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NATIONAL EARTHQUAKE PROBABILISTIC HAZARD MAPPING PROGRAM: LESSONS FOR KNOWLEDGE TRANSFER

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PREFACE

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INTRODUCTION AND ACKNOWLEDGMENTS

In concentrating on the national earthquake probabilistic mapping program, this study focused on one of the most important avenues used by earth scientists to transfer basic knowledge into the applied arena where the user community designs, builds, and approves the construction of structures. To guide the inquiry into the effectiveness of the transfer process, three sets of research questions were addressed.

First, do map preparers, building code officials, and earthquake design engineers agree on how maps should be drawn and what their content should be? What information do users seek from maps and how do maps currently impact the design process? Are users' needs considered in the map revision process? What information should be contained and what form should the information be displayed in to effectively meet the needs of the users?

Second, is the precision of hazard maps adequate for use in design? Is there a consensus in the scientific and engineering design communities that current and proposed maps are the best approach for engineers to design for earthquakes?

Third, from both the map preparers' and users' points of view, how well is the transfer process working? What improvements are desirable for this transfer process?

In order to address the research questions it was first necessary to do an extensive search of the literature and records that would provide insight into past practices of knowledge transfer, especially the chronology of seismic mapping efforts related to seismic codes. We are grateful to Jon Traw for giving us free access to the records and files of the International Conference of Building Officials, and to Allan Porush and Ed Zacher for making their files readily available. In addition to the examination of the literature, we conducted in-depth interviews with key individuals who have been involved in the development and use of seismic maps and/or seismic codes for over two decades. To each we owe a debt of gratitude, for without their willingness to give us the benefit of their experience and their insights, completion of this study would not have been possible. They are S.T. Algermissen, Robert Bachman, James Bailey, James Beavers, Thair Blackburn, Vincent Bush, C.B. Crouse, Susan Dowty, Art Frankel, James Harris, Walter Hays, E.V. Leyendecker, Newland Malmquist, David Perkins, Allan Porush, Larry Reaveley, Roland Sharpe, Jon Traw, Del Ward, John Wiggins, Richard Wright, and Ed Zacher. Finally, we are especially appreciative of the effort given by Jim Beavers, David Perkins and Allan Porush to review and comment on a draft copy of the final report.

Access to files and records: Jon Traw, ICBO; records and files, Ed Zacher; historical files on the development of maps and incorporation into the Uniform Building Code, Allan Porush; files pertaining to the issues leading to the development of Project 97, John Cohoon for his effort in preparing the many historical maps for inclusion in Appendix A of the report.

TABLE OF CONTENTS

Background and Problem Definition

Background

Following the 1925 Santa Barbara earthquake, the first seismic codes in the United States were developed and adopted in Santa Barbara and Palo Alto, California. In 1927, the first edition of the Uniform Building Code (UBC) contained an appendix on earthquake design. Not long afterwards, H.N. Heck of the U.S. Coast and Geodetic Survey (USCGS) developed a national seismic map based on historic seismicity (Map 1 in Appendix A), from which a seismic map of the 11 western states was developed and incorporated into the body of the 1935 edition of the UBC (Map 2 in Appendix A). In the UBC map, Heck divided risk into three zones of approximately equal seismic probability, and zone boundaries ran along county lines. All of California was mapped into the highest two zones, 2 and 3. This map remained in the UBC until 1949, when it was replaced by a national map developed by F.P. Ulrich of USCGS in 1948 (Map 4 in Appendix A). The Ulrich map added a zone 0, representing no damage, and the zones were contoured rather than conforming to county boundaries, although in some regions zone 1s bordered zone 3s without supporting logic, and a segment of southeastern California bordering Nevada and Arizona was placed in zone 1. A third USCGS map developed by Ted Algermissen in 1966 was incorporated into the 1970 UBC, one which retained the zone and contour characteristics of the Ulrich map. Here, however, California again was placed in only the highest two zones.

The tradition of USCGS map makers developing seismic risk maps for the UBC ceased about a quarter of a century ago. According to Algermissen (1983) and Traw (1995), the National Earthquake Probabilistic Hazard Mapping Program took over the function of developing seismic maps for use in building codes. Since its inception, this program has supplied maps conveying probabilistic earthquake ground motions for purposes of seismic zoning and building codes. Maps to date have been modifications of United States Geological Survey (USGS) seismic hazard maps and have served as the primary vehicle for the transfer of advanced knowledge in the earth sciences to the engineering and building industries.

At the current time, moreover, the national earthquake probabilistic hazard mapping program is undergoing changes in direction in response to issues raised both by scientists and map users. Recently, scientists and engineers have called into question some of the mapped products with respect to the Pacific Northwest, Hawaii, Sacramento, San Diego, Arizona, the Wasatch Front, Utah, southern Idaho, and the eastern United States. To resolve these disputes, the Building Seismic Safety Council has formed Project

'97 to develop consensus maps by 1997 (Hunt, 1995).

The incorporation of seismic maps in building codes is critically important, with far-reaching consequences. For the vast majority of buildings and their occupants, the adoption of, enforcement of, and compliance with seismic codes is the first and most cost-effective line of defense against destructive earthquakes. However, because initial design and construction costs vary directly with increasing levels of seismic resistance, it is considered inequitable to require that all buildings in all locales and regions be designed to the same level of seismic resistance. Seismic maps permit distinctions to be made between different seismic regions so that seismic designs can vary among locales such as San Francisco, Philadelphia, Tucson, and Memphis. Seismic maps thus serve as scientific inputs into the decision process of how to distribute seismic risks and costs inherent in the building life-cycle process.

By their very nature, maps are short-hand symbols intended to represent the application of technologies of various complexity and reliability. As such, these short-hand symbols are open to ambiguity and so may be misinterpreted by the user community. Seismic maps, as short-hand symbols, do not provide information on the building and occupant seismic vulnerabilities or even on the full range of strong-motion and geologic hazards involved in seismic risks. When the technology behind the maps is very complex, as is the case when seismic maps are based on probabilities, problems of interpretation are exacerbated.

In concentrating on the national earthquake probabilistic mapping program, this report analyzes one of the most important avenues used by earth scientists to transfer basic knowledge into the practical realm. The investigation took place under fortuitous circumstances, when stakeholders, who have definite opinions about the pros and cons of the national earthquake probabilistic hazard mapping program, were debating its future directions. From our inquiry, we have established parameters for effective interaction between the scientific community and the user community who design, build, and approve the construction of structures. Our intention is to describe successes and failures in the transfer process that can be of assistance to earth scientists and user communities as well as those who participate in other transfer programs.

Issues Addressed

The specific question being addressed in this study is:

What can be learned about knowledge transfer from the successes and failures of the national earthquake probabilistic hazard mapping program?

This problem statement assumes that maps are a very good but limited mechanism for transferring geological and seismological knowledge for use in the engineering design field. It also assumes that lessons can be learned from the assessment of successes and failures in the adoption and utilization of past maps, and, further, that this assessment can yield insights for other knowledge transfer programs, especially those involving maps.

To guide our inquiry into the effectiveness of the complete transfer process, three sets of detailed research questions were developed to gather opinions from the key people in the process—map preparers and users. Listed below, these reflect the contents of maps, the precision of maps, and the viability of the transfer process.

First, do map preparers, building code officials, and earthquake design engineers agree on how maps should be drawn and their content? What information do users seek from maps and how do maps currently impact the design process? Are users' needs considered in the map revision process? What information should be contained and in what form should the information be displayed to effectively meet the needs of the users?

Second, is the precision of hazard maps adequate for use in design? Is there a consensus in the scientific and engineering design communities that current and proposed maps are the best approach for engineers to design for earthquakes?

Third, from both the map preparers' and users' points of view, how well is the transfer process working? What improvements are desirable for this transfer process?

Methods Used

Several methods were used to answer our research questions, including:

1) an extensive literature search with reference to historic knowledge transfer, especially the chronology of seismic mapping efforts related to seismic codes;
2) interactive in-depth interviews of over 20 key participants, many of whom have been involved with seismic codes and/or seismic maps for over two decades;
3) model development of the knowledge transfer process and testing through application, interviewee response, and project principal discussion, as with the "force field" model used in chapter 3 of this report; and
4) reviews by selected key participants.

Models of the Transfer Process

As part of model development and testing, existing knowledge transfer models were evaluated. These, according to Weiss (1979) and Yin and Moore (1985), consisted of:

- the knowledge-driven model, also known as the research, development, and diffusion model, which posits that the publication of basic research is naturally followed by application;
- the problem-solving model, which posits that the user stimulates the need for the research through which specific answers are determined, which in turn have practical applications owing to the practical context in which the research begins;
- the interactive diffusion model, which assumes that knowledge transfer occurs through informal communication across social networks or groups; and
- the enlightenment model, which assumes that an elite group of knowledgeable scientists and public policy champions ultimately change the way in which problems are defined and solutions sought.

These models of knowledge transfer represent relatively limited attempts to capture the essence of how information is generated in the scientific community and then communicated to users. Each of the four models specifies beginning and ending states as a two-step process and the direction of the stimulus for change, but none provide the earth scientist concerned with knowledge transfer a great deal of insight into how a complex transfer process involving layers of concerned participants in a multi-step process might actually work. As will be shown later in our analysis of the transfer of mapped information to the user community, each model describes aspects of the process and illuminates some pieces of a large puzzle. However, each model is individually insufficient to explain the range of behaviors and interactions displayed by scientists, engineers, and others in the building industry or why some information has transferred easily and other information has been difficult to transfer. How one's very technical and professional studies make a mark on what is being done in response to earthquake hazards was still a question worthy of model development.

The Fate of Maps in a Dynamic Decision-Making Process

Figure 1 provides an outline of the steps taken by key participants in deciding how to distribute seismic risks and costs in the building life-cycle process. As different participants have different agendas and needs from maps, there is often a conflict concerning map contents, interpretation, and, ultimately, equity. Once new seismological and geologic information is transferred to maps, it is reviewed and modified by code developers ranging from professional engineering associations to materials interests, building code officials, and model code development organizations. Code organizations may then choose to adopt or reject proposed changes to the code, including seismic maps. Federal, state, and local representatives and building officials may then adopt, modify, or reject these codes and their maps to suit themselves. When construction begins, developers and contractors may then comply or not comply with these codes. Eventually, finished buildings, whose seismic integrity is relatively intact or compromised, are occupied.

At each stage in the implementation of seismic maps, issues may be raised that in turn cause maps and their implications to be re-examined. Rival scientific views, for example, may be marshaled as one vehicle to raise questions about these maps. The "encapsulation" of strong-motion values at specific return intervals could be questioned as being scientifically misleading. Furthermore, the suitability of the values on the maps may on general grounds be questioned. More locally, the building construction industry may balk at the implications of the seismic maps, especially when costs are seen to rise or certain materials are disadvantaged.

This process of revisiting the maps—not merely on scientific but on general equity grounds—refines the maps and their implications. In effect, the mapping process is not completed—fully understood—without reference to this implementation process, including the process of questioning map values and revisiting procedures used to derive the maps.

In general, maps are not stand-alone scientific products or symbols. Maps are more fully understood in terms of their uses. In the case of seismic hazard maps, these uses are defined in the context of many stakeholders in the building construction process, from scientists, structural engineers, building officials, and materials interests to financial institutions, owners, and occupants.

Scope of this Study

Although the implementation and enforcement of maps are critical to understanding whether maps are successfully employed, our study is limited to the development of maps and their adoption into building codes. In reference to Figure 1, we concentrate on the first four steps and consider successes in map transfer to occur when maps are adopted in building codes.

Because of resource limitations, the concentration of efforts in this project to date has been primarily on activities involving the International Conference of Building Officials (ICBO), publishers of the Uniform Building Code, and secondarily on Building Seismic Safety Council (BSSC) activities, publishers of the recommended National Earthquake Hazard Reduction Program (NEHRP) seismic provisions. Greater attention is due other principal code organizations, notably the Southern Building Code Congress International (SBCCI), publishers of the Southern Building Code; the Building Officials and Code Administrators International (BOCA), publishers of the National Building Code; and the American Society of Civil Engineers (ASCE), developers of ASCE-7 as well as many other standards. We recommend that future research efforts be undertaken that include these organizations and other knowledgeable people, who could not be interviewed for this study but who also had, in some cases, considerable influence in the development of seismic codes and maps.

Figure 1. Seismic Map Development in the Context of the Life-Cycle Building Process Equity Issue.

Step 1: Problem: How to distribute fairly seismic risks and costs in the building life-cycle process

Step 2: Mapping: the encapsulation of geologic and seismologic information in seismic maps

Step 3: Engineering/Model Code Developer incorporation/modification of seismic maps in the seismic codes (consensus process may be used)

Step 4: Code Organization Adoption of Codes through voting process

Step 5: Government Adoption, Modification, or Rejection of Seismic Maps in Codes

Step 6: Building Construction Compliance or Noncompliance with Seismic Design Map

Step 7: Buildings incorporating/not incorporating seismic map implications

Remaining Sections

The foregoing account begins our response to the leading question of this project: What can be learned from the successes and failures of the seismic mapping process? Successful mapping plays a vital role in serving as a quantitative and scientific basis for distributing seismic risks and costs in the life-cycle building process. Maps are not merely scientific products or symbols; adopted maps are bearers of social implications in this distribution process.

