is expected to be in effect. This alternative approach provides estimates of the total benefits and costs associated with the code provision which are not provided by the base year approach. However, the base year approach is suggested for decision making because the alternative approach is more complex, requires more data, and may be subject to greater uncertainty due to the need to forecast diffusion rates and the future number of buildings constructed.

[2]See the Ground Fault Circuit Interrupter Case Study in Section 4 for sources of these types of statistics.

3.4.1 Changes in Safety

The basic steps used for estimating changes in the level of safety are to:

- determine the annual loss
- determine the effectiveness of the code provision in averting the loss.

Determining the Annual Loss

Sometimes a code provision will affect only one type of hazard and one type of loss. Often however, more than one type of hazard and loss may be affected. A decision tree, illustrated in Figure 3.1, may be helpful to insure that all relevant hazards and losses are considered. The decision tree shows the set of probable outcomes which can occur from a building code provision decision. Whether or not the code provision is in effect, there are only two outcomes -- either a hazardous event occurs or it does not. For clarity, only one branch showing the loss outcome is illustrated in Figure 3.1. Several of the more important types of hazards (Fire, Natural Disaster, Accident) and losses (Death, Injury, Property Damage) are illustrated. In practice, a more comprehensive decision tree which shows the specific types of hazards and losses affected may be necessary.[1]

Once the types of specific losses have been listed, an estimate of the annual loss is made. Much of this information is published, but the source, level of detail, and accuracy vary with the type of hazard being investigated. For example, Accident Facts published annually by the National Safety Council and Vital Statistics of the U.S. published annually by the U.S. Department of Health, Education and Welfare provide information on accidents. The National Fire Protection Association (NFPA) publishes annual estimates of fire loss (deaths and dollar property loss) in the Fire Journal. The National Fire Prevention and Control Administration (NFPCA), U.S. Department of Commerce, is also beginning to publish fire loss information.

Some losses can be measured in dollars, some can be quantified but not in dollars, and some may be intangible. The minimum information needed for estimating death or injury losses is the annual number of deaths and injuries. Additional information concerning age, sex,

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[1] For one example see, Buchbinder, Benjamin, Helser, Susan G., and Offensend, Fred, Preliminary Report on Evaluating Alternatives for Reducing Upholstered Furniture Fire Loses, National Bureau of Standards Interagency Report 77-1381, November, 1977.

DECISION TREE

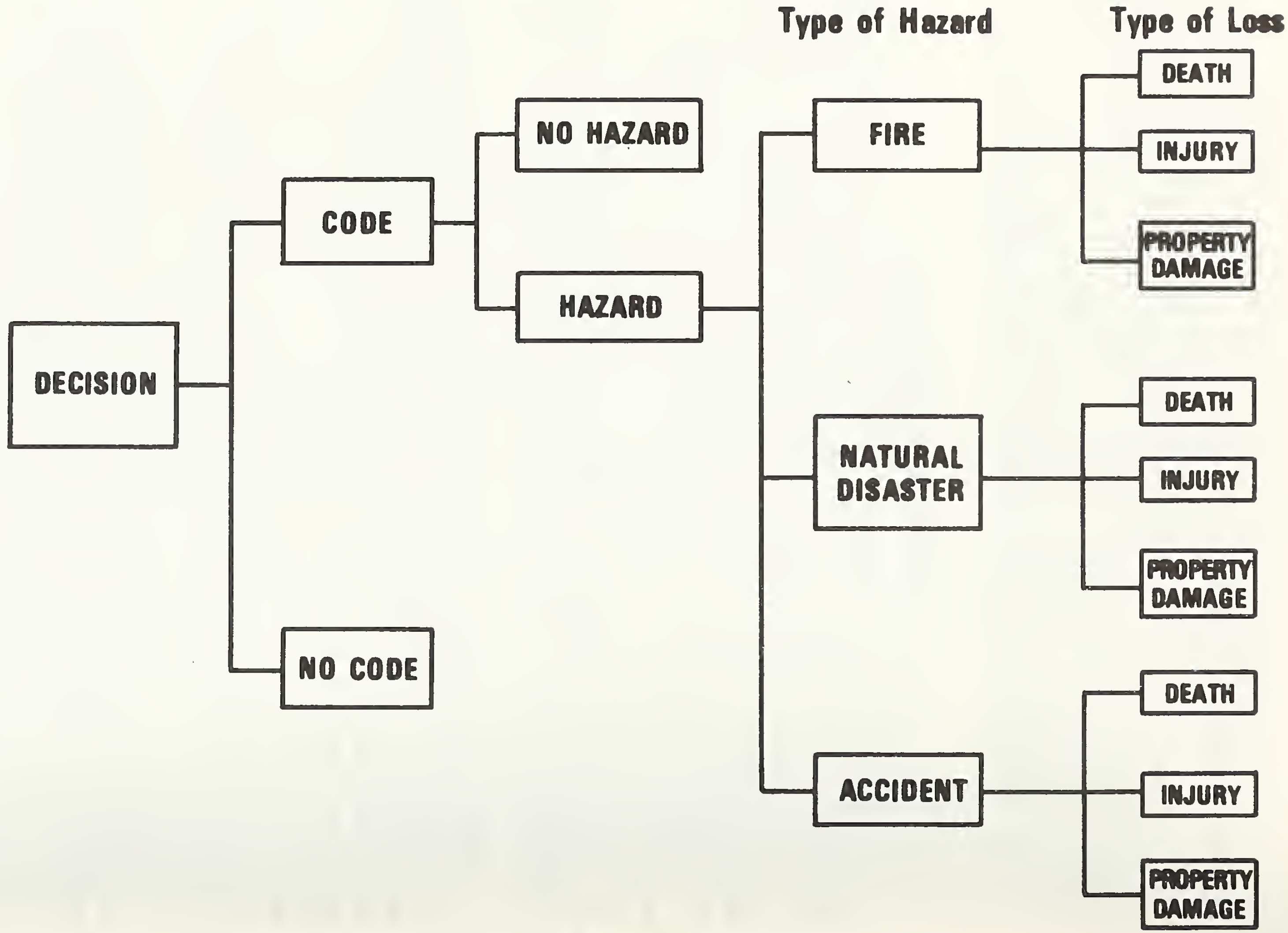

Figure 3.1

location, circumstances of occurrence, frequency and severity of injury, and dollar expenses such as medical costs should also be collected if available. Property damage information is normally measured in dollars. For natural disasters, the above information should be linked with geographic factors.[1]

Determining the Effectiveness of the Code Provision

Loss information and the basic assumption concerning the number of buildings protected is first used to estimate the loss in the base year which might be averted by the code provision if the provision were completely effective. To continue the above example, assume there are about 6000 fire related deaths in residences each year. If a code provision requirement which could prevent all fire deaths in residences was mandatory in 1975, then at most 144 fire deaths in that year could be averted (6000 x .024 = 144). This assumes that losses are evenly distributed between new buildings and existing buildings.

But code provisions are not expected to eliminate all risk of loss. Many aspects which affect loss outcomes are not influenced by codes. For example, a code provision intended to prevent fire loss may not be totally effective against an arsonist. A smoke detector may not be effective in reducing loss of life (even if it works properly) for persons under the influence of drugs or alcohol. An exit required by codes for emergency egress may be locked. A building designed to meet structural requirements for a low seismic risk area may not withstand a major earthquake.

To estimate the actual effectiveness of a code provision, some understanding is necessary of how building hazards and losses from building hazards occur, and how the code provision works to reduce the risk of loss. Often standards research or engineering/testing studies are available to provide information about how the code provision is to work. Less is known about causation, or the chain of events which lead up to hazards and losses.

One problem is that events which lead to death, injury, or property damage are complex. For example, what is the cause of death if a person falls from a ladder after receiving an electric shock from a power tool? Is the death due to a fall or electric shock?

Despite these difficulties, sufficient information is usually available to perform analysis. One primary source of information

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[1]See Sav, G. Thomas, Natural Disasters: Some Empirical and Economic Considerations; National Bureau of Standards Interagency Report 74-473, February 1974, for a description of natural disaster losses.

has been to examine case studies or investigate hazardous events to identify common patterns. Other primary sources of information are the technical studies, field tests, and documentation used for standards development or to support code provision change proposals. Generally, no one data source or study contains all the necessary information regarding a particular type of hazardous event.

One factor which is often very important in determining the effectiveness of a code provision concerns the initial assumption that losses are equally distributed between new and existing buildings. The code provision applies to new buildings, but the loss statistics are based upon losses in the existing building stock. Often more losses would be expected in older buildings than in newer buildings. For this reason the initial assumption that losses are proportionally distributed between new and existing buildings may often need to be adjusted in the analysis.

The effectiveness of the code provision can be analyzed for each type of loss (death, injury, property damage) for which annual loss data exists. The result of this analysis is an estimate of the annual loss averted for each type of loss in the base year. The case study in Section 4 illustrates how the effectiveness of the code provision can be analyzed using diverse data sources.

