A Program of Studies on the Socioeconomic Effects of Earthquake Predictions

COMMITTEE ON SOCIOECONOMIC EFFECTS OF EARTHQUAKE PREDICTIONS
Commission on Sociotechnical Systems
National Research Council

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NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the Committee responsible for the report were chosen for their special competences and with regard to appropriate balance.

The report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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Preface

The idea that it may become technically possible to predict earthquakes has been recognized by two reports from the National Academy of Sciences as well as by numerous scientific and popular publications. *Predicting Earthquakes: A Scientific and Technical Evaluation—With Implications for Society* considers the scientific and technical aspects of earthquake prediction and, given certain funding considerations, discusses the likelihood that such predictions will be technically feasible in the future.[1] Paralleling that study is the report *Earthquake Prediction and Public Policy,* which considers the possible impact such a capability might have on individuals, private institutions, and government.[2] Growing out of this report was the recognition that there was a need for a research agenda on the socioeconomic aspects of earthquake predictions. The National Science Foundation commissioned the National Academy of Sciences–National Research Council (NAS-NRC) to set up a committee to study the problem.

The Committee on Socioeconomic Effects of Earthquake Predictions, which was formed in May 1976, received the following instructions: "(1) to identify the key problems and information requirements to be addressed by future socioeconomic research on earthquake predictions; and (2) to develop comprehensive plans and guidelines for the conduct of

[1]Panel on Earthquake Prediction of the Committee on Seismology, *Predicting Earthquakes: A Scientific and Technical Evaluation—With Implications for Society,* 1976.
[2]Panel on the Public Policy Implications of Earthquake Prediction of the Advisory Committee on Emergency Planning, *Earthquake Prediction and Public Policy,* 1975.

such research." This report is the product of the Committee's efforts to fulfill these objectives.

As Committee chairman, I would like to express my appreciation to each of the members for their hard work on this project. On behalf of the Committee, I also want to acknowledge the important contributions of Dr. Gary A. Kreps, staff officer for the Committee while on leave from the College of William and Mary, and Dr. Ralph B. Ginsberg, a consultant to the Committee from the University of Pennsylvania, in preparing this report. Dr. Kreps did much to organize the final report, develop the concluding chapter, and refine the other chapters. Dr. Ginsberg played a key role in developing the conceptual framework (chapter 2) and in fitting the materials contained in the separate chapters into this framework. We also acknowledge with thanks the contribution of Jack M. Weller, of the University of Kansas, who helped prepare chapter 5.

Charles E. Fritz, Executive Secretary, who was instrumental in forming the Committee, brought expert testimony to our meetings, kept us abreast of technical developments, coordinated our activities, and gave us wise advice. We also thank Helen D. Johnson and Sharon D. Carpenter who provided excellent administrative support to the Committee throughout its work.

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Contents

A Program of Studies on the Socioeconomic Effects of Earthquake Predictions

Summary

Geological technology will probably reach a point within the foreseeable future at which scientifically credible earthquake predictions can be made. Constructive use of this new prediction technology will depend to a considerable extent on the accuracy and reliability of our knowledge about how people and organizations will respond to these predictions and warnings. Inadequate attention to the social consequences of using a particular technology may have counterproductive results.

Public announcement of an impending earthquake will be diffused rapidly and may have substantial effects on the social system and economy of the affected region. Current knowledge of the social effects of earthquake predictions is derived largely by analogy from experience with predictions of other kinds of disasters. Because earthquakes and earthquake predictions may differ fundamentally from other disaster phenomena, these analogies are far from satisfactory for predicting behavior. It is therefore important to develop a systematic and empirically grounded body of knowledge about earthquake prediction itself.

The purpose of this report by the Committee on Socioeconomic Effects of Earthquake Predictions is to point out the possible consequences arising from earthquake predictions and to suggest the research necessary to anticipate and deal with them. This report is part of a long-standing program of the National Academy of Sciences–National Research Council concerning natural and man-made hazards and disasters. In particular, it is an outgrowth of the report on *Earthquake Prediction and Public Policy,* prepared by the NRC Panel on the Public Policy Implications of

Earthquake Prediction, Advisory Committee on Emergency Planning, published by the Academy in 1975. That report provides valuable background information for the present volume.