To clarify further what can be learned from this process, we:

- provide in Section 2 and Appendix B a chronology of seismic mapping as it relates to seismic codes in the United States. This chronology assists us in further defining by historic examples the notion of "successful" transfers through maps. This chronology further clarifies what controversies have arisen over maps and how the adoption process itself requires and is improved by the clash of opinions on seismic maps. At the end of Chapter 2, we provide a perspective on the current situation and a discussion of the technical controversies currently being debated.
- provide in Section 3 the application of a "force field" analysis of stakeholders in this seismic hazard map adoption process to analyze the political aspects of the knowledge transfer process;
- provide in Section 4 conclusions about what has been learned in the mapping process from the National Earthquake Hazard Mapping Program and also provide recommendations about how to improve the knowledge transfer process.

Chronology of Earthquake Zone Mapping Used in U.S. Earthquake Building Codes

The purpose of this section is to examine the history of seismic codes and maps in the United States in order to provide a context for understanding current seismic hazard mapping activities. Often, we can date original events that have eventually given rise to current controversies and other questions. Our goal has been to document the dynamic aspects of the knowledge transfer process, including the identification of changes in code acceptance practices or in the financial support for code development activities that have affected procedures used in developing and evaluating seismic hazard maps for their inclusion in seismic codes. Using historical examples, we define "successful transfers" involving seismic hazard maps and codes.

Alternative Frameworks for Interpretation

Several interpretive frameworks exist for organizing the history of seismic maps and codes, and each provides a helpful and slightly different perspective concerning what has happened. Of three frameworks presented below, we describe but do not pursue the first two (the history from the standpoint of technical advances and the history in terms of financial support for seismic hazard maps and seismic code developments generally), and then we furnish an elaborate presentation of the third, an interpretation in terms of the growing role of the federal government in seismic code developing activities. This latter role is consistent with two key characteristics of the recent map transfer process: first, the growth of many more participants in the process, both from the standpoint of people conversant with seismic hazard mapping and of people directly interested in and affected by the potential implications of these maps for seismic design practice, and, second, the increase in the number of avenues that may be used to both develop maps and also transfer them to codes.

History from the Perspective of Technical Advances

One way to interpret the history of seismic mapping as it bears on seismic codes is to highlight scientific and technological changes that have modified these seismic maps. Unfortunately, we cannot present this history with reference to the four knowledge transfer models originally proffered by Weiss (1979) because history has not left us with clear references to what or who stimulated the changes. Thus, we cannot clearly categorize changes as being examples of knowledge-driven, problem solving, interactive diffusion, or enlightenment transfer processes.

The earliest seismic maps drawn before 1940 either used a "probability-based" approach, incorporating the entire range of historic earthquakes, or else basically emphasized expected maximum intensities (and/or accelerations). Maps drawn in the late 1940s and 1950s continued this approach but also included the use of stratigraphic and geomorphic information as a basis to fill in the limited historic record (Richter, 1958. p. 389). Probabilistic methods were introduced in the late 1960s and made some impact on seismic codes in the 1976 UBC edition (as well as the 1973 Tri-Services Manual developed by the Armed Forces for the construction of their buildings worldwide). Use of specific fault-related slip-rate data as a means to develop probabilistic models of earthquake activity was introduced in the late 1970s based on investigations of the Wasatch and San Andreas fault systems. More recently, spectra maps have been developed as well as alternative means of developing smoothed response spectra from these maps. The applicability of geodetic survey data and of Gaussian models of random areal sources are some of the technical issues currently under examination that are expected to show up in future maps (Perkins, 1995).

History from the Perspective of Funding Sources

A second way to evaluate seismic mapping and seismic codes is to examine the basic and broad funding sources behind mapping and code development efforts. These would include agencies of the federal government such as the USCGS, USGS, and the Weather Bureau, which dominated technical research and map development prior to 1970, and these agencies along with private petroleum companies which increased seismological studies at the time of the Eisenhower administration. Other funding sources would include the U.S. concrete and steel industries, especially after World War II when high-rise construction escalated in the west, the electric power industry in relation to the siting of nuclear power plants, and the more recent involvement of the federal government through the National Science Foundation, the National Bureau of Standards, and the Federal Emergency Management Agency in seismic building construction practices. While a detailed examination of these and related funding decisions and their impact on seismic map development would increase our understanding of the history of seismic maps and codes, such an endeavor was beyond the scope of our study and we could not pursue it.

History from the Perspective of the Growth of Federal Involvement

While a knowledge of the history of state-of-the-art mapping procedures and of financial sources for seismic mapping and code development is valuable in providing an understanding of two key elements within the knowledge transfer process, technology transfer issues, the heart of this research endeavor, are only referred to obliquely in these histories. To grasp the fundamentals of the transfer process requires an understanding of decision making by the people who create the maps and those who use them. From the standpoint of determining how maps are developed and then codified, a more direct approach is needed. Since there are now many persons representing many interests taking an active part in the transfer process, the dynamics inherent in code-making procedures and the nature of controversies surrounding them and seismic maps need to be better understood. Ross Cheit (1990) provides a valuable distinction between private and public safety standard-setting processes that undergirds our analysis.

Table 1 summarizes key differences as expressed by Cheit between voluntary and governmental safety standard-setting processes. In elaboration of Table 1, Cheit maintains that public safety standard-setting processes (pp. 151-157, 183, 191, 201):

- use prohibitions as central strategies;
- use retroactive laws on occasion;
- use controls on operations;
- use disclosure strategies;
- employ the earliest possible effective date;
- encourage entrepreneurial politics after disasters;
- require more than engineering judgment, common sense, and educated guesses when judicial review is involved;
- lead to accumulation of more information on the frequency and type of accidents; and
- do a better job of generating applied research.

In contrast, private standard-setting processes typically represent the dynamic adoption of state-of-the-art engineering practices. As such, they are oriented more toward engineers than lawyers or government officials, and they do not commonly emphasize prohibitions, disclosure strategies, human engineering or operational controls, or formal benefit-cost analyses. These private processes thus involve greater know-how (p. 196), are prospective and ongoing (p. 206), and are often subject to liability lawsuits. As Del Ward (1995) has brought out, private processes should be regarded as non-mandatory and incremental collective decision-making processes prompted by market forces and the people with an economic stake in what or whom they regulate.

Since their inception, model building codes have been prepared by private organizations using a voluntary standard-setting system in which parts of the codes are developed internally and parts are adopted from standards created by other organizations and "referenced" in the codes. According to William G. Kirkland (1969), at the time of his study there were over 550 standards referenced by existing model building codes, standards sponsored by over 60 nationally and internationally recognized organizations. James Gross (1990) maintains that the typical United States building code references 300 to 400 primary standards. Practically none of these standards are written or promulgated by the political jurisdictions adopting the code or the code organizations sponsoring the model code. Under the voluntary standards system, however, building officials, governmental officials, industry representatives, professional organizations, engineers and architects participate in the development of these standards including seismic elements.

Table 1. Differences Between Public and Private Standard-Making Processes

	Public Sector	**Private Sector**
Economic Perspective	Often too strict; overestimates benefits, underestimates costs.	Mixed results; rarely underestimates costs; sometimes overestimates benefits (and costs).
Regulatory Perspective	Paternalistic [protective]; technology-forcing; enforcement oriented.	"Buyer beware"; technology based; protective of managerial discretion
Evolutionary Perspective	Intervenes after a crisis; one-shot interventions with few changes.	Intervenes early; adjusts often, usually in the "right" direction; technologically comprehensive.

[Note: This table is based on the discussion in Cheit (1990, p. 206).]

To use Cheit's distinction as applied to seismic code-making processes, it must be remembered that

- the seismic code-making process has always to date involved government officials, specifically local and/or state building officials, in the final steps of casting ballots on proposed regional model codes and in adopting these codes within specific jurisdictions; and
- the distinctions that Cheit refers to are "rough and ready," typical rather than universal, and exceptions may be found to them (some exceptions, such as those resulting from changing antitrust or tort law may lead to significant modifications in "private" and/or "public" standard-setting procedures).

With these caveats in mind, we roughly divide the seismic code-making procedures and the nature of controversies surrounding them into three broad historical periods:

1) the early development stage (from about 1890 to 1925) prior to any adoption of seismic codes and associated maps in the United States;
2) the period from about 1925 through 1970 dominated by private standard-making processes (with, of course, significant involvement by building regulatory officials); and
3) the present period, beginning in about 1971, with mixed public and private sector processes, incorporating "consensus" or broader peer review procedures along with greater national interest in the code-making process.

We define "consensus" and "broader peer review" in greater detail later in this section and in the following section. However, at present, it is apparent that the number of scientists, engineers, and other interested parties assessing, reviewing, and revising seismic maps has grown in each successive period. Peer review and more formal consensus processes have been logical responses to the need to control the content and range of discussion when the number of interested parties in the seismic mapping process grew.

What "Successful Transfers" Might Mean in this History

In the fullest sense, successful transfers are maps that support actual effective seismic risk reduction efforts—in this case the construction of cost-effective seismically resistant buildings. Determination of success in this sense—requiring examination of the efficacy of seismic codes and the role of maps in this efficacy—however, goes beyond the scope of this project. For our purposes, a much more limited definition of "successful transfer" is employed, one in which a map "prevails" in the sense that it is adopted and incorporated in the seismic codes. Our limited definition recognizes the potential deficiencies of activities that merely prevail—such as the successful bidding, design, and construction of seismically unsafe structures—that are found out later to be failures. Similarly, maps (or alternative algorithms) that poorly depict state-of-the-art information may "prevail"—at least in the short run. And, at any given time, one can look back at old maps and point out various deficiencies that subsequent science and technology have removed.

Moreover, as decisions have become more politicized and take longer to resolve, success has become a multi-stage process in which a map—and its attendant issues—must pass through a series of reviews and prevail each time or at least provide valuable knowledge that can be revisited at a later time. Like a precedent in which the minority opinion later becomes the basis for law, a map can sometimes point to future developments and raise specific issues that need to be discussed when decision makers see the need, even though the "right time" is not when the map was initially proposed.

Historical Periods

First Period: 1890s to 1925

The first historical period was characterized by the systematic collection of data and the introduction of new theories of both earthquakes and earthquake-resistant construction. This data collection and theory construction were facilitated by the development of seismographs and seismograph stations. Theories of earthquake-resistant construction in the United States were developed and refined through the examination of damaged and undamaged structures, especially following the 1925 Santa Barbara earthquake and the even more influential 1933 Long Beach earthquake.

According to Tobriner (1984), even though no seismic codes were developed in the United States as a result of the 1906 San Francisco earthquake, the next 19 years involved many changes in earthquake engineering both here and abroad. Internationally, the 1908 Messina, Italy, earthquake and the 1923 Tokyo (Great Kanto) earthquake both stimulated earthquake engineering and code developments outside the United States. By the late 1920s, according to Tobriner, "a body of knowledge about the devastating effects of earthquakes and earthquake hazard mitigation was beginning to become available" (p. 55).

Second Period: 1925 to 1970

In the second historical period, through a private standard making process (see Cheit, 1990), engineers and building officials worked together to compose and upgrade earthquake codes needed primarily in California but gradually desired in the western United States (Strand, 1984). As time went on, building practices and code-making organizations became more influential in local communities. At the beginning of this stage, few municipalities adopted, let alone enforced, seismic codes; however, by the end of this stage, many more municipalities both adopted and enforced seismic codes (Ward, 1995). As seismic codes were implemented, the materials industries, especially the concrete and steel industries, funded significant research into building codes to establish the seismic worthiness of their products and ensure they would remain products of choice by builders (see *Building Standards Monthly*, March, 1965, Part I: p. 9; *Building Standards Monthly*, April, 1966, Part I: pp. 9-13).

Technical and political controversies existed in these early stages. For instance, in the 1920s, a geologist proclaimed Los Angeles to be a seismically inactive region. In another instance, the United States Coast and Geodetic Survey retracted a map in the 1950s in response to pressure applied by business and scientific interests on the grounds that the map (like all science) was subject to misinterpretation. During this historical period, the number of participants in the code-making process was comparatively small, and the incorporation of maps into the seismic codes was relatively rapid. As more than one interviewee has suggested, California structural engineers dominated the code development process by preparing seismic design provisions and then submitting them to the International Conference of Building Officials (ICBO) for adoption in the Uniform Building Code (UBC). Until 1970, few engineers outside California participated in the process or contributed to it. Beginning in the 1950s (and basically still in existence today), the Structural Engineering Association of California (SEAOC) developed an informal relationship with ICBO, becoming what Malmquist (1995) termed "the alpha and omega" of seismic code developers. In 1959, SEAOC formalized its role when it began publishing its seismic provisions in what is popularly known as its Blue Book and quickly developed an uncontested monopoly as the de facto preparer of seismic design provisions for ICBO (Porush and Zacher, 1987).