3.4.2 Changes in Construction Costs

The basic steps for estimating changes in construction costs are:

- Develop typical designs
- Estimate construction cost changes from the typical designs
- Estimate the total change in construction costs for the base year

Developing Typical Designs

The type and number of typical designs needed to establish a common base for evaluation depend primarily upon the characteristics of the buildings to which the code provision applies. The type and number of designs developed may also depend upon the level of complexity desired in the analysis. Sometimes the size of the building or the number of stories may be important, so that separate designs on the basis of these criteria may be appropriate. In other circumstances, typical designs may be based upon the type of building (single family detached, row houses, multi-family hi-rise), the type of material used (masonry, structural steel, reinforced concrete), or the type of construction practice used (prefabricated or conventional on-site).

Regional differences in building characteristics are also important in choosing typical designs.

Estimating Changes in Construction Cost from Typical Designs

Several methods can be used to estimate construction cost changes from the typical designs. The most common methods are either to use an established cost estimating guide, or to obtain specific estimates by professional cost estimators. Sometimes it may be possible to examine actual cost information gathered from construction sites. Whichever cost estimating method is used, it is important to specify the steps taken to arrive at a final dollar figure. For most methods of cost estimation this means that, whenever possible, both physical measures and price information are needed. Materials should be listed by type and quantity. Each labor skill or type of major equipment (excluding hand tools) should be measured in terms of time. The material prices, wage rates, equipment rental fees, and overhead/profit charges used to arive at the dollar estimate should be specifically identified.

Estimating the Total Change in Construction Costs for the Base Year

Once the cost estimate for each typical design is completed, it is multiplied by the number of buildings assumed to use that design in the base year. Then the total cost for each typical design is added to obtain the total change in construction costs for the base year.

3.5 PERFORMING THE ANALYSIS

It would not be reasonable to evaluate a code provision on the basis of estimates of the initial benefits and costs in the base year alone. Three additional steps are needed to complete the analysis. They are:

- Estimate the effective useful life of the technology required by the code provision
- Estimate the potential benefits and costs over the effective useful life
- Develop measures which compare the benefits and costs

3.5.1 Estimating the Effective Useful Life

Since buildings are durable, the benefit and cost impacts of the technology required by a code provision need to be evaluated over time. With regard to safety, a code provision may protect against death, injury or property damage for many years. But over time, for a variety of reasons (such as aging, fatigue, poor maintenance or repair, etc.), the code provision may lose its effectiveness to protect against hazards. Generally, there is no simple way to predict rates of failure to determine the change in effectiveness over time.[1] The approach recommended in this study is to estimate an "effective useful life" for the code provision. Sometimes manufacturers' studies or laboratory/field tests may provide information on durability or reliability for making an estimate of the effective useful life. Often reliable information is not available. In this case, when there is uncertainty associated with the estimate, sensitivity analysis is also recommended.

3.5.2 Estimating Potential Benefits and Costs Over the Effective Useful Life

Deaths and Injuries

The base year estimate of the change in the number of deaths and the number of injuries are assumed to be constant over the effective useful life.[2] To estimate the total deaths/injuries averted, the base year estimates are multiplied by the effective useful life. For example, assume that a code provision is estimated to avert 2.5 deaths and 7 injuries in the base year. Then for a 20 year life, the code provision will potentially avert 50 deaths (2.5 x 20 = 50) and 140 injuries (7 x 20 = 140).

Dollar Measures of Benefits and Costs

Benefits or costs measured in dollars which occur after the base year must be converted to a common base year dollar measure. The process of converting future dollar benefits or costs to a common time is called discounting. Discounting is necessary because money has a time value. Money today can be invested to earn a return. Money received in the future has less value than the same amount received today. For example, $1 today is worth $1.10 one year from now at a interest (or discount) rate of 10 percent. Conversely, $1.10 received one year from now is worth only $1.00 today.

Future benefits or costs can be discounted using discount formulas or factors. The result obtained from discounting is called a present worth (or present value). Table 3.1 gives the appropriate present worth factors for a 10 percent discount rate. The discount formulas,

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[1]There are statistical methods which may be possible in some cases. See, Apostolakis, G., Mathematical Methods of Probabilistic Safety Analysis, prepared for National Science Foundation, Washington, D.C., Research Applied to National Needs, University of California, Los Angeles, Sept. 1974.

[2]This approach assumes that all deaths averted are of equal value to society. No distinction is made between averting the death of a child or an adult, a male or female.

TABLE 3.1

PRESENT WORTH FACTORS FOR A DISCOUNT RATE OF 10%

Year	Uniform Present Worth Factor	Single Present Worth Factor	Year
1	0.909	0.9091	1
2	1.736	0.8264	2
3	2.487	0.7513	3
4	3.170	0.6830	4
5	3.791	0.6209	5
6	4.355	0.5645	6
7	4.868	0.5132	7
8	5.335	0.4665	8
9	5.759	0.4241	9
10	6.144	0.3855	10
11	6.495	0.3505	11
12	6.814	0.3186	12
13	7.103	0.2897	13
14	7.367	0.2633	14
15	7.606	0.2394	15
16	7.824	0.2176	16
17	8.022	0.1978	17
18	8.201	0.1799	18
19	8.365	0.1635	19
20	8.514	0.1486	20
21	8.649	0.1351	21
22	8.772	0.1228	22
23	8.883	0.1117	23
24	8.985	0.1015	24
25	9.077	0.0923	25

and the discount factors for other discount rates and periods of time are available in standards engineering economics texts.[1]

The uniform present worth factor is used when the dollar value of benefits or costs are assumed to be uniform, occurring each year of the effective useful life. It is likely that most dollar benefits or costs which have base year estimates (such as property damage averted, medical costs, routine operating, maintenance and repair costs) can be treated as uniform recurring dollar amounts. To obtain a present worth, simply multiply the appropriate uniform present worth factor by the base year estimate. For example, if the base year estimate of property damage averted is $2 million, and the effective useful life is 20 years, only two steps are needed to compute the present worth. First, the uniform present worth factor is obtained, which in this example is 8.514 (from year 20, Column 1 of Table 3.1). Second, this is multiplied by the base year estimate to obtain a present worth of about $17 million (8.514 x $2 = $17,028,000).

The single present worth factor is used if non-uniform dollar costs occur during the effective useful life. The following example illustrates how to calculate a present worth using single present worth factors. Assume that smoke detectors have an effective useful life of 10 years, and that battery operated detectors need batteries every two years. If there are 500,000 battery operated smoke detectors installed in the base year, and the base year price of batteries is $2, then the battery replacement cost is estimated at $1 million. The single present worth factors for years 2, 4, 6, 8, are each multiplied by $1 million and the present worths are summed. For this example the present worth is $2.6 million [(.8264 x $1,000,000) + (.683 x $1,000,000) + (.5645 x $1,000,000) + (.4665 x $1,000,000) = $2,600,400].

The discount rate chosen in this example is the 10 percent real rate used by the Federal government to evaluate government investment.[2]

3.5.3 Developing Measures for Comparing Benefits and Costs

If all benefits and costs are measured in dollars, a number of different criteria can be used for comparing benefits and costs. When the purpose of the analysis is to determine "how much" (i.e., the level or scope of application) of a particular type of code protection is desirable, then maximizing net benefits (total benefits minus total

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[1] See for example, Grant, Eugene L. and Ireson, W. Grant, Principles of Engineering Economy, 5th ed. (New York: The Ronald Press Co., 1970).

[2] See Office of Management and Budget, Executive Office of the President, Circular No. A-94 (Revised), March 27, 1972.

costs) is an appropriate measure.[1] When there is a "ranking" type of decision to select a limited number of code provisions, a benefit-cost ratio may be a more appropriate measure.[2]

However there will seldom be a case when all benefits and costs are easily measured in dollars. Often the most important benefits are the number of deaths and injuries averted. An approach is needed which allows comparison of benefits and costs which are measured in both monetary and non-monetary terms.

The preferred approach would be to estimate a current and future dollar value for the deaths and injuries averted. Then, standard benefit cost criteria could be used. Unfortunately, most of the existing methods used to put a dollar value on lives saved or injuries averted are not consistent with the economic theory which underlies benefit-cost analysis.[3]

A simpler variant of this approach is to assign standard dollar values for deaths or injuries averted. However, the central problem of selecting the proper set of standard values which are acceptable to decision makers remains. Promising theoretical and applied economic and behavioral research based upon concepts which are more consistent with benefit-cost analysis is being conducted.[4] This research may eventually result in adequate methods to estimate dollar values which are acceptable to decision makers.

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[1]See Chapman, Robert E. and Colwell, Peter F., Economics of Protection Against Progressive Collapse, National Bureau of Standards Interagency Report 74-542, September 1974 for an economic model which describes this concept.