The nature of an earthquake prediction itself is an overriding determinant of subsequent events. An earthquake prediction includes several elements—probability, intensity, location, advance notice, and time window (the period during which the earthquake is expected to occur). Variations in any of these elements can have an important effect on public reaction. Contrast, for instance, the possible impacts of a prediction for a 90 percent chance of an earthquake of Richter magnitude 8.0 during the first 3 days of next month with those of a prediction of a 60 percent chance of a 6.5 quake in the same place sometime during the summer months 2 years hence.

Many of the issues raised in this report are more pertinent to the second kind of prediction than to the first. If the timing and probability of an expected earthquake can be stated only in general terms—a circumstance likely to prevail in the early stages of a developing prediction technology—then the socioeconomic consequences of the prediction will depend chiefly on how people behave under conditions of uncertainty. Past studies have shown that such behavior is not purely rational. Indeed, people and organizations have proved to have difficulty in dealing with probabilistic situations, particularly low-probability events. In the case of predictions with long advance notice, furthermore, public response (and the details of the prediction itself) will almost surely change as the announced danger period approaches, arrives, and—perhaps—passes without incident.

One of the most significant consequences of earthquake predictions could be vast savings in life and property. Inaccurate predictions and inappropriate public responses, however, could conceivably combine with the earthquake to create a worse disaster than the quake would have produced unheralded.

Much of the research recommended in this report is intended to help anticipate and prevent the possible deleterious effects of earthquake predictions. Much of the discussion therefore involves the negative possibilities stemming from predictions, rather than the positive ones. Despite this emphasis, the exercise is intended not to cast doubt on the value of predicting earthquakes but to insure that value.

Chapter 1 of this report discusses more fully the implications of the state of the art in earthquake predicting. Chapter 2 presents a conceptual framework for use in assessing possible social and economic consequences of a prediction and the interrelationships of the consequences.

Those consequences and the substantive issues raised in chapters 3–7 of the report can be classified into five groups:

1. *Reactions of individuals and households.* The credibility attributed to the prediction is one variable; credibility could depend on who issues the prediction, the degree of scientific controversy surrounding it, and so forth. The amount of attention people pay to the prediction will vary according to such factors as their personal stake in the community, their own levels of education and knowledge, their experience with previous earthquakes, and the timing and magnitude of the expected earthquake.

People may react to the prediction in a variety of ways ranging from doing nothing to moving away from the neighborhood (or choosing not to move in). The course of action chosen, it is hypothesized, could depend on two groups of factors: (1) stakes in the community and (2) resources with which to gather information and respond to a prediction. People whose lives are tightly bound to the community—either economically, through employment or real estate, or socially, through friends, relatives, or social status—are likely to react differently from the way those with less investment in where they live will react. And people must weigh their resources—money, skills, intelligence, health—against the costs of the actions available to them.

Chapter 3 points out the need for research to discover more precisely the role these factors will actually play in how people will react to a predicted earthquake. Suggested methods include survey methods; preprediction-to-postearthquake studies that would either monitor the same people (panel method) or periodically sample different groups (cross-sectional method); studies comparing reactions in different types of communities; and sampling procedures tailored to study not only the general public but also the affluent and the influential, whose opinions are likely to sway the opinions of others.

2. *Reactions of businesses and effects on the regional economy.* When an earthquake is predicted, will businesses physically strengthen their workplaces and continue their services to those who rely on them for products and employment or will they attempt to avoid the threat of damage by moving outside the forecast vicinity? How much flexibility will firms have in choosing courses of action? What other factors will limit the behavior of businesses? What are the possible effects of earthquake predictions on housing, employment, and capital markets? How will the regional economy respond?

Chapter 4 discusses the range of adjustments open to firms and the internal and external organizational conditions likely to influence those adjustments. It then reviews the role of markets in economic adjustment processes and offers methods for understanding how the combined choices of firms translate into regional economic consequences.

Two kinds of research are recommended: studies of the behavior of

firms and of the market and other institutional forces that affect such behavior, and analysis of regional economic responses in terms of economic modeling techniques.

Information, of course, plays a vital role in directing how firms behave. Attention should be paid to identifying sources of information, determining the accuracy of information transmitted and received, and documenting the interpretation of information by the organization's decision makers.