In accordance with our limited definition of a successful transfer, having a map be adopted into a building code, the second historical period contains three examples of successful transfers: the Heck map in 1935, the Ulrich map in 1949, and the Algermissen map in 1970. From the period of 1925, immediately following the Santa Barbara earthquake, to 1935, the United States Coast and Geodetic Survey (USCGS) under the leadership of H.N. Heck undertook the responsibility for seismic mapping in the United States. In California, after the publication of the first edition of the UBC, several associations from insurance, architecture, engineering, contracting, and community development began their involvement with seismic code development. These complementary actions resulted in the adoption of an earthquake map in the 1935 edition of the UBC, a map which subsequently remained in the UBC until 1949. (See Map 1 in Appendix A for the USCGS map designed by Heck and Map 2 in Appendix A for the map used in the 1935 UBC.) In economic terms, the adoption of the USCGS map was relatively fast and straightforward because it involved a single vendor (monopoly—unless one regards a map published by Freeman (1932), Map 3 in Appendix A, as an alternative) and a single buyer (monopsony). The vendor was the USCGS, and the buyer was the Pacific Coast Building Officials (later renamed ICBO), publisher of the UBC.

In 1948, mirroring the current state of earthquake knowledge, the USCGS published a state-of-the art seismic map for the United States designed by Ulrich. (See Ulrich, 1948A and 1948B; and Roberts and Ulrich, 1951.) It was very quickly incorporated into the 1949 Uniform Building Code. As a result of the 1949 Pacific Northwest earthquake, Ulrich modified his map to include a higher seismic zone 3 in the Puget Sound region. This and a second change (the downzoning of Charleston, South Carolina, to zone 2) were included in the 1952 edition of the UBC (Map 4 in Appendix A). Here again, monopoly and monopsony conditions seem to apply. Additionally, the speed of transfer suggests no significant lag time between map construction and its acceptance in the model code.

While we consider the incorporation of the Ulrich maps into the UBC as a successful transfer, they illustrate a problem with our definition. In 1952, the USCGS removed its approval of the latest Ulrich map because it was subject to misinterpretation and too general to satisfy the requirements of many users (Perkins, 1974) (see also Richter, 1958: p. 389). According to Vincent Bush (1995), many people had complained about the map—on scientific as well as business grounds. Algermissen (1983) indicates that the fundamental flaw with the Ulrich map was Ulrich's failure to disclose what the basis was for his determination of seismic zones.

One early substitute for the Ulrich map was developed by Charles Richter in 1958 (Map 5 in Appendix A). However, it was never formally suggested to ICBO as a replacement. According to Perkins (1974: p. 12), this map "resulted in such large regions of risk that there was considerable incentive not to adopt it into an official code." The 1969 map (Map 6 in Appendix A) produced by S.T. Algermissen for the USCGS turned out to be the replacement for the 1952 Ulrich map. This 1969 map was incorporated into the 1970 edition of the Uniform Building Code. The Algermissen map considered three subjects not evaluated by previous map developers:

1) the distribution of Modified Mercalli intensities associated with the known seismic history of the United States;
2) strain release in the U.S. since 1900; and
3) major geologic features believed to be related to recent seismic activity (*Building Standards Monthly*, May, 1969: p. 104).

There is some misunderstanding concerning the development of this map. Yin and Moore (1985) claim that Algermissen decided on his own to design a seismic map without being influenced by anyone in the user community. However, in an interview with Algermissen (1995), he stated that he was asked by Karl Steinbrugge, a longtime representative of the insurance industry, to prepare a map that would eventually replace the Ulrich map in the UBC. Yin and Moore also claim that there was no initial demand for a new map from ICBO, although the Seismological Subcommittee of ICBO's Code Changes Committee had been requested to make a complete investigation of seismic zoning throughout the United States following the 1964 Alaska earthquake (see Bush, 1971). Where there is no dispute, Algermissen and the Seismology Subcommittee worked together so the final map would meet the requirements of the ICBO members.

Because Algermissen and ICBO members worked together to produce a map acceptable to ICBO, there was no significant lag time between the first publication of the map in engineering/scientific circles and its acceptance in the building code. For reasons described in the next section of this chapter, this was the last transfer in which a single map could represent the best scientific thinking and the last time there would be a monopsony situation.

Third Period: 1971 to the present

The third historical period coincides with many important developments in the early 1970s, several of which had their origins following the 1964 Alaska earthquake. First, standards and standard-making came under attack by the federal government. To prevent the establishment of standards through monopolistic practices and to ensure wide involvement in standard-setting procedures, the Office of Management and Budget began constructing rules on "consensus" procedures needed for the development of standards. At the same time, the Federal Trade Commission carried out antitrust suits against private standard-making organizations such as the American Society of Mechanical Engineers. Second, the federal government began extending its interest in natural disasters, disaster assistance, and mitigation. As a result of the Alaskan earthquake and Hurricane Betsy in 1965, the National Flood Insurance Program was enacted in 1968, and investigations were extended to consider the creation of a federal earthquake insurance program. Subsequently, the 1971 San Fernando Valley earthquake dramatized that a moderate-sized earthquake could produce large losses in heavily populated cities. More generally, the problems associated with population concentrations in flood-prone, earthquake-prone, and hurricane-prone regions were beginning to command national attention. Third, following the San Fernando earthquake, the seismic design community began to question its practices in light of the structural damage and loss of critical new structures such as the Olive View Hospital (see Harris, 1992).

One of the early involvements of the federal government in the seismic code arena after this much-studied San Fernando earthquake was the use of federal seed moneys to create the Applied Technology Council in 1971. In 1973 further federal moneys were allocated to support ATC-3, a model code development effort designed to speed seismic code changes. Later in the decade, the federal government created the National Earthquake Hazard Reduction Program (NEHRP) to establish national earthquake mitigation strategies and to allocate funds for research. In addition, existing federal disaster agencies were grouped together under a newly created agency, the Federal Emergency Management Agency, which was tasked with the management of NEHRP. Then, to cope with the tentative results of ATC-3 through the use of trial designs, the Building Seismic Safety Council (BSSC) was formed as an independent council of the National Institute of Building Standards (NIBS). As a consequence of these and other actions, as more resources were expended on seismic code development and other earthquake-related issues, ironically the lag time for the incorporation of seismic maps began to increase. However, Richard Wright (1995) has pointed out that the lag time phenomenon is not merely a function of the time between development of a map and its acceptance. Lag time is also a function of the difference in time between the acceptance of markedly different maps, whose creation has been accelerated by the advancement of geological knowledge and the increase in federal funding in the earth sciences.

With respect to UBC maps, the Heck map (1928) was adopted in 1935, the Ulrich map was adopted in 1949, with modifications in 1952, the first Algermissen map was adopted in 1970, with modifications in 1976 and 1982, and the next major mapping adoption, influenced by Algermissen and coworkers, was in 1988. The time periods between 1935, 1949, 1970, and 1988 may be conceived of as "lag times" in the latter sense. Lag times in this sense may be essential for the building construction industry and building regulatory authorities to perceive the need for marked changes, to evaluate proposed changes, and to adapt to these changes. Even during periods when significant earthquakes occur, there may be a reluctance to accelerate the change process because new problems and solutions may not be understood well enough for intelligent decisions to be made. Time provides an opportunity for deficiencies in knowledge to be filled.

The third historical period can be conceived of as "mixed," in Cheit's terminology, largely because federal moneys are used throughout to support various private code-making activities. The inclusion of these federally supported efforts has created competition for SEAOC in the development of seismic codes, especially BSSC, which produces the recommended provisions for NEHRP. Whereas governmental influence in seismic safety standard-making had always been apparent in the ultimate control, through balloting, by state and local building regulatory officials, now government control has expanded into federally supported efforts in the preparation of seismic codes.

The number of participants in the transfer process increased significantly as the national concern over seismic codes became more prominent. The ATC-3 effort in the 1970s marks a change in direction insofar as California structural engineers are concerned. They no longer have a monopoly over the seismic code preparation process. However, their influence is still strong as several SEAOC members are key members of BSSC committees and can, if they choose, resist or slow attempts by BSSC to supersede the efforts of SEAOC.

The third historical period contains several examples of successful transfers. During this period, probabilistic seismic hazard maps have become commonplace. However, all the transfers in this period involve maps containing negotiated strong-motion values, values developed not by probabilistic methods alone but also through the use of judgment, especially with respect to upper-bound and in some cases lower-bound values.

A partial success arose in 1976 when the California portion of the 1976 Algermissen-Perkins map produced for the USGS (Map 7 in Appendix A) was incorporated into the 1976 seismic map adopted in the UBC (Map 8 in Appendix A). The seismic zone 4 transferred from the Algermissen-Perkins map to portions of California had made its first appearance in 1973 in the Tri-Services Manual (Map 9 in

Appendix A). This "transfer" was only a partial success because other seismic zones in other states were not modified as a result of the 1976 Algermissen-Perkins map. As for the 1976 UBC map, the 1969 Algermissen map was used as a basis for the remainder of the states.

A minor but significant success occurred in 1982. Portions of the UBC map in Idaho were altered to accommodate studies and interests of the Department of Energy (see Map 10B in Appendix A). This signified the growing importance of non-California organizations in the development and proposal of successful changes to UBC seismic maps.

Another partial success occurred when the 1982 Algermissen-Perkins map (Map 11 in Appendix A) along with other influences led to a revamped UBC map in 1988 (Map 12 in Appendix A). From this time, the monopoly of the USGS in map preparation no longer prevailed. Many vendors were involved in producing seismic maps of various states or regions. The process that led up to the 1988 map clearly indicates that a number of information sources besides the USGS were contacted and asked for comment on various proposed maps (see chapter 3 for a full discussion of this process).

The 1978 ATC-3 map (Map 13 in Appendix A) was the basis for several later successful transfers into codes other than the UBC, starting with its use in the 1982 ANSI 58.1/ASCE-7 code (CABO, 1992; Wright, 1995). This ATC-3 map was based on the 1976 Algermissen-Perkins map, as well as maps developed by others such as Wiggins and Foss. ATC committees and subcommittees created the ATC-3 map by truncating and smoothing the scientific maps.

The ATC-3 map was incorporated into the recommended seismic provisions of NEHRP in 1985 and has remained in each edition up to the current 1994 edition (BSSC, 1995). It was also incorporated into the BOCA code in the mid-1980s and into the CABO one-and-two family dwelling code in 1989 (CABO, 1992). In 1992, Building Officials and Code Administrators International (BOCA) adopted the latest NEHRP provisions, first as part of its supplement, and then in 1993 as part of the National Building Code. Then, the Southern Building Code Congress International (SBCCI) adopted these provisions first, as part of its supplement in 1993, and then in 1994 as part of the Southern Building Code (Harris 1995). As a consequence of these actions, the ATC-3 seismic map has now been adopted by two of the three model code organizations in the United States.

The Current Situation

To recapitulate, the current situation arises in the context of significant increases over the past quarter of a century in:

- the geographical spread of engineers, building officials, and other parties interested and influential in seismic codes and their development;
- earth scientists, engineers, and others exposed to seismic mapping procedures, including the development of probabilistic seismic hazard mapping procedures; and
- federal support for seismic code development activities.

An enlarged community has come to realize that 1) alternative procedures and assumptions exist that may be used to develop seismic maps and values to be mapped (resulting in an indefinitely large number of possible maps, many resulting from contradictory assumptions or procedures), and 2) mapped values may conflict to a greater or lesser extent with current engineering and building construction practices.

A Controversy: To Recommend or Not to Recommend

When BSSC publishes its recommended NEHRP seismic provisions for the Federal Emergency Management Agency (FEMA), it also includes appendixes for controversial material that is not recommended but should be evaluated and studied and could potentially be recommended in subsequent editions. In 1991, BSSC included new spectral maps in an appendix with significant caveats. Two probabilistic values were estimated, a 10% probability of non-exceedance in 50 years and a 10% probability of non-exceedance in 250 years. Attached to both sets of maps was the caveat:

> These maps are presented to introduce new and relevant data for estimating spectral response acceleration. They should not be used for design at this time but should be evaluated by trial design (BSSC, 1992).

On the maps estimating probabilities of 10% non-exceedance in 250 years, even stronger caveats were attached to uncertainties in these estimates, and they ended with the statement that "any values on this map should be considered advisory and treated with caution" (BSSC, 1992). Older maps, those developed from ATC-3, were still included as the basic design maps in the 1991 recommended provisions.

This outcome, the retention of design maps based on 1976 scientific maps and the relegation of newer maps based on subsequent scientific maps to the appendixes, was the result of the BSSC consensus process to develop the 1991 recommended provisions. It began in 1988 when BSSC and SEAOC supported a request to USGS for spectral ordinates in the next generation of maps (Zacher, 1995). From 1988 through 1990, USGS developed national maps for spectral ordinates of 0.3 and 1.0 seconds, respectively (Perkins, 1995).