[2]See Mishan, E. J., Cost-Benefit Analysis: An Introduction, New York, Praeger, 1971, or Dasgupta, Ajit and Pierce, D. W., Cost-Benefit Analysis: Theory and Practice, New York, Harper and Row, 1972 for a thorough description on the uses of Benefit-Cost analysis for decision making.

[3]For excellent summaries of the various measurement approaches and their deficiencies see, Mishan, E. J., "Evaluation of Life and Limb: A Theoretical Approach," Journal of Political Economy, July-August 1971, pp. 687-705; or Jones-Lee, M. W., The Value of Life: An Economic Analysis, University of Chicago Press, Chicago, IL, 1976.

[4]Recent economic literature has focused on the willingness-to-pay approach. Behavioral literature has focused upon evaluating attitudes towards risks. See Clark, E. M. and Van Horn, A. J., Risk-Benefit Analysis and Public Policy: A Bibliography, Energy and Environmental Policy Center, Harvard University, November 1976, for citations.

The approach proposed here is to develop ratios which estimate how much a code decision will cost society to save one life. In this approach, the net dollar cost is divided by the estimated total number of deaths averted over the code provision's useful life to obtain a "cost per life saved" statistic. This approach assumes that deaths averted in the future are of equal value to society as deaths averted in the present.[1]

To illustrate the concept, assume that a code provision will avert 30 deaths, 900 injuries, and a total of $50 million of property damage (in base year present worth dollars) over a 20 year life. The initial added construction costs to incorporate the code provision requirement in the base year is $150 million. Since the property damage averted (a benefit) is in base year dollars, it can be subtracted from the initial added construction costs to obtain a net cost (dollar costs - dollar benefits) of $100 million. The "cost per life saved" is $3.33 million ($100 million/30 deaths averted = $3.33 million per life saved). In comparing two alternative code provisions, the provision having the lowest cost to save a life is preferred. Note that all benefits and costs measured in dollars are combined to form a net cost. If dollar benefits exceed dollar costs then a code provision is already cost effective using standard benefit-cost criteria. For these measures the net cost has a negative value, and the comparison rule that the code provision having the lowest "cost per life saved" is preferred still applies.

A similar ratio can be calculated for code provisions which are proposed to reduce initial construction costs but which may introduce a small added risk of death or injury. The statistic is formed by dividing the net dollar benefits (dollar benefits - dollar costs) by the estimated total number of added deaths over the useful life. In comparing code provisions of this type, those provisions having higher ratios are preferred.

To evaluate injuries both the frequency and the severity of the injuries averted should be considered. When severity information is not available (as in the above illustration) the number of injuries averted can still be considered. For example, in the illustrative example above, there are 30 injuries averted for each death averted. The "cost per life saved" ratio can also be considered the cost to

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[1]This assumption means that the "value" of a death averted in the future is not discounted to be the present. Although It is also reasonable to assume that a life saved in the present is of more value than a life saved in the future, there are a number of problems associated with the appropriateness of discounting to reflect this difference. See Zeckhauser, Richard, "Procedures for Valuing Lives," Public Policy, Vol 23, No. 4, Full 1975, pp 419-464.

save one life and avert 30 injuries. This interpretation provides added information for ranking code provisions.

If information on severity is available, one method which might be adopted is to weight different types of losses.[1] Several different weighting schemes which relate losses from death to serious and minor injuries are shown in Table 3.2

Table 3.2

Weighting Schemes

Type of Loss	Weighting Scheme Number		
	1	2	3
Death	1	1	1
Serious Injury	1	0	.35
Minor Injury	1	0	.009

Schemes 1 and 2 represent two extremes. In Scheme 1 each type of loss is given equal weight, while in Scheme 2 only loss of life is given weight. Scheme 3 is intermediate, giving the most weight to death and the least to minor injuries. The primary problem with weighting schemes, like that of assigning standard dollar values, is the need to develop adequate methods to estimate weights which are acceptable to decision makers.[2] There are several potential approaches to assigning weights. One is to ask people through interviews and surveys. A second method might be to develop weights based upon past studies which estimate dollar values for lives and injuries. This was done in weighting Scheme 3 using values obtained from 1975 Societal Costs of Motor Vehicle Accidents.[3] The Average value of a traffic fatality in 1975

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[1]For one approach, see Lave, L. B., "Product Safety: An Economic View," ASTM Standardization News, February 1973, pp. 14-21.

[2]See for example, Kelman, S., "Regulation by the Numbers - A Report on the Consumer Product Safety Commission," Public Interest, No. 36, Summer 1974. pp. 82-102.

[3]Faigin, B. M., 1975 Societal Costs of Motor Vehicle Accidents, U.S. Department of Transportation, National Highway Traffic Safety Administration, December 1976.

was estimated to be $287,175, the value of a severe injury was $101,169, and of a minor injury was $2,576.[1] The weight for serious injuries is calculated by dividing the average value of a serious injury by the average value of fatility ($101,169/ $287,275 = .352).

The weighting scheme chosen can then be used to develop a loss index. For example, if a code provision is estimated to avert 50 deaths, 200 serious injuries, and 500 minor injuries over its useful life the loss index is the sum of the amount of each loss multiplied by its weight. For weighting Scheme 3 the loss index is 124.5 [(50 x 1 + 200 x .35 + 500 x .009) = 124.5)]. A "cost per loss" statistic (net dollar cost divided by the loss index) similar to the "cost per life saved" statistic can then be calculated. Code provisions could then be ranked by the "cost per loss averted," with provisions having lower ratios preferred.

Choosing a weighting scheme makes explicit the relative weights assigned to different types of non-monetary losses. This approach may be preferred to the standard dollar value approach because this explicit type of comparison between deaths and types of injuries may be more intuitively understandable than dollar values. However, further research is recommended to develop the weighting scheme approach more fully before it is implemented.

3.6 ASSESSING THE RESULTS

The "cost per life saved" statistics depends upon several sets of assumptions and estimates. The accuracy of these assumptions are subject to a good deal of uncertainty. The final step in the analysis is to examine how sensitive the outcome of the analysis is to changes in the basic assumptions. This type of analysis is called sensitivity analysis. In this assessment approach, two types of sensitivity analysis are recommended.

The first type of sensitivity analysis is to change only one assumption to see how the "cost per life saved" outcome varies with a higher/lower value for the parameter in question. The useful life, the change in construction costs, the effectiveness of the provision, and the basic annual loss estimates are all examples of parameters for which there may be a high degree of uncertainty.

The second type of sensitivity analysis is to evaluate an "optimistic" and a "pessimistic" case. For the optimistic case, assumptions are changed which increase benefits (for example, the

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[1]Values calculated from Table 2 of 1975 Societal Costs. Severe injuries were calculated from AIC Code 4 and 5. Minor injuries for AIC Code 1-3.

effectiveness of the code provision) or which decrease costs. Calculating the cost per life saved using the optimistic case will give a lower bound estimate of the cost per life saved. For the pessimistic case, assumptions are changed which decrease benefits or which increase costs. The "pessimistic" case will give an upper bound estimate of the cost per life saved.

Examples of both types of sensitivity analysis are contained in the Ground Fault Circuit Interrupter case study in Section 4.

4.0 GROUND FAULT CIRCUIT INTERRUPTERS--A CASE STUDY[1]

The ground fault circuit interrupter (GFCI or GFI) is a device which is designed to protect against death and injury from line-to-ground electric shocks.[2] A ground fault occurs when current leaks from a voltage source to ground (such as through a person's body). If the current flow to ground over the unintended path exceeds a certain level (5 milliamperes for the GFCIs we are discussing), the device rapidly opens the circuit. The 1975 National Electrical Code requires GFCI protection at construction sites, for swimming pools, and for certain receptacle outlets in new residential construction. This case study examines the 1975 National Electrical Code requirement for GFCI protection in new residential construction for all receptacles installed outdoors and in bathrooms.[3] The first part of this section contains a detailed analysis of electric shock deaths, and estimates the cost per life saved. The analysis section also briefly discusses electric shock injuries and loss from electrical fires. Sensitivity analysis and conclusions regarding the case study are contained in the final portion of this section.

4.1 ESTIMATING GFCI BENEFITS

4.1.1 Electric Shock Deaths

Table 4.1 presents recent statistics for the United States on annual electric shock death in the home. These statistics are based on information reported on death certificates. The total number of deaths averages 289 for the five years shown. For the period 1963-1974, the average number of deaths was 290.

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[1] An early paper, prepared while on this research was in progress, presented a similar GFCI case-study. However, the earlier case study was presented for illustration of the assessment technique only and was not based upon completed cost estimates. See McConnaughey, John S., "Economic Impacts of Building Codes," in Research and Innovation in the Building Regulatory Process, National Bureau of Standards Special Publication 473, June 1977, pp. 397-419.

[2] For a comprehensive survey of GFCI usage, see Beausoliel, Robert W. and Meese, William J., Survey of Ground Fault Circuit Interrupter Usage for Protection Against Hazardous Shock, National Bureau of Standards, Building Science Series 81, Washington, D.C., 1976.