The nature and interpretation of information will influence the choice of adjustments, but the final mix of actions will be strongly influenced by each firm's organizational characteristics. The interaction of information and the internal and external organizational conditions and business stakes in the community need to be studied.

Development of regional models provides a mechanism for integrating the decisions of individual firms. Regional interindustry/econometric models could be developed for areas thought to be particularly vulnerable to a predictable quake. Studies could assess the types of actions, if any, that would be postponed by businesses as a result of predictions. Properly timed and broad-based surveys can identify adjustment patterns, and intensive case studies can determine how decisions were made. Business and household financial plans and behavior, and assessments of the role of market forces, should be studied. Studies of bank vulnerability and of changes in insurance programs are also important, but they receive somewhat lower priority in this report.

3. *Government issues.* Government will clearly play a central role in earthquake prediction, preparation for disasters, and response to them when they occur. Many of the issues this report discusses with regard to individuals, firms, and economic and legal systems are closely related to potential government actions.

The government's domain may include authenticating predictions and issuing earthquake warnings, controlling and offsetting detrimental side effects of the predictions, implementing emergency preparedness measures, and enacting a hazard reduction program to minimize community disruption and loss of life and property when the earthquake occurs.

Although earthquake predictions themselves will be based on the work of scientists, warnings that advise citizens about how to respond to a prediction will involve government, thrusting upon it tasks of assessing the credibility of predictions, acquiring information needed to advise potential victims, and warning them. Also, government will probably assume tasks designed to reduce economic stagnation, social dislocation, population redistribution, and tax revenue losses that may follow issuance of an

earthquake warning. Government's role potentially touches most aspects of human and community survival.

Proposed monitoring research includes monitoring of results of policy implementation on government organizations, with emphasis on measures to prepare for and mitigate the effects of earthquakes; studying the effects of policies and innovations strictly related to earthquake predictions and their consequences; and attempting to understand the political pressures that affect measures related to earthquake predictions and hazard reduction.

Research is recommended on the making and implementation of policy relating to earthquake preparedness programs and predictions and their consequences; the impact of political processes on earthquake prediction and hazard reduction measures; the responses of government organizations to major disasters of any kind; and the study of policy analogues (land management, building codes, insurance) in the federal floodplain management program.

Monitoring surveys of government organizations will generally provide information about policies adopted and problems encountered, but intensive case studies of the integration of earthquake-related and other hazard reduction measures are needed. Case studies are also needed to assess the effects of these measures in disasters and the ways in which public and special interest groups respond to hazard reduction issues.

4. *Legal problems.* Chapter 6 approaches the legal problems of earthquake prediction primarily from the perspective of the role of law in influencing human conduct. Because the law is probably the most useful and most frequently employed tool of social policy implementation and because the law is an important social variable, it must be considered in almost any sociological, economic, or political study. Lawyers are necessary participants in this research, but few are adequately trained in methodology to perform social science research independently.

Any sophisticated policy-making effort requires knowledge of how law operates to control uncertainty and to influence human behavior. Existing research on this subject generally falls short of the type of research urged in this report. Because the understanding of the relationship between law and human conduct is currently very limited, initial inquiries must be at the level of basic research. The report recommends assessment of the processes by which individuals, groups, and government acquire information about laws and legal institutions, how they interpret that information, and how they respond to laws and legal institutions.

In addition to this concern for studying law and human behavior the chapter also recommends continued legal research of a more traditional

nature. Economic, political, and social researchers will need to recognize legal variables that are relevant to their research. Lawyers should be supported in the provision of this information. The study of earthquake prediction policy alternatives will require knowledge of the status of the law, since policy options will be limited by existing law and the possibilities for change in that law.

A central concern to public officials involved in earthquake prediction is government liability for harm resulting from negligence of an inaccurate prediction. Legal research can inform this issue and suggest policy alternatives for optimizing the benefits of earthquake prediction in the existing law of tort liability. Other legal issues are also suggested, making it clear that the formulation and examination of legal hypotheses are appropriate subjects for research.