With S.T. Algermissen as its chair, the BSSC seismology subcommittee (technical subcommittee 1 or TS-1) proposed the spectral maps drawn by USGS in response to the original BSSC-SEAOC request be included in the 1991 recommended provisions. However, the design values subcommittee, TS-2, composed largely of structural engineers, had serious misgivings about the map. The SEAOC contingent of this subcommittee did not want the maps to be published at all. The contingent of structural engineers east of the Rockies wanted them published, and so did BSSC and FEMA. As is typical when controversies cannot be resolved and a consensus cannot be reached, a compromise to publish the maps in an appendix of the 1991 recommended provisions was arrived at, along with the aforementioned caveats (Beavers, 1995; Sharpe, 1995).

Reasons for a strong negative response to the proposed USGS mapped products among both scientists and structural engineers included:

1) the great uncertainties in the values developed for the 250-year return intervals, especially in the Central and Eastern United States; these uncertainties had been a concern of the mappers themselves (Sharpe, 1995; Wright, 1995);
2) the radical changes implied by the maps in structural engineering and building practices in California—in increasing design values in the San Francisco Bay and Los Angeles Basin regions and in lowering values in the Sacramento region (Bachman, 1995); and
3) the treatment of the Cascadia subduction zone and its potential impacts on Pacific Northwest seismic design procedures (Beavers, 1995).

Following this outcome, the TS-2 committee worked briefly with S.T. Algermissen of the TS-1 committee in order to understand and rectify the situation, but moneys at USGS were cut for Dr. Algermissen to continue these efforts (Sharpe, 1995). The controversy continued through 1993 as the 1994 NEHRP provisions were being considered and was enlarged by the addition of other issues, including:

1) the accusation that USGS mappers did not provide adequate consideration of differing opinions, methods, or judgments of geoscience professionals outside the USGS (Porush, 1993A);
2) administrative problems of the enforceability of contours going through local jurisdictions (CSSC, 1993; Porush, 1993A);
3) problems of the attenuation equations used, especially with respect to near field estimates (Porush, 1993A);
4) successes of buildings designed to lower values than were being proposed (Porush, 1993A);
5) the use of probabilistic as opposed to deterministic methods (Jacob, 1993; McClure, 1993);
6) special considerations near active faults (Beavers, 1993);
7) the role of structural engineers in setting the fundamental characterization of seismic risk in default of the public and public representatives who are ignorant of technical details of seismic risk (CSSC, 1993; Porush, 1993B);
8) the role of long-term practitioners in guiding (or misguiding) BSSC efforts, specifically, the lack of appreciation of these practitioners of more objective mapping procedures and their resistance to change (Jacob, 1993); and
9) the possible negative response of the public to the proposed seismic maps (CSSC, 1993).

Reorganized Activities To Resolve the Controversy

Because it was felt that the routine BSSC process to develop recommended provisions each three years was inadequate for the mapping controversy to be resolved by 1994, BSSC asked FEMA for additional funds to support a "Design Values Committee" made up of representatives from three revised technical subcommittees of BSSC's Provisions Update Committee (PUC). These included members from TS-1 (Seismic Hazard Mapping), TS-2 (Structural Design Criteria and Analysis), and TS-3 (Foundations and Geotechnical Considerations). Even with additional resources, the Design Values Committee was unable to agree on several issues, and the disputed maps were again placed in the appendix of the 1994 recommended provisions (see BSSC, 1995).

To finally get closure on the mapping controversy and to reach a consensus on new maps by the publication of the 1997 edition of the NEHRP recommended provisions, and following the failure of the Design Values Committee, BSSC proposed a joint effort between itself, FEMA, and the USGS, referred to as Project '97, which would work separately from but in conjunction with the BSSC provisions update process. Scientific issues would be addressed by the USGS, and their goal was to deliver new maps by April 1996. Working in parallel, BSSC would determine how to develop design value maps, would incorporate the USGS maps when they were received, and then would produce consensus design value maps or their equivalent for inclusion in the 1997 NEHRP recommended provisions.

Contemporaneous with the start of Project '97, the three regional model code organizations, BOCA, ICBO, and SBCCI, had decided to move toward a single national code by the year 2000. A joint directive, dated December 9, 1994, led to the creation of the International Code Council (ICC), the mechanism for the development and maintenance of the unified international codes.

Part of the reason for consolidating the codes lies in the growing international demand for uniform standards. The collapse of the Soviet Union, the creation of the European Common Market, and the increased involvement of the United States in international trade agreements have altered the world economy significantly in the last 10 years and prompted governments, manufacturers, and their customers to support means to guarantee product quality and performance. In addition to supporting these goals, uniform building standards would address other areas of concern, including disability, environmental, and energy regulations and the effects of natural disasters (Fowler and Smith, 1994: pp. 4-5). If the United States is able to produce a single model code, the ICC would be able to market that in other parts of the world as part of an effort to develop truly international codes, and it would also provide an opportunity for the U.S. materials industry to gain a competitive advantage in the sale of their wares (Beavers, 1995; Wright, 1995).

More specifically, the impetus for the development of the ICC and the movement toward a single code includes the following benefits:

- the standardization of building construction practices, which would eliminate unnecessary complexity caused by a multicode system and which would also provide for more uniform education and certification programs;
- increased innovation in material products and their use caused by the elimination of three sets of design standards; and
- the retention of private-sector code development caused by the consolidation of the three model code groups, which will also unify opinions regarding national issues and federal government policies and will allow the three model code organizations to put their collective efforts toward better code enforcement and disaster reduction (EERI, 1995).

Started in 1993 and funded by the California Office of Emergency Services (OES) from Northridge earthquake post-disaster moneys, Vision 2000 was initiated by SEAOC to develop their version of a seismic code. The goal of Vision 2000 is to develop the framework for procedures that yield structures of predictable seismic performance (SEAOC, 1995).

The National Center for Earthquake Engineering Research (NCEER) has also entered this process with three workshops on technical issues related to seismic mapping controversies (Perkins, 1995).

Issues Addressed

The initiation of Project '97 and Vision 2000 along with the development of the ICC have all underscored the need to develop a universally acceptable seismic code and seismic maps. To do so implies that the fundamental bases for these end products be evaluated so they may eventually stand on firm ground. Exhibit A (included at the end of this section) summarizes many of the technical issues and uncertainties implicated in a seismic hazard mapping program that are currently being addressed (see also Bender and Perkins, 1993; Frankel, 1995B). Exhibit A also includes a few policy issues that have significant technical components.

Among the many issues and uncertainties that exist in the seismic mapping program, those especially referenced in our interviews include:

- What is the suitable ground motion parameter to use? Does the testing program have a consistent protocol to provide data on actual response of structures? What does earthquake experience imply about the strong motion parameter to be used? (Anderson, 1995; Bachman, 1995; Crouse, 1995; Perkins, 1995; Reaveley, 1995; and Zacher, 1995)
- What standard site conditions should be used? (Perkins, 1995)
- Should there be an equal hazard level or levels across the country? Should there be a lower bound on strong motion values used in seismic code design procedures? Should there be an upper bound

on strong motion values used in seismic code design procedures? (Bachman, 1995)

- Should there be a two-level or one-level design? (Perkins, 1995)
- Are the scientific criteria adequate for the selection of attenuation functions, estimation of near-field effects, incorporation of uncertainties, use of slip rates and characteristic earthquake models, and application of other source zones models, etc. as a basis for seismic maps? (Crouse, 1995; Frankel, 1995A; and Zacher, 1995)
- Should probabilistic methods be used for all maps? (Krinitzsky, 1993; Anderson, 1995; and Cornell, 1995)
- Should complexity be added to or removed from the seismic design process? (Algermissen, 1995; Hays, 1995; Perkins, 1995; and Ward, 1995)

An Analysis of the Knowledge Transfer Process

Discussion

According to Allan Porush and Ed Zacher (1987), developing seismic code provisions, including the ongoing incorporation of geological knowledge, has become a complex, time-consuming process in which the number of government, industry, volunteer, and other group participants has expanded greatly. To reflect the complexity and dynamism of this process, our analysis of how geological knowledge is transferred into seismic codes is based on field theory developed by Lewin in the 1930s, conceived by him to represent changing behaviors as a function of changes in thinking, knowledge, and goals, within a changing environment (Lewin, 1951). Basically, what Lewin says is that one can understand the actions of individuals or groups only in the context of choices facing them, their attitudes concerning these choices, and the environment within which these choices are made.

To encompass the universe of relevant variables in a field theory analysis, the following discussion will be broken down into four separate categories: 1) characteristics of the formal and informal decision processes that combine to make up the knowledge transfer process; 2) characteristics of proposed code changes; 3) characteristics and attitudes of the participants; and 4) the environmental context. An attempt will be made within each of these topics to describe their significant aspects and the impact they have on the overall knowledge transfer process. Subsequent to this discussion, the field theory analysis will be presented.

Characteristics of the Decision Processes

The development of seismic code provisions takes place in a relatively ordered sequence of decision processes conducted by different participants in the knowledge transfer process. Initial ideas for prospective code enhancements or changes come from the results of scientific (geological, geoscientific, seismological, engineering) investigation or practical experience (analysis of postearthquake damage). They arise in a nonprogrammed way, emerging unscheduled from peer review analyses. In the normal course of events, ideas first must stand on their own and then compete with vying theories before consensus is reached on their viability.

At any time, often before attaining consensus among experts, these ideas may be transformed into proposals for code change by any of the participants. However, to successfully have ideas adopted into actual code requires that the participants adhere to a strict schedule embodied in the three main code groups' code development processes. (See Figure 2 for a schematic illustration of the ICBO code development process.) To accommodate the publication of the three main code groups' new editions of their model codes every three years or supplements in the intervening years, changes are programmed or made in time-certain procedures.

Logically, then, for knowledge transfer to be successful, the participants must think in a programmed fashion, adopting the schedules laid out by the model code groups. In our interviews, we confirmed that the timing of these decisions drives the knowledge transfer process. There are consequences to operating in a programmed innovation process. Knight (1967) argues that a programmed innovation process works best for small-scale or routine change, while a nonprogrammed innovation process works best for large-scale or radical change. The term radical change corresponds to a high degree of risk, novelty, or creativity. While a proposed change may be routine or radical, so may the situation in which the decision is made. As the number of people "in the loop" increases, so does the degree of radicalness of the situation. For radical knowledge transfer to be successful, nonprogrammed thinking and actions are typically required. However, when a radical change is proposed within a programmed innovation process or when the programmed process is radical, then the time to achieve consensus increases and the probability of successful change within the time constraints of the code change process diminishes.

- PROPOSITION 1: Within a programmed innovation process, the more radical the proposed change, the less likely the change can be accomplished within the parameters of the process.
- PROPOSITION 2: Within a programmed innovation process, the more radical the situation in which the process occurs, the less likely the change can be accomplished within the parameters of the process.

Although the two propositions above suggest that radical change is less likely to be accommodated in the programmed innovation process, the participants can alter their behaviors and procedures to reduce the radicalness of their proposed changes. Zaltman and his colleagues (1984) suggest that radical ideas be tested on a limited basis before formally submitting them to the programmed process. If proposed changes are amenable to demonstration and the advantages of the innovation are clearly visible, then the test results can overcome inherent uncertainties in radical ideas or reduce opposition among decision makers in structurally radical processes.

This behavior can presently be seen in the actions of many groups, including SEAOC, BSSC, and the model code groups. In SEAOC and BSSC, radical ideas that have not achieved consensus agreement on inclusion in recommended code changes are often placed in the appendix of their proposed code changes,

Exhibit A: Technical Issues Surrounding Mapping.

These technical issues revolve around (a) the uncertainties involved in seismic mapping and (b) policy issues surrounding the uses of mapping results. The presence of large-scale uncertainties in seismic mapping is also a policy issue.

Quantitative uncertainties involved in seismic hazard mapping pertain to

* uncertainties in modeling earthquake sources and

* uncertainties in modeling the propagation of earthquake waves through the earth's crust from earthquake sources to individual sites.

In modeling earthquake sources, the following uncertainties are apparent:

* models ultimately used in estimating distances of sources to sites
    * spatial models of sources
        * linear models ("known active faults") and segmentation boundary uncertainties
            * areal models
                * polygons
                * fuzzy patches
        * depth dimension (e.g., focal depth, three-dimensional modeling, modeling of dip angle)
    * randomization models for diverse sources
        * characteristic earthquake models and their uncertainties
        * use of uniform distributions for fault rupture centers, epicenters, hypocenters, etc.
        * use of Gaussian distributions for fault rupture centers, etc.
        * magnitude-rupture length uncertainties
        * uncertainties in the orientation of rupture zones
    * scientific basis for application of spatial models
* estimates of frequency of occurrence of specific earthquake magnitudes within diverse earthquake sources
    * reliability of historic and instrumental databases of past earthquakes in terms of location, magnitude and frequency of occurrence
    * application of models to interpolate frequency of occurrence for diverse earthquake magnitudes
        * Gutenberg-Richter relationship and its applicability to the source model
            * "a" and "b" values derived for the source model
        * characteristic earthquake model and its applicability to the source model
            * frequency of occurrence estimated and its basis (e.g., the uncertainty in the application of slip rate data
    * application of models to determine upper bound magnitudes in earthquake source models, and
    * application of time-independent (Poisson) or time-dependent (strain-build up versus contagious) models.