[3] See Article 210-8 of the National Electrical Code, 1975 Edition, National Fire Protection Association, Boston, 1975.

TABLE 4.1

Deaths from Electric Shock in the Home

Year	Home Wiring and Appliances	Other	Total
1970	211	66	270
1971	216	72	288
1972	206	86	292
1973	232	71	303
1974	203	80	283

Source: 1970, 1971, and 1972 editions of Vital Statistics of the United States Vol. II, Mortality Part A, Table 4-5. U.S. Department of Health, Education, and Welfare, National Center for Health Statistics. The 1973 and 1974 statistics were obtained from the National Center for Health Statistics.

Not all of these deaths can be potentially averted by the use of GFCIs. The "other" cause, which represents about one fourth of the reported deaths, includes accidents such as contact of TV antennas or kites with overhead wires, or contact with electrical wires which have fallen after a storm. However, the statistics presented in Table 4.1 may also understate the number of deaths in the home due to electric shock. Some deaths may not have been recognized as due to electric shock and may have been recorded as a heart attack or from some other cause. Also, the location of deaths is not specified on nearly 15 percent of the death certificates reporting electric shock death. An unknown proportion of these deaths classified as "place unspecified" probably occurred at home, but are not included in Table 4.1.

Given the uncertainty of the actual number of deaths due to electric shock the analysis uses an initial estimate of 290 deaths per year. In the subsequent sensitivity analysis this estimate is varied by about 10 percent.

4.1.2 Establishing a Base Period and Estimating the Proportion of Building Affected

The base year used is 1975. In that year there were approximately 72 million occupied housing units.[1] The average number of private single and multi-family units completed from 1971-1975 was 1.736 million units.[2] Using the assumption that GFCIs were required in the 1.736 million units, the proportion of the total occupied housing stock protected by GFCIs is approximately 2.4 percent (1.736/72 = .0241).

4.1.3 Determining GFCI Effectiveness

The National Electrical Code only requires GFCI protection for outside or bathroom receptacles, but electric shock occurs throughout

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[1] The Annual Housing Survey: 1974 Part A, U.S. Bureau of Census, U.S. Department of Commerce, Current Housing Report Series H-150-74, Wash., D.C., 1976 estimated that there were 70.83 million occupied housing units in 1974. There were nearly 1.3 million housing units completed in 1975. See U.S. Bureau of Census-Series C25, Characteristics of New Housing: 1975, U.S. Department of Commerce, Washington, D.C., 1976.

[2] Calculated from Table 1 of Characteristics of New Housing: 1975. Public housing units and mobile homes were not included in this estimate.

the residence. A newspaper clipping study reported on fatal and non-fatal electric shock accidents in homes.[1] The study provided information on 200 fatalities.

Of the fatalities, 91 (45.5 percent) occurred outdoors or in bathrooms. The 1975 National Electrical Code requires at least one outdoor receptacle. However, one outdoor receptacle may not be adequate for every location outdoors. It is likely that homeowners will use extension cords plugged into non-GFCI protected circuits originating in the house. Other deaths occurring outdoors which may not be averted by the outdoor GFCI protected receptacle are accidents involving fallen or overhead wire.

To estimate the effectiveness of GFCIs in averting deaths outdoors or in bathrooms an initial assumption is that 2/3 of the deaths occuring outside could be protected by GFCIs and that all of the deaths occurring in bathrooms could be prevented by GFCIs. In the clipping study, 62 deaths occurred outside. Using the above assumption, about 41 of those deaths could be averted by GFCIs. Adding the 29 fatalities which occurred in bathrooms, a total of 70 out of 91 deaths (or 77 percent) are assumed preventable by GFCIs. Later in the sensitivity analysis it is assumed that only 1/2 of the deaths occurring outdoors would be protected by a GFCI. This gives a pessimistic estimate of 66 percent protection. For the optimistic estimate, it is assumed that 80 percent of the deaths occurring outdoors would be protected by a GFCI. This gives an optimistic estimate that 86 percent of the deaths occurring outdoors or in bathrooms are preventable by GFCIs.

The final factor in estimating the effectiveness of GFCIs is to note that an important difference between new residences and older residences is that all receptacles in new residences are grounded. A grounding conductor, used and maintained properly, is another method which protects against line-to-ground shock. Since grounding is already required in new residences, the benefit (in terms of lives saved) from GFCIs which we need to measure is the added number of lives which the GFCI will

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1 A summary of this study was submitted to the National Electrical Code Panel which reviewed GFCI proposals. See the comment by A.W. Smoot of Underwriters' Laboratories which appears in Preprint of the Proposed Amendments to the 1971 NEC, National Fire Protection Association, Boston, p. 45.

save over and above lives that grounding will save. The clipping study estimated that at most, GFCIs could potentially avert 81 percent of the 200 the electric shock deaths examined[1]. The study also estimated that "effective" grounding could avert 64 percent of the electric shock deaths examined. Using these estimates the added percentage effectiveness of GFCIs is only 16 percent (.80 - .64 = .16) over "effective" grounding. In the clipping study, "effective" grounding was assumed if it was possible that both the receptacle and the electrical device plugged into the receptacle were properly grounded. However, in practice there is evidence that grounding would not be "effective" in the clipping study sense due to improper maintenance or use. Moreover, improper grounding may result in some accidents which might not otherwise occur.[2] Since grounding is not always effective, this case study will assume that only 50 percent of the deaths which GFCIs could prevent can also be prevented by grounding. It was previously estimated that 77 percent of the deaths outdoors or in bathrooms are preventable by GFCIs. If grounding could also prevent 50 percent of these deaths, then the added effectiveness of GFCIs over grounding is 38.5 percent (.77 x .5 = .385).

The above loss estimates and assumptions can now be used to estimate the potential number of lives saved in the base year by GFCIs. This is the product of: (1) the annual loss (290 lives) times, (2) the proportion of the housing stock protected (.024) times, (3) the percentage of deaths which occur outdoors or in bathrooms (.455) times, (4) the added effectiveness of GFCIs over grounding (.385). Performing this multiplication, the potential number of lives saved by GFCIs in the base year is about 1.2 lives (290 x .024 x .455 x .385 = 1.219).

4.2 ESTIMATING GFCI COSTS

There can be a wide range in the actual installation cost of GFCIs to meet the 1975 National Electrical Code requirements. Costs will vary due to factors such as the type of GFCI used, the type of residence, the electrical layout of the circuits, the types of cable used, and regional differences in wage rates and building design characteristics.

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[1] A later newspaper clipping study reported a higher percentage of overall GFCI effectiveness. This study only investigated a subset of electric shock deaths and had a smaller sample than the first. The data it presented is not appropriate for this analysis. See the comment submitted by the National Electrical Manufacturers Association in Preprint of the Proposed Amendments for the 1978 NEC, National Fire Protection Association, Boston, p. 30.

[2] See Survey of the Ground Fault Circuit Interrupter Usage for Protection Against Hazardous Shock, pp. 5-6 for a description of some of the problems associated with grounding.

Three typical designs are specified: (1) D1, a small (1200 square foot), 1 1/2 bathroom, one-story, ranch-style unit; (2) D2, a larger (2000 square foot), 2 1/2 bathroom, two-story, single-family unit; and (3) D3, a small (1000 square foot), one bathroom, multi-family unit.

An electrical layout is a circuit plan grouping outlets into circuits. To determine the most typical types of electricl layouts, electrical trade journals, local electrical contractors in the Washington, D.C. area, and architects in a number of regional offices of the Department of Housing and Urban Development were consulted. There are two general types of GFCI devices. The circuit breaker type is installed in a conventional circuit breaker panelboard and protects an entire branch circuit. The receptacle type has the GFCI built into the receptacle. The receptacle type may be either "dead end" which protects itself only, or "feed through" which protects other receptacles further along in the circuit. The survey of trade journals, electrical contractors, and HUD regional offices suggests that the most common type of GFCI used for new construction is the circuit breaker type, and that only one GFCI is usually required. The subsequent cost analysis assumes that one circuit breaker type GFCI is used in a typical design.[1]

Figure 4.1 shows the basic electrical layout for design D1. The panel may be either mounted on an outside wall or in a basement. The numbers adjacent to the panel and the receptacles (encircled R's) represent the feet of wire needed for the vertical portions of the run plus any extra wire needed for the junction/receptacle boxes. The numbers between the panel and the bathroom receptacle, or between two receptacles, represent the feet of wire needed for the horizontal portion of the run. For this design, a total of 75 feet of wire is required.

Figure 4.2 shows a similar basic electrical layout for design D2. For this design a total of 80 feet of wire is required. Both designs D1 and D2 assume that a new GFCI protected branch circuit is needed. For design D3 no outdoor receptacle is assumed to be required. It is also assumed that a new GFCI protected circuit is not required. Instead, it is assumed that a circuit breaker type of GFCI replaces

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[1] Receptacle type GFCIs appear to be the most common type used for rehabilitation. They are also used extensively in new construction. Manufacturers of each type of GFCI claim their device is least costly to the electrical contractor. Proponents of the receptacle type, which costs more to purchase than the circuit breaker type stress fewer callbacks due to nuisance tripping and savings in installation costs.

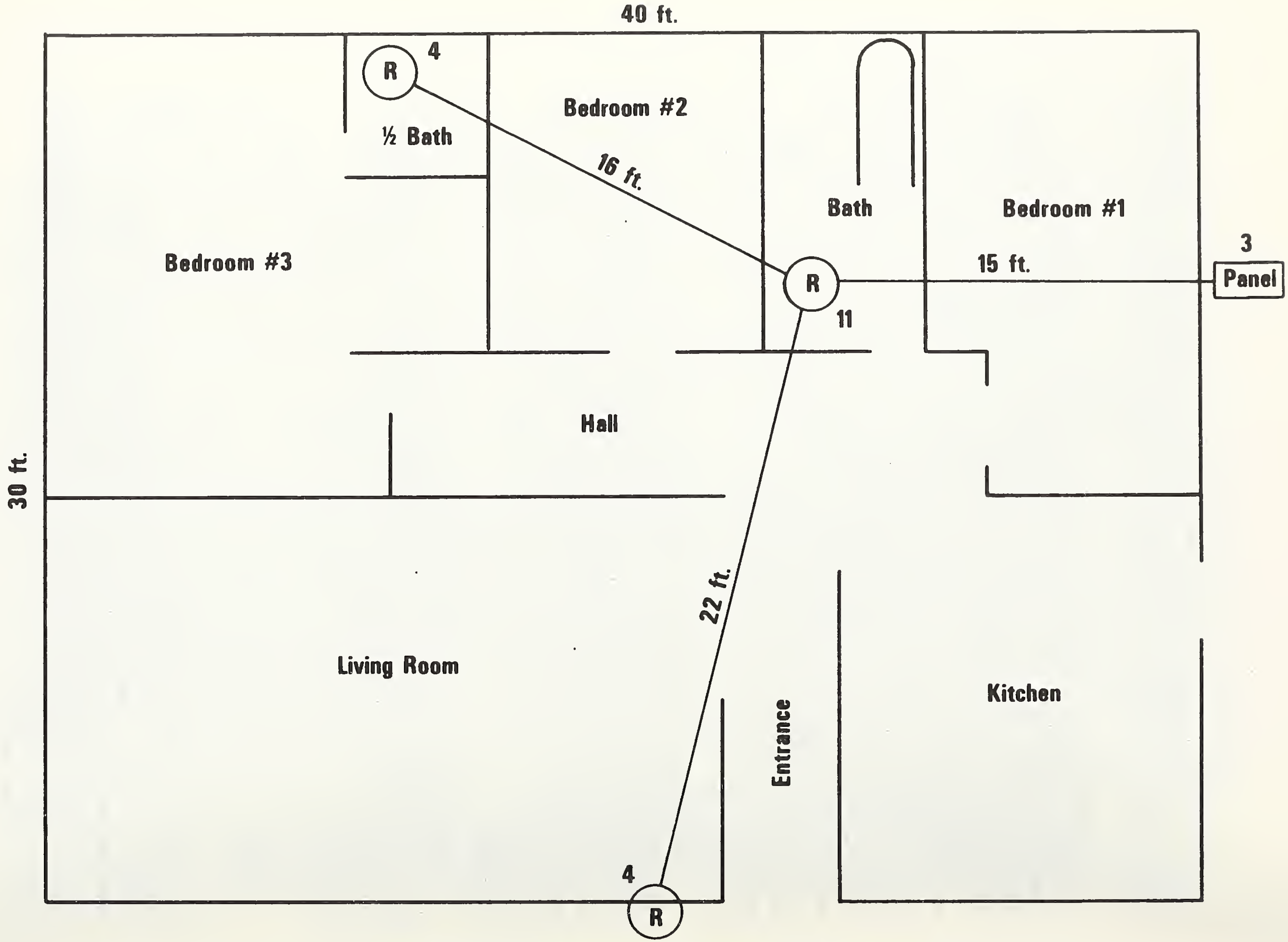

Figure 4.1 DESIGN D 1: 1200 Sq. Ft. RAMBLER

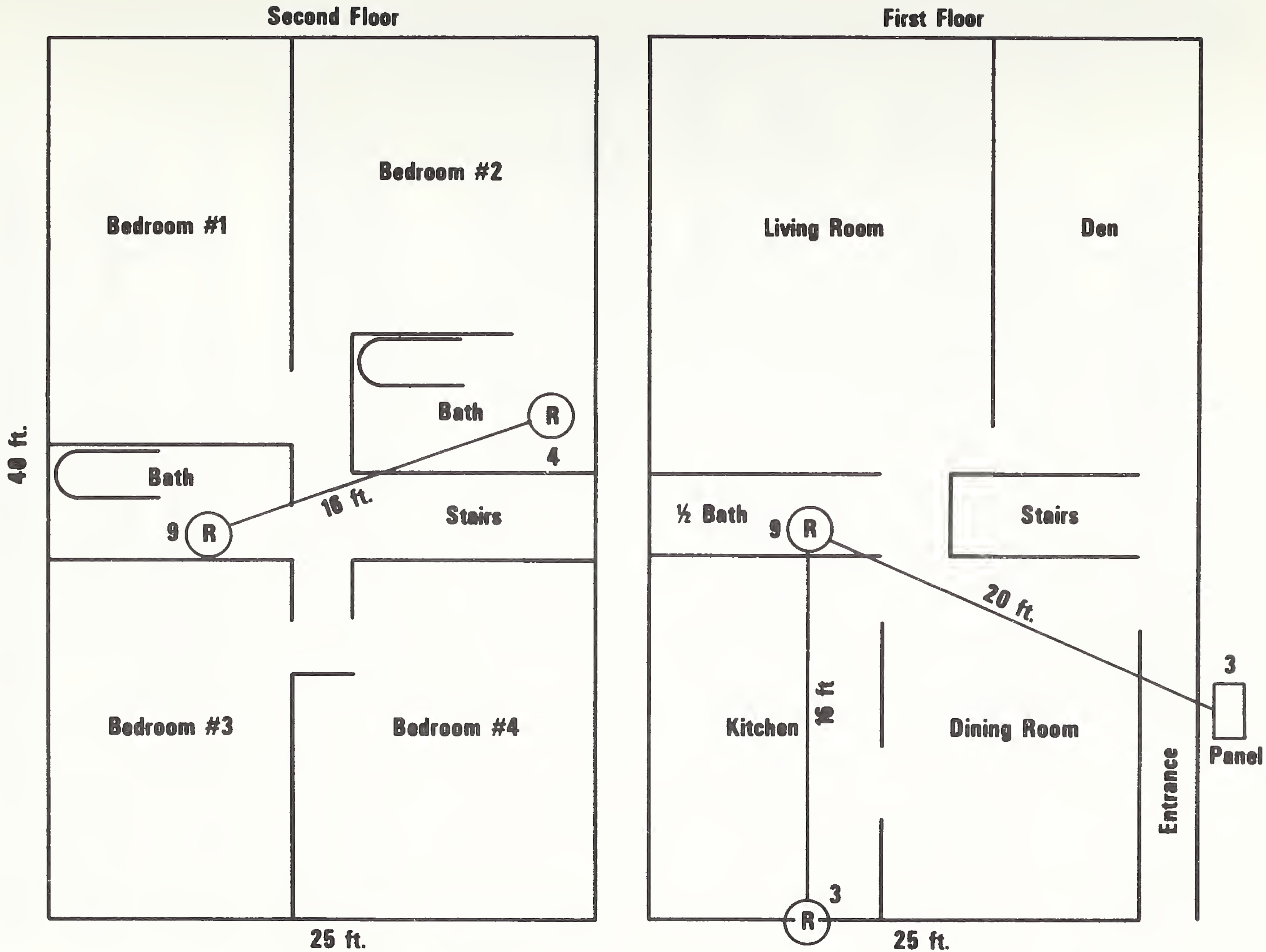

Figure 4.2 DESIGN D2: 2000 Sq. Ft. TWO STORY

a regular circuit breaker on the normal circuit which contains the bathroom receptacle. Under these assumptions no major additional changes in wiring are necessary, and an electrical layout diagram is not required.