Exhibit A (continued)

In estimating the propagation of earthquake waves from the earthquake sources to individual sites, the following are uncertainties of interest:

* the reliability of past data and models for evaluating how earthquake waves attenuate as they propagate from source through rock to the site
  * the applicability of results derived from one region to other regions
  * uncertainties in the functional form used to evaluate the data
  * uncertainties of the data and models to capture "near field" phenomena
  * uncertainties resulting from faulting style (strike-slip, dip-slip)
  * uncertainties resulting from direction of the fault propagation
* the application of these models to diverse local soil circumstances
  * uncertainties in the definition of "rock" as used in the models and data
  * uncertainties in free field/basement/first story strong motion data used
  * uncertainties in the modeling of soils and soil types (and effects on the natural periods of the earthquake waves).

Specific policy choices involved include:

* selection of return interval or intervals to be mapped (e.g., 474-year return intervals have been standard since about 1976, but shorter and longer return intervals have been proposed)
* selection of which strong ground motion index or indexes to be mapped (e.g., peak horizontal acceleration, spectral acceleration, spectral velocity, duration of earthquake(s))
* usability of "deterministic" estimates of strong ground motion

the Blue Book and the NEHRP recommended provisions respectively, as nonbinding changes and suggestions for inclusion in subsequent editions of their recommended changes. Engineers are encouraged to use these ideas on an experimental basis and then to comment on their usefulness. Trial designs are commonly used to confront controversies. Similarly, the three model code groups include novel ideas in their appendixes that local jurisdictions have the option to adopt or not. These procedures allow for the introduction of radical changes on a limited basis when it is likely that they would be rejected in the formal code change process.

- PROPOSITION 3: When radical ideas are not likely to be adopted in a programmed knowledge transfer process and when tests can be conducted that demonstrate the benefits of these ideas, then opposition to radical ideas can be tempered through the use of demonstration tests. When organizations who employ a programmed knowledge transfer process acknowledge that radical ideas will be introduced on a regular basis, they can institute education programs prior to and subsequent to adoption in order to build a knowledgeable constituency and to reduce any opposition to adoption. This behavior is currently practiced in the three model code organizations, which both notify building officials of new code sections in their publications and offer courses to train building officials in the interpretation and implementation of new code sections.

- PROPOSITION 4: When radical ideas are commonly introduced in programmed knowledge transfer processes, opposition can be reduced through the education of the decision makers and those who must implement the changes.

Characteristics of Proposed Code Changes

Proposed code changes are inherently multidimensional. Although described in the last section as either routine or radical, they can display many additional characteristics that either inhibit or enhance their adoption. In this section, 12 potential attributes will be described, and their impact on the knowledge transfer process will be assessed. Much of this analysis is based on the attributes of innovation developed by Zaltman, Duncan, and Holbeck (1984).

- *Cost*. Proposed changes may impose financial and social costs on various persons in the engineering, construction, code enforcement, real estate, and other industries as well as owners and occupants of structures. Financial costs include initial costs, ongoing costs, and long-term economic costs. Social costs include changes in power and status. As a general rule, as the costs increase, the probability of change adoption decreases.

- *Efficiency*. Proposed changes may simplify or make tasks easier to accomplish. They may also reduce uncertainties in decision making. To the extent that proposed changes increase efficiency, the probability of change adoption increases.
- *Risk and uncertainty*. Risk and uncertainty arise when proposals are untested or when the implementation of proposed changes is thought by some to lead to undesired results. As a general rule, the greater the risk and uncertainty, the less likely change adoption will occur.
- *Safety*. Proposed changes may provide increased safety to protect life and property. To the extent that proposed changes increase safety, the probability of change adoption increases.
- *Communicability*. How well a proposed change represents what is expected to occur if implemented influences whether a proposal will be accepted. The more imprecise the language, the less likely change adoption will occur.
- *Compatibility*. New ideas challenge the status quo. Compatibility concerns how consistent the proposed change is with existing values, current practices, and current needs. A proposed change may be pervasive in the sense that its adoption will require changes or adjustments in other parts of the system or attitudes held by participants. As a general rule, the greater the pervasiveness of a proposed change, the less likely change adoption will occur.
- *Complexity*. Complexity can manifest itself in two ways in a proposed change. It can be conceptually involved, or it can be difficult to implement. As a general rule, the more complex the change proposal or the more difficult to implement, the less likely change adoption will occur.
- *Scientific status*. A proposed change may represent the consensus view of experts or the opinion of a few experts, where the merits of the view are still being debated in scientific circles. Depending on the degree of acceptance within the scientific community, as a general rule, the more accepted the change proposal, the more likely adoption will occur. However, as Zaltman et al. (1984) point out, one should remember that "not all scientifically sound innovations are adopted, nor are all unsound innovations rejected" (p. 39).
- *Point of origin*. Who suggests a change influences the resulting decision concerning a change. A proposal has a greater chance of being accepted if it comes from a person or group acceptable to the decision makers, irrespective if the proposer is qualified to make the proposal.
- *Commitment*. As the knowledge transfer process is often a prolonged effort, change proposers must dedicate themselves to the adoption process, believing both in what they are attempting to accomplish and in the process of change. As a general rule, the more committed the proposers, the more likely change adoption will occur.
- *Interpersonal relations*. Changes can disrupt old ways of doing things. When disruption occurs, often what is most upset are the relationships among the participants in the decision-making and implementation systems. On the other hand, changes can overcome poor relationships and substitute more integrative ones. On a disruptive-integrative continuum, the more disruptive change is to interpersonal relations, the less likely change adoption will occur.
- *Capacity*. If change is to occur, the personnel and organizations that must implement the change must have the resources and ability to adequately meet the demands of implementation. As a general rule, the more a change proposal requires additional capacity, the less likely change adoption will occur.

Characteristics and Attitudes of the Participants

The participants in the seismic code change process come from a variety of organizations and represent a wide range of viewpoints. Among them are federal government agencies such as the U.S. Geological Survey (USGS), the Federal Emergency Management Agency (FEMA), and the National Institute for Standards and Technology (NIST), state government agencies such as the California Seismic Safety Commission, quasi-government organizations such as BSSC, trade organizations such as the American Iron and Steel Institute, the Portland Cement Association, and the Masonry Institute, engineering associations such as the American Society of Civil Engineers (ASCE), the Earthquake Engineering Research Institute (EERI), and state structural engineering associations such as SEAOC, research organizations such as ATC, and model code groups whose members include local building officials. Over time these and other organizations have taken a small or large part in transferring scientific knowledge into seismic codes. Later in this section, during the field analysis, specific notice will be taken of them and their roles. The remainder of this section will concentrate on general characteristics of the organizations and the potential implications of these on the knowledge transfer process.

According to Perrow (1970), a useful distinction is to differentiate volunteer from nonvolunteer organizations that include governmental and economic organizations. While he posits that governmental organizations attempt to control resources to meet political agendas and that economic organizations attempt to control resources to generate profits, Perrow states that voluntary organizations "mediate between the individual and society, or between groups in society, and that they represent group interests that are best met by cooperative action" (p. 98). Within society, voluntary organizations function as "pressure groups to alter the behavior of governmental or economic organizations, either because members are reluctant to have services provided by these other types, or because the other types have failed to provide services" (p. 98).

The process leading to the development of seismic code provisions in model codes is replete with volunteer organizations that have thrived because the federal government has been reluctant to establish a national code. Especially prominent are the state structural engineering associations, the trade associations, and the model code groups themselves. The effect of having many voluntary organizations in the seismic code process, especially when demands on their resources have increased, is critical to understand the process.

The main resource provided by volunteer organizations in the seismic code process is expertise to develop code change proposals and to evaluate code change proposals. Individuals who contribute their efforts to voluntary organizations typically do so in exchange for the power to control the goods or services provided by these organizations. When the organization's output is represented by creative endeavors, resources will also be expended to "create, establish, or convince people of the legitimacy of the output" (Perrow, 1970: pp. 107).

As greater demands are placed on voluntary organizations, they become less able to complete their tasks because "the proportion of members of voluntary associations who do any more than attend an occasional meeting is quite small" (Perrow, 1970: pp. 105). To reduce the time spent on tasks, in situations where voluntary groups provide complementary products, political logrolling may occur as groups trade support for one another's output.

Perrow further argues that the position leaders of volunteer organizations take on issues is independent of who the leaders are. Among the leaders, "there is probably little difference in commitment and ideological conformity" (Perrow, 1970: 113). Therefore in discussing voluntary groups at different points in time, one need not reference the specific leaders as the stance taken by the organization generally represents the positions of the leaders.

Voluntary organizations generally profess to be democratic; however, they seldom make collective decisions in which the majority of the members are active participants. Most often, a dominant coalition substitutes for the members and participates in decisions on behalf of the members. A consensus decision is typically one in which a super majority of the dominant coalition agree.

The Environmental Context

Decisions affecting change processes are made in the context of societal needs and concerns. Some societal attitudes encourage change and some mitigate against it. As a backdrop, the actions of society in general influence the scope and content of change proposals and the processes that evaluate them. Two important sources of societal concerns are government and public opinion. Government, especially the federal government, can enact laws promulgating specific actions, can create committees to investigate and recommend actions, can fund research projects to enhance the development of science or engineering, can publish papers, can fund or sponsor conferences, and can adopt programs that encourage the private sector to devote more time and resources to specific actions. In an opposite direction, the government can withdraw support from certain actions, repeal laws, and curtail funding of research, publications, and conferences. The public can either become more or less concerned about actions it wishes to see addressed by private industry, the government, or researchers.

As to the process of developing code provisions, the federal government has engaged in all of the above actions at various times. When positive actions occur, we expect to see more change proposals than at other times. The public generally encourages the investigation and improvement of seismic codes following major earthquakes. After earthquakes occur, we expect to see more change proposals than at other times.

Earthquake events also create testing sites for research projects and the investigation of structures to determine the practical value of existing seismic codes and construction practices. After earthquakes occur, when research is completed, we expect to see a greater number of code change suggestions. Although we are not specifically tracking the number of research articles, we also expect to see a greater number of publications and, consequently, an enhanced picture of many earthquake-related topics. More publications should eventually lead to a better understanding of certain seismic issues and then recommendations to improve seismic codes.

Field Theory Analysis

Kurt Lewin (1951) looked at institutional behavior as a dynamic balance of factors encouraging and facilitating change (driving forces) and factors opposing change (restraining forces). He defined forces as tendencies to locomotion toward a specific goal and a force field as the distribution of forces in space. Driving forces are concerned with ambitions. Where multiple factions promote competing change programs, he noted that certain goals are not universally sought and driving forces supporting change but opposed to a specific goal or aversions would be present. Restraining forces are typically environmental or institutional elements inhibiting driving forces, including such things as organizational status, organizational relationships, governmental laws and programs, and organizational capacity.

Zaltman et al. (1984) suggest that change initiation occurs when a performance gap or a discrepancy between what could be done and what is actually done is perceived to exist and a desire to close the gap results. Force-field analysis permits the analysis of change to take place by organizing the information pertaining to change into two categories representing forces for change and forces to maintain the status quo.

As indicated in the last chapter, seismic codes in general and seismic maps in particular have been changing since the 1920s. However, the dynamics of the change process have accelerated in recent years. To understand these changes, we have selected five time frames to analyze using force-field analysis, each ending with an important development in the seismic code change process. All but the first of these time frames have significant map revisions contained within them; what is being highlighted is the dynamic nature of the code change process and the knowledge transfer that occurs, especially in change proposals involving seismic maps. These time frames include:

1) 1951-1961: development of the first SEAOC Blue Book;

2) 1962-1970: development of the first Algermissen map;

3) 1971-1978: development of ATC 3-06:

4) 1979-1988: development of NEHRP and 1988 Blue Book;

5) 1989-present: development of new maps and code proposals.

1951-1961: Development of the first SEAOC Blue Book

The publication of Separate 66 in 1951 caused leaders in the northern and southern California structural engineering associations to work toward the development of a uniform seismic code that would be acceptable to all structural engineers in California and would replace several codes currently in use in the United States and in different parts of California. With the ultimate goal of having this code adopted into the UBC, SEAOC formed a committee to develop a uniform code in 1957. The committee's task was completed in 1959 and published in blue covers, hence the name Blue Book. Thenceforth, the Blue Book was submitted to ICBO and adopted in the 1961 UBC without opposition.

The main force for the development of a uniform seismic code was the structural engineers of California. Their effort was successful because ICBO and its members were receptive to the change. The development and adoption of the Blue Book into the UBC was a classic case of closing a performance gap. The main participants in the knowledge transfer process, the structural engineers and ICBO concurred that a performance gap existed and that SEAOC had the expertise to develop needed earthquake provisions in the UBC and was the appropriate point of origin to submit the proposal. The proposal had many positive attributes; it provided efficiency and scientific status, integrated disparate seismic codes, and was able to be implemented within the capacity of members of ICBO.