To estimate the cost for each design, an estimating procedure outlined in the Electrical Estimating Handbook was followed.[1] The general approach involves: (1) counting the additional materials used, (2) calculating the amount of labor required to install the materials, (3) determining the dollar value of the materials and labor, and (4) calculating the electrical subcontractors' overhead and profit. A GFCI circuit breaker device cost of $25 was used. This cost is representative of the 1975 electrical contractor price (which is almost a 50 percent reduction from the list price) of several manufacturers of GFCI devices. Number 14 non-metallic sheathed cable with ground costing $.05 per foot was assumed to be used.[2] The labor time was estimated using the Electrical Estimating Handbook. Hourly union wages including fringe benefits, by Census region were used to calculate the dollar labor cost. An overhead rate of 15 percent and a profit rate of 10 percent were used to estimate subcontractor overhead and profit.[3]

Tables 4.2 through 4.4 summarize the results. Table 4.2 presents the estimated installation cost by type of electrical layout and by census region. Table 4.3 presents the estimated number of electrical layouts by census region. The aggregate installation cost by census region and type of electrical layout is presented in Table 4.4. The total added installation cost is estimated at over $92 million, or about $53 per unit. Of the $92 million about $49 million was for materials, $24 million for labor, and $19 for electrical contractor, overhead and profit.

The $53 per unit estimate falls within the range of other GFCI cost estimates. The 1975 Building Construction Cost Data estimated a cost of $60 per residence to provide GFCI protection in bathrooms and outdoors using a circuit breaker GFCI.[4] The Florida Homebuilders Association claimed in early 1976 that GFCI requirements added between

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[1] Cohen, I.M., Electrical Estimating Handbook, Construction Publishing Company, Inc., New York, New York, 1975.

[2] This price was obtained from the 1975 edition of Building Construction Cost Data, Robert Snow Means Company, 1975 for 14-2 TW type cable.

[3] Obtained from Building Construction Cost Data, Robert Snow Means Company, 1975, for electrical subcontractors having an annual volume of between .4 to 1.5 million dollars.

[4] Ibid, p. 201.

TABLE 4.2

Estimated Installation Cost Per Unit by
Electrical Layout and Census Region

	Dollars*			
Type of Design	Northeast	North Central	South	West
D1	69.00	68.30	63.60	68.60
D2	71.10	70.30	65.40	70.70
D3	32.60	32.60	32.60	32.60

* Rounded to nearest $.10

TABLE 4.3

Estimated Number of Electrical Layouts, by Census Region
Number of Units (in thousands)

Type of Design	Northeast	North Central	South	West	Total*
D1	82	136	260	119	596
D2	55	89	192	94	430
D3	104	147	281	179	710
Total	241	372	733	392	1736

* Components may not add to totals due to rounding. Computed as a 1971-1975 average from Characteristics of New Housing, Construction Reports Series C25-75-13. Design D1 and D2 statistics derived from Table 14, where houses less than 1600 square feet are defined as D1 and houses more than 1600 square feet are defined as D2. Design D3 statistics derived from Table 17.

The states contained in each major census region are:

Northeast--Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, and Pennsylvania; North Central--Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, and Kansas; South--Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida, Kentucky, Tennessee, Alabama, Mississippi, Arkansas, Louisiana, Oklahoma, and Texas; West--Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada, Washington, Oregon, California, Alaska and Hawaii.

Table 4.4

Estimated Aggregate Installation Cost by Type of Electrical Layout and Census Region

Type of Design	Millions of Dollars				
	Northeast	North Central	South	West	Total*
D1	$5.66	$9.30	$16.54	$8.16	$39.66
D2	3.91	6.26	12.56	6.64	29.37
D3	3.39	4.79	9.16	5.84	23.18
Total	$12.95	$20.35	$38.26	$20.64	$92.21

* Components may not add to totals due to rounding.

$60 and $135 to the cost of a unit.[1] A December 1976 survey by the National Association of Homebuilders listed the median cost to provide GFCI protection for an outdoor receptacle at $35 and the median cost to provide GFCI protection in bathrooms at $40.[2]

4.3 GFCI ANALYSIS

4.3.1 GFCI Technical Characteristics

The technical characteristics of GFCIs which relate to design, reliability, durability, quality, and installation are primarily governed by Underwriters' Laboratory Standard 943.

There is only limited information available on durability, or on mechanical/electrical failure. The most significant problem associated with GFCIs concerns "false" or "nuisance" tripping. A typical complaint was voiced by a representative of the National Association of Home Builders to the National Electrical Code Panel considering proposal amendments for the 1978 National Electrical Code.

> During the past 2 years, our firm has made over 2000 GFI installations in single family dwellings and has experienced numerous operational failures due to normal leakage in television sets, in fluorescent ballasts, in defrosting mechanisms of refrigerators, in heating appliances, in excessive humidity areas, and on circuits totaling more than about 200 feet of wiring. Some local jurisdictions are limiting the GFI protected circuits to only 4 outlets in order to avoid the inherent accumulated leakages encountered in normal circuit distances . . . many homeowners will deliberately make the GFI inoperative rather than submit to the many nuisance trippings.[3]

Some tripping problems in early GFCI devices from failure of the device to function properly or due to electromagnetic interference have been corrected. The Underwriters' Laboratory GFCI Standard requires a test circuit which is to be used monthly to determine if the GFCI is functioning properly. Other tripping problems occur due to misapplication of the GFCI such as improper installation, or long circuits

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[1] "Florida Builders Open Fire on Regulations that Up Housing Costs," House and Home, January 1976, p. 40.

[2] Economic News Notes for the Building Industry, National Association of Homebuilders, February 1977, p. 3

[3] Preprint of the Proposed Amendments for the 1978 NEC, p. 31.

with too many outlets so that the current leakage exceeds the trip level. As builders and electrical contractors gain more experience with GFCIs many of the misapplication causes of tripping are likely to be resolved.

Perhaps the primary effect of continued tripping may be that building users will avoid using GFCI protected circuits, or they may replace or remove the GFCIs. Builders or electrical contractors experiencing tripping problems may respond in various ways which increase the installation cost (such as installing two GFCIs where only one is required) to reduce customer complaints and call back costs.

The tripping problem may also affect the effective useful life. Over time, the waterproof outdoor receptacles may deteriorate, admitting moisture. Since moisture may greatly reduce the electrical resistance of non-metallic materials, additional current leakage (which will cause tripping) is likely to occur.

In the absence of more complete information, this case study will use an effective useful life of 20 years.

4.3.2 Estimating the Potential Benefits and Costs

Benefits

The potential number of lives saved in the base year was estimated (in Section 4.1.3) to be about 1.2. The potential number of lives saved over the assumed useful life of the GFCIs is about 24 (1.219 x 20 = 24.38).

Costs

The initial change in construction costs was estimated (in Table 4.4) to be about $92 million. In addition to installation costs, each GFCI has a small electrical operating cost. Preliminary laboratory measurements at the National Bureau of Standards of several 1975-76 manufactured GFCIs indicate that the models tested used between 7 and 9 kilowatt hours (KWH) per year. Using a consumption rate of 8 KWH per year for the 1.736 million GFCIs assumed to be installed in 1975 gives an estimate of annual energy consumption of nearly 14 million KWH. At $.04 per KWH, the yearly operating cost is $555,520. The present worth of the annual energy consumption is about $4.7 million in 1975 base year dollars. This is obtained by multiplying the uniform present worth factor for year 20 from Table 3.1 (8.514) by the annual energy cost (8.514 x $555,520 = $4,729,697).

Adding the initial construction cost and the present worth of energy costs together gives a total cost over the useful life of nearly $97 million ($96.939 million).

4.3.3 Estimating the Cost Per Life Saved

The estimated cost per life saved is nearly $4 million ($96.939 million/24.38 lives = $3.976 million per life saved).

4.3.4 Analysis of Injuries and Electrical Fire Losses

Injuries

There are no national statistics on electric shock injuries in the home. The State of California has records for the years 1963-1972 on electric shock deaths and injuries at constructions sites. There were a total of 888 injuries requiring medical attention and 11 deaths, or about 80 injuries for each fatality.[1] In the newspaper clipping study which reported on fatal and non-fatal electric shock in the home, over 80 percent of all accidents reported were fatalities (200 of 243).[2] Thus for every non-fatal accident reported in a newspaper, about 5 fatal accidents were reported.

Both sets of data are extremely limited. The California data does not contain information on the severity of injuries and concerns electrical accidents at the construction site rather than at the home. In the newspaper clipping study it is likely that the injuries reported are relatively severe. However, newspapers are probably far less likely to report injuries than deaths. Taken together, the two studies suggest that there are more injuries than deaths due to electric shock, but that most injuries are not severe.

If the California construction site injury to death ratio is typical of the injury to death ratio for electric shock accidents in the home then the estimate of the annual number of injuries averted by GFCIs is about 98 (80 x 1.219 = 97.52).

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[1]These statistics are cited in a report to OSHA: Ground Fault Circuit Protection: Preliminary Assessment of Technolgoical Feasibility and Economic Impacts, Arthur Young and Company, 1976, pp VI 9 to VI 11.

[2]Preprint of the Proposed Amendments to the 1971 NEC, p. 45.

Fire Losses

Although GFCIs are intended to avert electric shock deaths they may also reduce fire losses in residences. However it is not likely that the magnitude of such benefits would be large. Since specific information on the effect of GFCIs in preventing fire losses is limited, the brief analysis presented here is only intended to show that these benefits are relatively small.

The National Fire Prevention and Control Administration (NFPCA) estimated that between (7000-9000) fire deaths occurred annually during the period 1970-74.[1] A recent Fire Journal article estimated that 2 percent of U.S. fire deaths resulted from residential fires in which electrical equipment ignited a part of the building structure.[2] If there were 8000 fire deaths in 1975, then the estimate of electrical fire deaths in the home resulting from electrical equipment igniting a part of the building structure is about 160 (8,000 deaths x .02 = 160). For houses built in 1975, the estimated number of fire deaths in this base year is about 3.8 (160 x .024 = 3.84). Electrical circuits protected by GFCIs are only a small proportion of the electrical circuits in residences. For example, if they represent 15 percent, then the estimated number of fire deaths which might be averted by GFCIs becomes about .58 (.15 x 3.84 = .576). Finally, a GFCI will not trip a circuit which is overheating unless a ground fault occurs. Circuit breakers (which are already required) will trip a circuit under short circuit conditions. Thus the added protection of GFCI over that of a circuit breaker is likely to be small. If, for example, ground faults which did not occur under short circuit conditions ignited 25 percent of the electrical fires, then the potential number of electrical fire deaths saved in the base year is estimated to be about .14 (.576 x .25 = .144). Over a useful life of 20 years the total lives saved are estimated to be about 2.88. A similar analysis could possibly be made for fire injuries and property damage; however even less information is available.[3]

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[1] Fristrom, Geraldine, Fire Deaths in the United States: Review of Data Sources and Range of Estimates, National Fire Data Center, National Fire Prevention and Control Administration, Washington, D.C., 1977.

[2] Clark, Frederic B. and Ottoson, John, "Fire Death Scenarios and Firesafety Planning," Fire Journal, May 1976, pp. 20-22 and 117-118.

[3] "Fire and Fire Losses Classified, 1975, "Fire Journal, National Fire Protection Association, November 1976, pp. 17-19 estimated property loss of over $1.9 Billion for one and two family dwellings and apartments in 1975. However, a similar analysis to the fire death analysis above would estimate that annual property damage averted by GFCIs in 1975 was less than $100,000.

4.4 GFCI Sensitivity Analysis

The estimates of the cost per life saved in Section 4.3 depend upon several sets of assumptions and estimates which are subject to a good deal of uncertainty. Sensitivity analysis is one way to evaluate such uncertainty. Table 4.5 illustrates the technique. The left column describes the set of key assumptions and estimates used in the analysis. For reference the calculations in Section 4.3 have been repeated as Case 1. Case 2 uses a set of "optimistic" estimates and assumptions. Case 3 uses a set of "pessimistic" estimates and assumptions. Some parameters remain constant in all three of the cases. They are the percentage of the housing stock protected, the useful life, the number of units protected, and the present worth analysis of energy consumption.

For the optimistic set of assumptions in Case 2, the following changes in assumptions were made: (1) An annual death estimate which is about 10 percent larger than the reported deaths is used to account for the uncertainty of the reported statistic; (2) Recognizing that newspaper clipping studies are not based upon statistical sampling, the estimate of the percentage of deaths occuring outdoors or in bathrooms is increased by about 10 percent; (3) The added effectiveness of GFCIs over grounding is increased to .43. This assumes that all electric shock deaths in bathrooms and 80 percent of all outdoor electric shock deaths can be averted by GFCIs. Case 2 continues to assume that grounding will avert half of the deaths which GFCIs avert; (4) Table 4.2 estimates an installation cost for Designs D1 and D2 between \$63.65 and \$71.20. These costs are high compared with the \$60 estimate by the 1975 Building Construction Cost Data cost estimating guide.[1] However, the estimate for design D3 in Table 4.2 of \$32.60 is probably too low because some multifamily units are as large as single family units and have outdoor receptacles. Since these estimates are subject to uncertainty, the average cost per unit is reduced about 15 percent to \$45. The optimistic set of assumptions yields an estimate of about \$2.5 million cost per life saved.

For the pessimistic set of assumptions in Case 3, the following changes in assumptions were made: (1) Recognizing that newspaper clipping studies are not based upon statistical sampling, the estimate of the percentage of deaths occuring outdoors or in bathrooms is decreased by about 10 percent; (2) The added effectiveness of GFCIs over grounding is decreased to .26. This assumes that all electric shock deaths in bathrooms and 1/2 of all outdoor electric shock deaths can be averted by GFCIs. This also assumes that grounding will avert 60 percent of those deaths which GFCIs might avert; (3) Finally, a small increase in the average installed cost per unit is assumed.

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[1] Building Construction Costs Data, Robert Snow Means Company, 1975, p. 201.

Table 4.5
Sensitivity Analysis

	Key Assumptions	Case #1	Case #2	Case #3
(1)	Annual Deaths	290	320	290
(2)	% Housing Stock Protected	.024	.024	.024
(3)	% Deaths Outdoors/in Bathrooms	.455	.50	.40
(4)	Added GFCI Effectiveness	.385	.43	.264
(5)	Annual Lives Saved (1) x (2) x (3) x (4)	1.219	1.651	.724
(6)	Useful Life	20	20	20
(7)	Lives Saved Over Useful Life (5) x (6)	24.38	33.02	14.48
(8)	Number of Units (in millions)	1.736	1.736	1.736
(9)	Average Installation Cost	$53.11	$45.00	$55.00
(10)	Total Installation Cost (8) x (9)	$92,210,000	$78,120,000	$95,480,000
(11)	Annual Energy use per GFCI (in KWH)	8	8	8
(12)	Cost per KWH	$.04	$.04	$.04
(13)	Annual Energy Cost per GFCI (11) x (12)	$.32	$.32	$.32
(14)	Number of GFCIs (in millions)	1.736	1.736	1.736
(15)	Annual Energy Cost (13) x (14)	$555,520	$555,520	$555,520
(16)	Present Worth of Energy Cost	$4,729,697	$4,729,697	$4,729,697
(17)	Total Cost (10) + (16)	$96,939,697	$82,849,697	$100,209,697
(18)	Cost per Life Saved (17) ÷ (7)	$3,976,198	$2,509,076	$6,920,559

A comparison of Case 1 and Case 3, which have nearly the same total costs, shows the strong influence which assumptions concerning the effectiveness of GFCIs have on the outcome.

Sensitivity analysis in which only one assumption is varied was also performed. One assumption which has an important effect on the outcome is the effective useful life. Table 4.6 shows how the cost-per-life saved changes for different assumed GFCI useful lives.

Table 4.6

Cost Per Life Saved for Different GFCI Lives*

Assumption	Case #1	Case #2	Case #3
20 years	$3,976,000	$2,509,000	$6,921,000
15 years	$5,275,000	$3,325,000	$9,181,000
25 years	$3,192,000	$2,015,000	$5,554,000

* Rounded to the nearest thousand dollars

The first row repeats the results for each case from Table 4.5. Reducing the useful life increases each outcome while increasing the useful life decreases each outcome.

An alternative way to use sensitivity analysis is to establish a benchmark value for the cost per life saved and then vary the parameter of interest keeping all other parameters fixed. For example, as the market for GFCIs expands the price for the device may decline due to economies of scale in production or increased competition by producers. Price reduction has occurred for smoke detectors and may possibly occur for GFCIs.[1]

Using sensitivity analysis the question can be asked "By how much would the 1975 average installation cost need to decline to reduce the cost per life saved to a given level?" Table 4.7 examines this question for the three cases, and for three levels of outcome.

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[1]There is little evidence that installation costs have declined since 1975. The 1978 edition of Building Construction Cost Data estimates an average installation cost of $70.

Table 4.7
Average Installation Cost Needed
to Achieve a Given Cost Per Life Saved

Case	Cost Per Life Saved		
	$1 Million	$2 Million	$3 Million
Case #1	$11.30	$25.40	$39.40
Case #2	$16.30	$35.30	$54.30
Case #3	$5.60	$14.00	$22.30

* Average Installation cost rounded to nearest $.10.

The analysis shows that a significant decline in average installation costs is necessary before the cost per life saved would reach a $2 million level.

The sensitivity analysis summarized in Tables 4.5 and 4.7 suggest that a lower bound estimate of cost per life saved from electric shock using the most optimistic assumptions is probably about $2.5 to 3 million. The Case 1 estimate of nearly $4 million appears more likely.

5.0 SUMMARY AND CONCLUSIONS

This report has developed a taxonomy to define and categorize the different types of building code impacts. Three major types of building code impacts were described. Building code system impacts are related to the institutional system which has evolved to regulate building construction through building codes. Income distribution impacts concern the way building codes affect the welfare of different groups in the economy. Benefit-cost impacts concern positive and negative effects or consequences of a code or of code provisions upon society as a whole.