Happenings in the environment. There were many occurrences that encouraged earthquake research and publications that improved the state of knowledge. Each of these either stimulated driving forces for future change or reduced the strength of restraining forces, leading to major changes in subsequent years. Some of the more significant ones are listed below.

At the federal level, President Eisenhower created the Berkner panel in 1958 to promote research in seismology leading to the distribution of $250 million in the following decade. The steel and concrete industries were active in sponsoring research, especially to demonstrate that their products would withstand earthquake forces in highrise buildings soon to be constructed in California. To support its arguments, the

Portland Cement Association commissioned and published *Design of Multistory Reinforced Concrete Buildings for Earthquake Motions* by Blume, Newmark, and Corning in 1961. EERI conceived of and held the first world conference on earthquake engineering in Berkeley, California, in 1956, leading to the establishment of the International Association of Earthquake Engineering.

In the area of seismic maps, in 1958 Richter developed and published a seismic regionalization map that "depicted the estimated maximum ground motion rather than the distribution of earthquake epicenters, and it introduced the notion of frequency of occurrence of earthquakes in a qualitative way" (Algermissen, 1983: pp. 105). Kanai (1958) published the first graphical attenuation function.

1962-1970: Development of the First Algermissen Map

The defining event of this time frame prompting the new USGS map was the 1964 Alaskan earthquake. Shortly thereafter, ICBO requested that the Seismology Subcommittee of its Code Changes Committee make a complete investigation of seismic zoning throughout the United States.

According to Ted Algermissen (1995), about this time, Karl Steinbrugge asked him as a representative of the US Coast and Geodetic Survey (USCGS) to develop a seismic zone map for the United States to update the map used in the UBC since 1949. Algermissen agreed, developed a map for the contiguous 48 states in conjunction with discussions with the ICBO Seismology Subcommittee, and presented it in his paper, "Seismic Risk Studies in the United States," at the Fourth World Conference on Earthquake Engineering held in Santiago, Chile, in 1969 (Algermissen, 1983; and Yin and Moore, 1985).

In 1967, the Greater Juneau Bureau of ICBO, on advice of the US Army Corps of Engineers, submitted a code change proposal requesting that the state of Alaska be included in the UBC maps and that it be designated as seismic zone 3, then the highest seismic zone. The Seismology Subcommittee and the membership of ICBO approved the request.

In 1969, the Seismology Subcommittee recommended and approved that the Algermissen map and additional seismic zone maps for Alaska and Hawaii replace the map that had been part of the UBC since 1949 and be included in the 1970 edition of the UBC. The Seismology Subcommittee introduced the formal code change proposal, which was approved by the membership of ICBO.

The main force behind this map change was ICBO, whose leaders believed that the status quo maps had become obsolete and that the benefits of recent seismological research should be incorporated into the UBC. The knowledge transfer process proceeded smoothly because the new maps were compatible with existing map design parameters (they looked similar and had the same number of seismic zones) and were not pervasive, had scientific status, and had been thoroughly reviewed by an ICBO code changes subcommittee before being approved for submission.

Happenings in the environment. Not only did the Alaskan earthquake prompt ICBO action, it also led to a veritable explosion in government programs and investigations and the start of many important research thrusts in seismology and earthquake engineering whose effects are still being felt in the discussions over the content and scope of seismic maps. In the area of research, Housner (1965) published an important graphical attenuation function (empirical functions had to wait until data from the 1971 San Fernando earthquake were available), and several authors, including Cornell (1968), Lomnitz (1969), Esteva (1969), Cornell and Vanmarcke (1969), and Milne and Davenport (1965 and 1969), published pioneering papers on probabilistic methods. The Alaskan earthquake also stimulated academic courses devoted to applied earthquake engineering at the University of California at Berkeley, leading to the publication of *Earthquake Engineering*, a compilation of articles based on the lectures, edited by Wiegel in 1970.

Organized postearthquake investigations by structural engineers, geological scientists, insurance investigators, and others continued as major earthquakes occurred worldwide. The American Iron and Steel Institute, for example, sent teams to Agadir, Morocco, in 1962; Skopje, Yugoslavia, in 1963; Anchorage, Alaska in 1964; and Caracas, Venezuela, in 1967. These trips provided a growing number of people first-hand knowledge about the effects of earthquakes on structures.

Following the Alaskan earthquake, where the federal government provided disaster assistance in excess of actual losses to bolster the state economy (Dacy and Kunreuther, 1969), and in the wake of Hurricane Betsy, congressional investigations into the role of the federal government following natural disasters were initiated. Two important results included the establishment of the National Flood Insurance Program in 1968 and the rejection of a proposal to establish a national earthquake insurance program. To protect their buildings from earthquakes, the Departments of the Army, Navy, and Air Force jointly developed a seismic building code (entitled *Seismic Design for Buildings* but referred to as the Tri-Services Manual) based on the 1964 UBC and referencing the 1963 revised Blue Book as commentary. In the state of California, the legislature established the Joint Committee on Seismic Safety in 1969 to investigate seismic issues and recommend legislative responses.

1971-1978: Development of ATC 3-06

After completing its second revised Blue Book in the late 1960s, which was adopted by ICBO in 1970, leaders in SEAOC became convinced that volunteer effort alone was insufficient to guarantee the continued development of state-of-the-art lateral force design criteria on a timely basis. They believed that paid full-time professionals conducting research, publishing the results, and maintaining currency in the field would relieve the volunteers from much of the necessary work and prevent the deterioration of the organization's quality output. Therefore, in 1970, SEAOC proposed the establishment of the Applied Technology Council (ATC) to assist design practitioners in structural engineering to keep abreast of technological development and to conduct government-sponsored research. The organization was established in 1971 as an independent, nonprofit body with start-up funds and institutional support provided by the National Science Foundation (NSF), the National Bureau of Standards (NBS), and SEAOC.

The federal desire to control disaster losses and to minimize disaster assistance had not abated when the 1971 San Fernando earthquake occurred. The damages caused by the earthquake reinforced the efforts of federal officials to develop mitigation methods to reduce loss of life and property damage caused by natural disasters. As a direct result of this concern, NSF and NBS initiated in 1972 a Cooperative Program in Building Practices for Disaster Mitigation to integrate the efforts of public and private organizations to develop improved building practices applicable throughout the United States, essentially providing recommendations for upgrading building codes. ATC was contracted to develop the seismic design provisions with participation from concerned interests in both the public and private sectors to meet OMB concerns that a consensus process be used to develop national standards. Fourteen task committees organized under five task groups supported by two advisory groups, one consisting of prominent professionals in earthquake engineering and one consisting of representatives from building code organizations and local building officials, conducted the work. The SEAOC Seismology Committee reviewed the work of ATC as it progressed. Before final publication, NBS funded an analysis of ATC-3 that included an objective to provide technical and editorial assistance to ATC as it prepared ATC 3-06, eventually published in 1978.

As part of the ATC project, national seismic hazard maps specifying earthquake ground shaking for design were sought. Coincidental to this effort, Algermissen and Perkins were developing probabilistic ground motion maps for the conterminous 48 states using new knowledge from studies showing the application of probabilistic models to earthquake hazard estimation and from new models of the attenuation of ground motion. In 1976, Algermissen and Perkins published their probabilistic acceleration map, forming the basis for the two ground motion maps published in ATC 3-06 based on effective peak acceleration and effective peak velocity.

The Algermissen-Perkins map was not transferred directly into the ATC maps. They differed in several ways. The Algermissen-Perkins map was a contour map that displayed accelerations as high as 0.8 g in California. The ATC maps displayed seven differently colored map areas representing gradations of four seismicity zones with boundaries shifted to lie along county lines and to include just the highest

Tri-Services manual was completed in 1973 with the help of SEAOC. In this revision, the 1969

contour in every county, with accelerations truncated at 0.4 g.

In the commentary within ATC 3-06 (ATC, 1978: pp. 296-331), the decisions to select probabilistic ground motion maps and to make modifications to the Algermissen-Perkins map are explained. In essence, the ATC task group concerned with seismic input rejected the UBC maps based on the 1969 Algermissen map as being scientifically outdated and wanted to incorporate the most up-to-date scientific thinking that was included in the 1976 Algermissen-Perkins map. However, because there was debate among scientists and engineers concerning the probabilities and durations of maximum accelerations and the ability of structures to provide added protection against accelerations above 0.4 g, design engineers wanted to eliminate accelerations and substitute what they termed "effective" peak accelerations. Support for this decision came from those who noted that the cost of constructing buildings to withstand extreme motions might make construction of certain structures prohibitive. After analyzing its recommended changes, ATC estimated that the increased costs of designing to its design criteria would be less than 1% of the total cost of a building. County-by-county maps were selected to reduce the ambiguity of determining values between contours and to simplify the job of local building officials. Where a county or area within a county was subject to multiple earthquake risks, ATC recommended that the local jurisdiction consider microzonation studies to map their jurisdictions.

As a document that could be used to foster code changes, ATC 3-06 has mixed characteristics. It addresses financial costs and implies that the recommended design changes would have a small financial effect. However, there is no empirical evidence to support this conclusion, and the document does not address social costs arising from the changes; it could be envisioned that the county maps might simplify the life for local building officials, but they could also add additional job stress if microzonation was needed to evaluate design of critical buildings. When ATC 3-06 was published, the scientific theories that served as the basis for the maps were still being debated; therefore, the scientific status of the recommendations was unclear. Many of the scientific theories underpinning the new maps also differed radically from and were more complex than those undergirding the status quo maps, which had relied mainly on historical seismicity. Finally, due to unwillingness of federal officials to mandate building codes, there was no commitment to see ATC 3-06 become the law of the land.

After the publication of ATC 3-06, the NBS assessment was released in a technical note. It recommended that a thorough systematic analysis of the recommended provisions be conducted by any and all interested parties and that trial designs be conducted to establish the technical validity of the recommended provisions and to assess their economic impact (Harris et al., 1979).

While ATC was involved in the development of its seismic design recommendations, a revision of the preliminary survey in a 1971 Geological Survey professional paper (USGS, 1971). During the 1970s, EERI, with the cooperation of the International Association of Earthquake Engineering, created its "Learning from Earthquakes" program, which includes the creation and dispatch of a multidisciplinary reconnaissance team to any location throughout the world that has been struck by a major earthquake, the publication of their report, and the sponsorship of lectures on their findings.

1979-1988: Development of NEHRP and the 1988 Blue Book

When ATC 3-06 was published and the NBS analysis of it concluded that tests were needed to verify the technical and economic claims implied in the tentative provisions, and when the NEHRP was created to promote improved seismic building design, there was no public or private organization or forum agreeable to concerned interests that should manage the seismic hazard reduction project or conduct the tests. FEMA had been given federal responsibility for the NEHRP, but it was a new agency without the proven skills within it to carry out the program requirements. Ultimately, a suggestion of Charles Thiel at NSF to form an independent council under the aegis of NIBS, later named the Building Seismic Safety Council (BSSC), was adopted "following a series of meetings between representatives of the original participants in the NSF-sponsored project on seismic design provisions, FEMA, the American Society of Civil Engineers and the National Institute of Building Sciences" in the spring of 1979 (BSSC, 1995, Part 2: pp. 322).

BSSC was established under the NIBS authorizing legislation as a voluntary membership body of a wide spectrum of building community interests providing a forum fostering the development of seismic safety provisions suitable for use throughout the country. Essentially, its creation institutionalized the situationally radical decisionmaking process employed to develop ATC 3-06. As an organization, BSSC does not establish mandatory seismic safety provisions, but it recommends, encourages, and promotes the adoption of such provisions by voluntary standard and model code organizations. When BSSC was founded, it was faced with the task of reviewing the tentative provisions of ATC 3-06 and establishing a trial design program plan to determine which provisions could be recommended to the model code organizations. The initial goal was to have a list of recommendations published in 1985, when new editions of the model codes were issued, and then to develop updated editions of recommended provisions in the same three-year cycle as the model code groups.

BSSC contracted with 17 design firms to conduct the trials. When they completed their work, a draft version of the recommended provisions was drawn up and sent to the member organizations for a vote. Draft provisions were revised to reflect objections, and a second ballot was sent out with the revised draft. As a result of the changes, consensus approval was achieved. A final document, the first *NEHRP*

Recommended Provisions for the Development of Seismic Regulations for New Buildings, was sent to FEMA for publication and published in December, 1985. Among the recommendations were the two seismic ground motion maps based on effective peak acceleration and effective peak velocity that were included in ATC 3-06. Newer maps published by Algermissen, Perkins, and their colleagues (1982), based on spectral response, and others were placed in an appendix for further consideration when they were unable to gain consensus acceptance.

Efforts to produce the 1988 edition began with a restructuring of BSSC. Nine technical committees, including one dedicated to seismic risk maps, under the general direction of a Technical Management Committee (TMC), were established to finish the work of evaluating the tentative recommendations of ATC 3-06, unresolved at the publication of the 1985 recommendations, and to deal with new issues. Votes by member organizations ultimately determined which proposals would be included in the 1988 *Recommended Provisions*. As in 1985, even though more recent maps by Algermissen and Perkins were available to be adopted into the *Recommended Provisions*, a consensus could not be reached on their adoption, and, therefore, BSSC again retained the ATC 3-06 maps in the recommendations and kept the newer maps in the appendix.

The 1988 Blue Book. Following the publication of ATC 3-06 and the establishment of BSSC, the SEAOC Board of Directors authorized its Seismology Committee to prepare a total rewrite of the Blue Book, the first time this had been attempted since the publication of the first edition. Three reasons were given. First, effects of the 1971 San Fernando earthquake indicated that "serious damage to many presumably 'code designed' buildings caused building officials in particular, and the structural engineering profession in general to perceive that codes of the day contained serious gaps that needed to be closed" (SEAOC, 1988: p. viii). Second, ATC 3-06 contained "many new and innovative ideas for the earthquake-resistant design of structures" (SEAOC, 1988: p. viii). Third, ATC 3-06 was "perceived by many practicing engineers as excessively complex and not in proper code language (not in a form directly reusable by a designer or enforceable by a building official)" (SEAOC, 1988: p. viii).

With these reasons in mind, the seismology committee set out to develop an up-to-date code revision that structural engineers and building officials would find useful and valuable. Due to its long history as the "de facto preparer of seismic design provisions for ICBO" (Porush and Zacher, 1987: p. 335), the seismology committee was considered to be the bridge between new knowledge and final code language in the UBC. However, this time, the seismology committee took on an added responsibility. In the past, the Blue Book had been written primarily for the structural engineering profession in California; now it was also being written for a much larger audience "with the knowledge that others outside of California may wish to adopt or adapt these recommended requirements for their areas" (SEAOC, 1988: ix).

Originally, as part of its recommended code revisions, the seismology committee envisioned recommending a seismic zone map for the state of California. However, according to Porush and Zacher (1987) (then the chair and vice-chair of the SEAOC Seismology Committee), ICBO, in early 1986, "asked SEAOC to coordinate the preparation of a national zone map" and "further indicated that not to have a national map accompanying the submission of the Blue Book provisions would probably mean the tabling of the SEAOC submission until such a time as the map was developed" (p. 339). They were told in essence that, without a map, there would be no seismic code change.

Updating the seismic zone map proved to be a challenging task. By 1985, there were a surfeit of maps (both published by Algermissen and his USGS colleagues and also by code and standards organizations based on the USGS maps), and supporting scientific theories and models to examine. Even a cursory look indicated that important contradictions existed. The current UBC seismic zone map, based on the 1969 Algermissen and 1976 Algermissen and Perkins maps, reflected the facts that California was mapped in only zone 3 and zone 4 and that SEAOC historically had written its Blue Book for the highest two zone values. The 1976 Algermissen and Perkins map, the ATC 3-06 maps, the 1982 Algermissen, Perkins, et al. maps, the 1982 ANSI A58.1 map, and the 1985 NEHRP maps all placed a large portion of north central California in zone 2, and all but the ATC maps placed a small portion of southeastern California bordering on Arizona and Nevada in zone 2. This raised an immediate concern among practicing engineers and later among building officials and the materials industries.

With only a short time to prepare a national seismic zone map for acceptance into the 1988 edition of the UBC, the seismology committee drafted a tentative map that retained many of the characteristics of the maps found in the UBC (a single map, four seismic zones, zone boundaries) but incorporated the basic principles and ideas in the ATC and 1982 Algermissen et al. map (probabilistic seismic ground motion, peak accelerations) and additional geologic data (fault slip rates) not integrated into those maps (SEAOC, 1988: p. 66c). For specific information on areas outside California, the initial draft map was modified by input from the structural engineering associations of Alaska, Arizona, Colorado, Hawaii, Idaho, Nevada, New York, Oregon, Puerto Rico, South Carolina, Texas, Utah, and Washington, as well as other members of SEAOC, and the Portland Cement Association. A copy of the proposed seismic zone map, dated June 28, 1986, was published in the September-October issue of *Building Standards* for comment by members of ICBO. (See Figure 2 for a complete list of steps in the ICBO code revision process.)

To be included in the 1988 edition of the UBC, the full Blue Book revision with a national seismic map was published with all other suggested code revisions in the subsequent issue of *Building Standards*

(November-December, 1986), the issue where proposed code changes are first published as part of the annual ICBO code development process. This seismic map differed in many ways from the June 28 draft. The zone boundaries were changed throughout the western states, with seismicity raised in several locations, especially in north-central California where much of zone 2 was now zone 3 and in Arizona and New Mexico where a large zone 2 was created from a previous zone 1.

Four months later, when the annual report of the code development committees was published in the March-April, 1987 *Building Standards*, the revised Blue Book recommendations were approved as revised. A different national seismic zone map was included that retained the zone boundaries of the November-December, 1986 map, but divided zone 2 into two separate regions, zone 2A and zone 2B. Zone 2A reflected a Z factor of 0.15 and replaced all previous zone 2s east of the 105th Meridian. Zone 2B reflected a Z factor of 0.2 and replaced all previous zone 2s west of the 105th Meridian. Olshansky (1993) mentions that zone 2A was the recommendation of a Purdue University study, and Zacher (1995) commented that the change in the map was suggested by the concrete industry.

The ICBO code change agenda was published in the July-August, 1987 issue of *Building Standards*. Included were the challenges to the code change proposals. Eighteen challenges to the entire Blue Book revision were printed; six specifically referred to the proposed map. Of the challenges to the map, the Brick Institute objected to the division of zone 2 and recommended that all of zone 2 reflect a Z factor of 0.15; the Northwest Concrete Masonry Association proposed modifying the seismic zones in the northwest to reflect more accurately studies conducted by the USGS and the ANSI 58 Committee that would downzone much of the region; the Brick Institute and J.R. Harris & Co. proposed that the entire 1982 ANSI 58.1 map be substituted for the SEAOC map; A.R. Turk requested that all of Arizona be placed in zone 2B; the California State Building Standards Committee and the Shasta County Building Department requested that zones 3 and 4 in California be extended, thereby eliminating almost all of zone 2 in California; and finally, SEAOC proposed a new national map that reflected comments solicited from interested parties received up to May 27, 1987. The last SEAOC map contained many seismic zone boundary changes and retained the zone 2A-2B distinction.

As reported in the November-December, 1987 issue of *Building Standards*, challenges to the proposed code changes were discussed and voted on during the annual meeting of ICBO. When the SEAOC proposal was moved for adoption with amendments, including removing all zone 2s from California, the proponents of most of the other challenges withdrew them in support of the SEAOC proposal and the motion was carried (see Map 11 in Appendix A). Later, the code change proposal representing the entire Blue Book recommendations was approved with minor changes. These changes were incorporated into the 1988 edition of the UBC.

The SEAOC Seismology Committee completed its task of revising the Blue Book in eight years, four times longer than it took to write the original edition, using approximately "10,000 volunteer and donated [hours]"(Porush and Zacher, 1987: pp. 334). The effort required working with many people and organizations outside of SEAOC and reconciling many difficult technical issues. However, on reflecting how and why the Seismology Committee met the challenge and completed its task, Porush and Zacher (1987) stated:

> A key point to keep in mind is that the adoption of a code is a political process first, and a technical exercise second. Failure to have recognized this all-too-obvious fact of life, not only on the map but on other issues as well, would have doomed the SEAOC submittal to rejection. Some may express discomfort with the final zone map itself or even more so with the way decisions on zone boundaries were made. The authors share this discomfort. However, the one bright note is that this final national map was accepted almost without objection by the full membership of ICBO (p. 339).

The development of the two NEHRP Recommended Provisions documents (1985 and 1988) and the 1988 Blue Book illustrate the difficulties of transferring radical knowledge in a radical situation within a programmed change context. Since multiple interests must be accommodated within a rigid schedule, time requirements necessitate the incorporation of negotiation and compromise into technical decision making, thus leaving many participants partially satisfied or "satisficed" (using a term coined by Simon (1947). To get closure on controversial issues, as indicated by Porush and Zacher above, politics takes precedence over technical concerns. What ultimately may decide a scientific debate are related issues of costs, compatibility, complexity, and who controls the decision process. Choices that limit financial and social costs, that are not pervasive, and that are conceptually easy to understand and not difficult to implement are more likely to be adopted than those with opposing characteristics, and, thus, can generate the driving forces needed for adoption. Additionally, change adoption is more likely when the decision process is moderated by respected leaders from the "politically correct" organizations.

Happenings in the environment. This period can be generally characterized by the implementation of previously enacted federal programs and the reluctance of the Reagan administration to create new ones. Only in 1988, at the end of this time period, does Congress enact a significant piece of legislation. Then, the Disaster Recovery Act was modified with the passage of the Robert T. Stafford Disaster Relief and Emergency Assistance Act, which mandated that local governments receiving federal aid following a presidentially declared disaster must initiate hazard mitigation measures to reduce the potential damage from subsequent disasters.

Earthquake research, especially outside California, was boosted by several federal agencies. As examples, in 1982, the Nuclear Regulatory Commission funded the Electric Power Research Institute (EPRI) to make a comprehensive study of east coast seismicity, and, in 1986, after a national competition, NSF selected a consortium of universities headed by the State University of New York at Buffalo to house and operate the National Center for Earthquake Engineering Research, whose activities support the fundamental goals of NEHRP.

Four moderate to severe earthquakes with significant damage occurred, in Coalinga (1983), in Mexico City (1985), in Whittier (1987), and in Armenia (1988). In response to the first two events and NEHRP, the California legislature enacted the California Earthquake Hazards Reduction Act of 1986, directing the Seismic Safety Commission to prepare and administer a California Earthquake Hazard Reduction Program to significantly reduce the earthquake threat to citizens by the year 2000. In later years, other states followed California's lead in establishing their own state earthquake hazard reduction programs.

1989-Present: Development of New Maps and Code Proposals

This time frame is characterized by a slowing of the knowledge transfer process caused by an increase in the radicalness of both the technical issues being put forward and the decision-making situation. The inability of BSSC to generate a consensus to move the 1982 Algermissen, Perkins et al. maps from the 1985 appendix of the NEHRP Recommended Provisions to the recommended provisions of NEHRP in 1988 presaged the activities of the current time frame. Since then, these maps have remained in the appendixes of subsequent 1991 and 1994 NEHRP documents and have been joined by more recent map developments, including spectral maps produced by Algermissen, Perkins et al. in 1991. Quite clearly, scientific advances have continued, but they have not been translated into recommended code provisions (see Algermissen et al., 1991; Algermissen and Leyendecker, 1992). One can conclude that a performance gap exists, but it cannot be closed because every radical change proposal related to seismic maps has been unable to gather the support of a consensus of the BSSC committee members to place these maps on the recommended provisions list. Using Lewin's field theory terms, the driving forces for change are not sufficient to overcome the aversions and restraining forces.

Rather than describe the technical issues being debated, which have been described in detail in the previous chapter, this section will concentrate on the organizational developments that have slowed the knowledge transfer process and made it more complex. Then, it will describe actions taken to overcome the impediments.

To understand the knowledge transfer process in order to identify the driving forces, aversions, and restraining forces, it is critical to understand the decision making procedures in the three forums where change proposals are decided, the USGS, BSSC, and SEAOC. What follows is a brief overview of the internal steps used in these organizations.

- *USGS*. The USGS national maps are prepared in the mode of a scientific project headed by an individual project manager with support from colleagues and input from experts outside the organization. That individual project manager may accept or reject input and make compromises, but ultimately makes the final decisions.
- *SEAOC*. SEAOC works in a slightly different fashion. The Seismology Committee prepares Blue Book revisions with input from structural engineers within and without the organization and confers with the USGS and ICBO. The chair and vice-chair of the committee control the decision process but use a consensus process in the committee for final decisions. Blue Book revisions are then voted on by the Board of SEAOC.
- *BSSC*. BSSC decision processes vary considerably from the others. Because it is a voluntary organization composed of several voluntary, government, and economic organizations within the building industry, including ICBO and SEAOC, and utilizes the talents of experts from these and other organizations like the USGS, BSSC has established a more complex decision making process to gather and review proposed changes from its wide array of members. It has organized itself into a web of overlapping technical and oversight committees and subcommittees to design, debate, and recommend changes. Decisions in each committee and subcommittee are made using a super majority consensus process. Final decisions are made by ballot of the BSSC member organizations where, again, a super majority consensus process is employed. Of the three decision processes, the BSSC process is the most radical, and, thus, BSSC is the least likely forum to adopt radical change proposals.

If the USGS, SEAOC, and BSSC worked independently of one another and were free of outside influences, it would be possible to investigate each organization and determine the forces supporting and opposing suggested changes. However, those conditions do not exist. The USGS and SEAOC consult with one another, and many of their key personnel are members of various BSSC committees, including the Provisions Update Committee (PUC), which is ultimately responsible for drafting the final NEHRP recommended provisions. SEAOC is also a voting member of BSSC. Under these conditions, where committee members represent multiple organizations, there can be a blurring of responsibilities. Also confusing the situation is the fact that map preparers work alongside map users on the development of change proposals. While in principle bringing innovators and users together can create a situation that leads to common ground, it can also exacerbate differences of opinion and prevent consensus from occurring.