The major purpose of this report has been to suggest a method to measure and evaluate many of the potential benefit and cost impacts of specific building code provisions. A fundamental assumption is that more complete information will lead to better public decisions. The assessment approach provides more complete information by developing a model to assemble and organize available information. Each step is explicit, and the approach requires that assumptions be clearly identified. Sensitivity analysis is used when benefit or cost information is incomplete or uncertain.

The 1975 National Electrical Code requirement for the use of Ground Fault Circuit Interrupters was presented to illustrate the evaluation methodology. Using sensitivity analysis, a range of estimates were made of how much it costs society to save one life from electric shock by means of the GFCI provision. The cost per life saved was estimated to be nearly $4 million. Under the most optimistic set of assumptions the lower bound estimate is about $2.5 to $3 million. A more pessimistic set of assumptions placed the cost per life saved at nearly $7 million.

In an area as complex as building regulations, no claim is made that this approach can be applied to every code provision. Statistics for some types of non-residential buildings and for some types of building hazards may not be adequate. However, there would appear to be many code provisions for which the approach is appropriate.

To make the assessment approach easier to use, it is recommended that existing information on building characteristics, and building hazards and losses be compiled and a step-by-step handbook containing worksheets and working aids be prepared. For some building types a computer based model might be appropriate.

To implement and familiarize members of the building community with the approach, it is also recommended that the assessment methodology be applied to other building code provisions. In addition, a similar assessment methodology can be developed for other types of building regulations and standards. The methodlogy might also be extended by developing a more formal probabilistic approach to evaluate uncertainties.

REFERENCES

A Decent Home, Report of the President's Committee on Urban Housing, U.S. Government Printing Office, Washington, D.C., 1969.

The Annual Housing Survey: 1974 Part A, Current Housing Report Series H-150-74, U.S. Bureau of Census, Washington, D.C., 1976.

Apostolakis, G., Mathematical Methods of Probabilistic Safety Analysis, University of California, Los Angeles, September 1974.

Beausoliel, Robert W. and William J. Meese, Survey of Ground Fault Circuit Interrupter Usage for Protection Against Hazardous Shock, National Bureau of Standards Building Science Series 81, Washington, D.C., 1976.

Buchbinder, Benjamin, Susan G. Helser and Fred Offensend, Preliminary Report on Evaluating Alternatives for Reducing Upholstered Furniture Fire Losses, National Bureau of Standards Interagency Report 77-1381, November 1977.

Building Codes: A Program for Intergovernmental Reforms, Advisory Commission on Intergovernmental Relations, Washington, D.C., 1966.

Building the American City, National Commission on Urban Problems, Washington, D.C., 1968.

Characteristics of New Housing: 1975, Construction Report - Series C25, U.S. Bureau of Census, Washington, D.C., 1976.

Clarke, E.M. and A.J. Van Horn, Risk-Benefit Analysis and Public Policy: A Bibliography, Energy and Environmental Policy Center, Harvard University, November 1976.

Clarke, Frederick B., II and John Ottoson, "Fire Death Scenarios and Firesafety Planning," Fire Journal, May 1976.

Cohen, I.M., Electrical Estimating Handbook, Construction Publishing Company, Inc., New York, 1975.

Dasgupta, Ajit, and D.W. Pierce, Cost Benefit Analysis: Theory and Practice, Harper and Row, New York, 1972.

Economic News Notes for the Building Industry, National Association of Homebuilders, February 1977.

Faigin, B.M., 1975 Societal Costs of Motor Vehicle Accidents, U.S. Department of Transportation, National Highway Traffic Safety Administation, December 1976.

Feeley, Rich, Chapman, Diana, and Fielding, Jonathan F., "Structural Codes and Patient Safety: Does Strict Compliance Make Sense?." American Journal of Law and Medicine, Vol. 3, No. 4, Winter 1977-78, pp 447-454.

Field, Charles G. and Steven R. Rivkin, The Building Code Burden, Lexington Books, Lexington, 1975.

Field, Charles G. and Francis T. Ventre, "Local Regulation of Building Agencies, Codes and Politics," Muncipal Yearbook 1971, International City Management Association, Washington, D.C., 1971.

"Fire and Fire Losses Classified, 1975," Fire Journal, National Fire Protection Association, November 1976.

"Florida Builders Open Fire on Regulations That Up Housing Costs," House and Home, January 1976.

Fristrom, Geraldine, Fire Deaths in the United States: Review of Data Sources and Range of Estimates, National Fire Data Center, National Fire Prevention and Control Administration, Washington, D.C., 1977.

Grant, Eugene L. and W. Grant Ireson, Principles of Engineering Economy, 5th ed., The Ronald Press Co., New York, 1970.

Ground Fault Circuit Protection: Preliminary Assessment of Technological Feasibility and Economic Impacts, Arthur Young and Company, 1976.

Hemenway, David, Industrywide Voluntary Product Standards, Ballanger Publishing Co., Cambridge, Mass, 1975.

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

Kelman, S., "Regulation by the Numbers - A Report on the Consumer Product Safety Commission," Public Interest, No. 36, Summer 1974.

Lave, Lester B., "Product Safety: An Economic View," ASTM Standardization News, February 1973.

Mahaffey, C.T., A Special Study on Building Codes, Background Paper No. 18 for the National Commission on Urban Problems, Wash. D.C., 1968.

Mishan, E.J., "Evaluation of Life and Limb: A Theoretical Approach," Journal of Political Economy, July-August 1971.

Mishan, E.J., Cost-Benefit Analysis: An Introduction, Praeger, New York, 1971.

National Electrical Code, 1975 Edition, National Fire Protection Association, Boston, 1975.

Office of Management and Budget, Executive Office of the President, Circular No. A-94 (Revised), March 27, 1972.

Oster, Sharon and John Quigley, "Regulatory Barriers to the Diffusion of Innovation: Some Evidence from Building Codes," The Bell Journal of Economics, Vol. 8, No. 2, Autumn 1977.

Petersen, Stephen R., The Role of Economic Analysis in the Development of Energy Conservation Standards for New Buildings, National Bureau of Standards Interagency Report 78-1471, May 1978.

Posner, R.A., "Theories of Economic Regulation," Bell Journal of Economics and Management Science, Vol. 5, No. 2, Autumn 1974.

Preprint of the Proposed Amendments to the 1971 NEC, National Fire Protection Association, Boston, (undated).

Preprint of the Proposed Amendments to the 1978 NEC, National Fire Protection Association, Boston (undated).

Ruegg, Rosalie T., John S. McConnaughey, G. Thomas Sav and Kimberly A. Hockenbery, Life-Cycle Costing: A Guide for Selecting Energy Conservation Projects for Public Buildings, National Bureau of Standards Building Science Series 113, June 1978.

Sav, G. Thomas, Natural Disasters: Some Empirical and Economic Considerations, National Bureau of Standards Interagency Report 74-473, February 1974.

Schoen, Richard, Alan Hirshberg and Jerome Weingart, New Energy Technologies for Buildings: Institutional Problems and Solutions, Ballinger Publishing Company, Cambridge, Mass., 1975.

Terner, I.D. and F.C. Turner, Industrialized Housing: The Opportunity and the Problem in Developing Areas, U.S. Department of Housing and Urban Development, Washington, D.C., 1972.

Ventre, Francis T., "Decision-Aiding Communications in the Regulatory Agency: The Partisan Uses of Technical Information," Research and Innovation in the Building Regulatory Process, National Bureau of Standards Special Publication 473, Washington, D.C., 1977.

Ventre, Francis T., Social Control of Technological Innovations: The Regulation of Building Construction, Unpublished PhD dissertation, Department of Urban Studies and Planning, Massachusetts Institute of Technology, 1973.

Vital Statistics of the United States Vol. II Mortality Part A, National Center for Health Statistics, U.S. Department of Health, Education and Welfare, 1970, 1971 and 1972 Editions.

Zeckhauser, Richard, "Procedures for Valuing Lives," Public Policy, Volume 23, No. 4, Fall 1975.

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16. 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 suggests an evaluation approach which can be used by building officials and legislative bodies faced with making building code decisions. A method to evaluate many of the potential benefit and cost impacts of specific building code provisions is developed. The report also defines and categorizes the economic impacts of building codes. While no approach to classifying building code impacts will be fully appropriate for all uses, the definitions and categories proposed may help to clarify or reconcile some of the differing opinions concerning the impact of building codes. Finally, the report illustrates the suggested approach by evaluating the 1975 National Electrical Code requirement for the use of Ground Fault Circuit Interrupters (GFCIs) in residences. Based on sensitivity analysis, estimates are made of how much it costs society in order to save one life through the GFCI code provision. This case study conclude that the estimated cost to save a life is nearly $4 million. A lower bound estimate of the cost to save a life is about $2.5 to $3.5 million.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Benefit-cost analysis; benefit-risk analysis; building codes and standards; building regulations; building safety; economic analysis; economics of safety; electric shock; ground fault circuit interrupters.

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