To make matters even more complex, the traditional decision processes used by the USGS and SEAOC described above have been altered by outside forces. The NEHRP program, through the combined efforts of FEMA, USGS, NSF, and NIST, has expanded the seismic map preparation task to include organizations other than the USGS. For example, the Southern California Earthquake Center

(SCEC) was established in 1991 as an NSF Science and Technology Center to investigate seismic sources in southern California. In cooperation with USGS, SCEC recently produced a comprehensive probabilistic map of southern California earthquake hazards. Also under the NEHRP banner, the California Department of Mines and Geology was contracted by FEMA to develop a regional seismic map of California. Consequently, USGS must now coordinate the production of its national maps with more detailed regional maps being developed by these and similar agencies in other states to achieve consistency, or they will not be acceptable to potential users.

The development of regional maps outside California since the mid-1980s has also increased the involvement of state structural engineering associations in the design value map decision process. Without the knowledge of seismic risk and building practices outside California, SEAOC has consulted with their sister structural engineering associations and deferred to their judgment concerning seismic zones in their states when national maps were requested by ICBO. In addition, many state associations have become members of BSSC, thereby expanding the number and variety of structural engineering inputs in the BSSC decision processes. As was pointed out in the last chapter, the associations in different parts of the country differ significantly in how seismic hazard and design value maps should be drawn.

NCEER has also begun to take an active role in the development of codes and seismic hazard maps. In the early 1990s, NCEER assisted in the development of seismic codes for New York City and New York State that included a seismic zoning map for the state. That map was proposed for adoption in the 1994 NEHRP Recommended Provisions, but failed to achieve consensus and was placed in the appendix as map 15 to illustrate innovative regional hazard mapping. In 1993, as part of its knowledge transfer activities, NCEER provided a grant to ATC to establish a multiyear project entitled "Critical Code Issues." This project, ATC-34, examines the current building codes to determine deficiencies and will recommend desirable features of an ideal code.

These and other complications have made the task of developing new map change proposals difficult to accomplish using traditional USGS, SEAOC, or BSSC procedures. To their credit, each organization has recognized this fact and taken actions to remedy it. The difficulty of attempting to complete this task in a three-year update cycle was demonstrated by BSSC in the preparation of its 1994 recommended provisions. During that time, FEMA provided funds to an independent BSSC Design Values Panel specifically to develop seismic hazard maps and an appropriate design procedure based on those maps. Even with the charter and money, the Design Values Panel was unable to complete the task in the required time and was not able to reach consensus on a final product. The main stumbling blocks were deciding what constituted the best scientific map and how to present, translate, or modify the information on that map into a form that can be used by code writers, practicing engineers, and building officials uniformly throughout the United States.

Shortly thereafter, to resolve the map issue, BSSC proposed a joint effort between BSSC, FEMA, and the USGS, referred to as Project '97, tasking the USGS to produce revised seismic hazard maps based on the most currently accepted ground motion studies, then tasking BSSC to produce from these maps new seismic design procedures for use by engineers and architects. The project was formally approved by the three organizations at the end of July 1994, with the goal of adopting the results in the 1997 edition of the NEHRP Recommended Provisions. An advisory panel was established to monitor the project and provide advisory input.

The memorandum of understanding (MOU) between the USGS and BSSC specifically stated that the USGS conduct regional workshops on "relevant seismic source zones, recurrence rates, attenuation, and maximum magnitude." These would be organized in conjunction with regional liaison groups to include experts in seismology and geology as well as persons recommended by BSSC. As of the writing of this report, the seven designated workshops have been completed. Final ground motion maps were expected in April 1996. While already working in parallel with USGS, the BSSC Design Values Group is expected to complete its task after receiving the USGS maps.

At the time the BSSC Design Values Panel was attempting to develop seismic hazard maps and design procedures for inclusion in the 1994 edition of the NEHRP Recommended Provisions, the USGS independently realized that its earth sciences research results were not being incorporated quickly into state-of-the-art seismic design. To shorten the knowledge transfer time, USGS entered into a cooperative agreement with ATC establishing ATC-35, *Enhancing the Transfer of USGS Research Results into Engineering Practice*. As part of its recommendations, ATC proposed that the USGS conduct ground motion mapping workshops covering ground motion mapping issues, seismic source characterization in different regions of the United States, and ground motion attenuation to educate users of its research, including maps. In a complementary vein, ATC proposed that the USGS hold workshops with structural engineers and other users as part of a Ground Motion Initiative to examine their ground motion needs for future generations of seismic design regulations and practice. The first workshop was held in September, 1995, in Los Angeles, where issues were presented to invited practitioners and Art Frankel and his USGS colleagues, presently developing the seismic hazard maps for BSSC in Project '97.

A third initiative to develop state of the art seismic design, including up-to-date design value maps, Vision 2000, was begun by SEAOC in 1993. A first draft of their report supports the idea that future seismic design should be performance based.

Happenings in the environment. There were four important events in this time period. First was the realization by the insurance industry and the federal government that major earthquakes in populated centers will be very costly and steps should be taken to reduce future damages and spread the financial risk. Second was the establishment of the International Decade for Natural Disaster Reduction (IDNDR) by the United Nations. Third was the occurrence of several billion dollar earthquakes, hurricanes, and floods. Fourth was the recognition by the three model code groups that a single national code should be developed by the year 2000 (Dowty, 1995).

In 1989, the Earthquake Committee of the National Committee on Property Insurance issued its report, *Catastrophic Earthquakes: The Need to Insure Against Economic Disaster*. In this report, it was claimed that a major earthquake in a populated center would cause up to $60 billion in damages, far beyond the ability of the insurance industry to handle. Shortly thereafter, several bills to create a federal insurance program with mandatory mitigation were introduced in Congress. None has passed yet, but there are still bills being considered, the latest being H.R. 1856, introduced by Representative Emerson.

Internationally, the threat of catastrophic disasters also led the United Nations General Assembly in 1989 to establish the IDNDR. Member nations were encouraged to accelerate their research efforts in a concerted effort to invest in disaster reduction.

The publication of the insurance report preceded Hurricane Hugo, the first in a string of billion dollar natural disasters in the United States. Later came the Loma Prieta earthquake in 1989, Hurricane Andrew in 1992, the Midwest floods in 1993, the Northridge earthquake in 1994, and Hurricane Opal in 1995. Internationally, the 1995 Kobe, Japan, earthquake became the most costly natural disaster to date, exceeding $60 billion in losses, which the insurance industry once thought was a loss ceiling.

The model code groups made several important decisions. In 1993, BOCA adopted the NEHRP provisions in its current code edition. This was followed in 1994, when SBCCI adopted the NEHRP provisions in its current code edition. As a consequence of these actions, a direct link was established between BSSC and the development of codes. Finally, in 1995, the three model code groups formed the International Code Council (ICC) as the mechanism to unify their codes and publish a national code in the year 2000 that might also be adopted by other countries.

Understanding the Knowledge Transfer Process

As described in the last chapter, the knowledge transfer process of moving USGS maps into the model codes has met with limited success since 1951. Maps developed by Algermissen alone or with associates in 1969, 1976, and 1982 have been wholly or partially adopted by ICBO in the 1970, 1976, and 1988 editions of the UBC. The 1976 Algermissen-Perkins map was also successfully adopted into ANSI-7 and the 1985 NEHRP recommended provisions and subsequently adopted by reference by BOCA and SBCCI. In recent years, maps generated at the USGS have been relegated to the appendices of later editions of the NEHRP recommended provisions.

There appear to be four reasons to explain why the 1969 and 1976 maps were adopted into model codes while the later maps were either partially adopted or not adopted at all. First, the later maps were based on increasingly more complex and detailed, hence controversial, theories. The 1969 map was based on historic seismicity and was developed in the same format as the Ulrich map, which was still being used in the UBC. In 1976, Algermissen and Perkins published a single probabilistic ground acceleration contour map based on the earliest attenuation functions. In 1982, Algermissen, Perkins and their colleagues published probabilistic maximum acceleration and velocity maps. Then, in 1990 and 1991, Algermissen and his colleagues published probabilistic spectral response ordinate acceleration maps for three exposure times. As time went on, the maps differed more and more from the way maps had been drawn in the UBC prior to 1970 and differed more and more from the theories underlying them.

Second, the decision-making process has become more complex with more institutions playing important roles. In 1969, the only institutional participants in the transfer process were the USGS, SEAOC, and ICBO. At the present time, there are dozens more, including several additional federal agencies (i.e., FEMA, NSF, NIBS, NIST), state structural engineering associations, research organizations (i.e., NCEER, ATC, SCEC), and code development organizations (i.e., BSSC). Just in terms of sheer numbers and organizational agendas, defining and attaining consensus has become increasingly more difficult.

Third, the code adoption process lacks a formal means of demonstration testing. When BSSC was formed, its first task was to test the tentative provisions of ATC 3-06 and then recommend those that were shown to be technically feasible and cost effective. However, after the 1985 NEHRP recommended provisions were published, BSSC abandoned the testing of controversial code changes. No new maps have been recommended since 1985.

Fourth, placing controversial code change proposals in the appendices of the Blue Book, NEHRP recommended provisions, and the model codes has not proven sufficient to permit the necessary testing to evaluate the proposals in the next code change cycle. The creation of Project '97, basically a dedicated project to transfer spectral ordinate maps into the NEHRP recommended provisions, points out the failure of this traditional method and suggests that a new approach might improve the knowledge transfer process. One option would be to reinstate the concept of a "transitional provision" and to reinstate the formal testing of transitional provisions in the BSSC evaluation process. Then there would be a formal mechanism to develop evidence either to support the inclusion of a transitional provision in the next edition of the recommended provisions or to support the rejection of the transitional provision.

Overall, in field theory terms, over the past 25 years, the force field surrounding the transfer of scientific maps into model codes has gradually changed, from a few strong driving forces and few aversions to many weaker driving forces and many aversions and from a few restraining forces to many and a great variety of restraining forces. According to Lewin (1951), this course of events signals a decrease in change potential. Also, according to Lewin, change can be enhanced by either instituting programs and policies to strengthen certain driving forces or to reduce the strength of aversions and restraining forces. The dedicated task groups formed by the USGS, BSSC, and SEAOC in recent years are examples of programs created to break decision logjams. They compel competing forces to confront one another in the expectation that many will join together through negotiation and compromise and ultimately produce a coalition strong enough to form a consensus.

Problems with a Consensus Process

In addition to the four reasons listed above why the adoption of recent scientific maps into codes has not taken place, there is an underlying concern with the use of a consensus process. ANSI defines consensus as:

> Substantial agreement reached by concerned interests according to the judgment of a duly appointed authority, after a concerted attempt at resolving objections. Consensus implies much more than the concept of simple majority but not necessarily unanimity (Gross, 1990, p. 33).

Using this definition, there is an implication that an authority can be appointed to manage the process and that a concerted effort must be made to deal with objectors. What if, as in this situation, the concerned interests have different levels of expertise to bring to the discussion? Should there be a method to evaluate contributions from different sources? In a discussion over who should participate in the development of seismic hazard maps, Walter Hays of the USGS (1993) responded that "the idea of engineers deciding on recurrence rates is as appropriate as it would be for USGS to decide on the design of a reinforced concrete building."

Critiquing consensus procedures, the National Forest Products Association (1980) has maintained that "the idea of establishing building code regulations by consensus amounts to a popularity contest, in which objectivity is virtually impossible . . . To permit all groups, irrespective of interest, knowledge or bias to vote on building regulations can only lead to diminution of quality. It would increase conflict among competitive products and encourage use of delaying and obstructing tactics." Defending model code organization procedures in which only building code officials cast ballots for code changes, the association maintains that "the local building official . . . is the key to the success of the three model codes. [He or she] is constantly exposed to opinions of designers, builders, consumers, and manufacturers" (p. 38).

Casting a similar opinion from a slightly different perspective, Henry Degenkolb, a structural engineer from northern California, after participating in the development of ATC 3-06 in 1978 and observing the opposition to strict standards among some in the materials industry, commented, "The code used to be a consensus of what the experts thought. Now it's not only the experts but also the people affected: such as real estate interests, or the people who enforce it . . . And there were compromises. But they were compromises made among people who knew the necessity of designing for earthquakes" (Scott, 1994A, pp. 146-7).

Ultimately, the answer to the question "Who decides?" will determine who will participate in the knowledge transfer process and whether consensus methods will be applied. The recent actions by BSSC, the creation of the Design Values Panel, and then the establishment of Project '97, suggest that a modified consensus process is being formulated, one that, in order to make timely decisions, relies more on subsets of experts organized into task forces to generate propositions, procedures, and maps and one that limits the larger group of "concerned interests" to vote on the results. In other words, participation may be increasingly determined by expertise, but no one will be totally excluded from the process.