5. *Generation and dissemination of predictions.* Chapter 7 identifies a series of research topics dealing with the processes by which earthquake predictions are generated, updated, and disseminated. Earthquake predictions will originate primarily from the activities of earth scientists; geophysical data will be evaluated by scientists or a government agency, either of which may decide to issue a public prediction. Scientific judgmental and social factors will be important at three points in the prediction process: (1) whether to issue a prediction (and of what kind), given the geophysical data; (2) whether to issue a warning, given a prediction; and (3) whether (or how) to revise predictions, given new geophysical information and social feedback. Thus it is important to know the following: Who belongs to the earthquake prediction community? What are the sentiments of seismologists regarding anticipated benefits and problems of earthquake prediction? How do these persons relate to other predictors, the public, and the government?

The public will typically receive its initial information from mass media reports. Thus studies of the news media's handling of earthquake prediction information are also very important for understanding the socioeconomic consequences of earthquake predictions. The content of both written and broadcast news reports should be described and analyzed for the entire cycle of the prediction, from the first announcement through the postearthquake period. The structures and policies of news organizations should be examined to see how they affect the content and handling of information on predictions and warnings. News media links with scientific organizations and with government agencies should be identified and described. Studies of the mass media and the way they report predictions, near predictions, and quasi predictions are recommended.

RECOMMENDED RESEARCH

The Committee on Socioeconomic Effects of Earthquake Predictions did not try to develop detailed proposals; rather its recommendations are intended to provide guides to research policy and to clarify the research issues for public and private policy makers.

The Committee's recommendations address the need for both description and prescription—for both theory and policy. The three sets of research recommendations should help resolve the substantive issues raised in the body of the report.

The first set calls for longitudinal monitoring, that is, periodic measurement (preprediction, postprediction, and postearthquake) of selected characteristics of the population under study. The second set recommends research aimed at developing methodologies and building theories that can explain and predict the behavior being monitored. Realistic theories can give better direction to the research and improve its usefulness. The third group of recommendations pertains to policy analysis, both basic (that is, how policies are derived) and applied (what these policies should be).

Research priorities are based on three factors: (1) the importance of timing in monitoring research, (2) the theoretical or methodological value of other social science research, including research on other natural hazards that pertain to the earthquake prediction problem, and (3) the degree to which research contributes to policy analysis.

RESEARCH ON THE EFFECTS OF EARTHQUAKE PREDICTIONS

The Committee's recommendations are listed below in order of priority:

1. Longitudinal surveys of individuals, households, firms, and governmental units (discussed in chapters 3, 4, and 5) that assess the socioeconomic effects of earthquake prediction are highly recommended. However, they should not be undertaken until there is a high probability that scientifically credible earthquake predictions will be forthcoming within a few years.
2. Regional interindustry/econometric modeling research (discussed in chapter 4) that assesses regional economic consequences of earthquake predictions is highly recommended. However, it should not be undertaken until there is a high probability that scientifically credible earthquake predictions will be forthcoming in a few years. This research should be coordinated with the surveys listed under recommendation 1.

3. Intensive case studies of how firms and governmental units will adjust to the predictions (discussed in chapters 4 and 5) should for the most part be undertaken after the surveys listed under recommendation 1 have identified research sites for comparative analysis of policy-making and policy implementation processes. However, given the important policy implementation role of governmental units and the unique problems of assessing government performance, some case studies of government agencies located in the initial prediction areas should be undertaken simultaneously with longitudinal monitoring surveys.

4. Studies of the organizational problems related to the scientific development of earthquake predictions should be initiated now.

5. Longitudinal monitoring studies of mass media policies and reporting of earthquake prediction news (discussed in chapter 7) should be initiated now.

Both of these recommendations derive from the issues raised in chapter 7 of the report. Both sets of studies should be started without waiting for the surveys proposed in recommendation 1 to begin, because developments in the earth sciences will help trigger that work and mass media practices may already be influencing the public attitudes to be surveyed.

RESEARCH OF THEORETICAL AND METHODOLOGICAL RELEVANCE

The following recommendations, listed in decreasing order of priority, call for the studies that would contribute to the earthquake prediction monitoring research and would help resolve questions of policy.

6. Methodological studies on the development of socioeconomic survey systems should be undertaken to prepare for the data collection, management, and dissemination requirements of research on the socioeconomic effects of earthquake prediction.

7. Small-scale field surveys of individuals, households, firms, and government units should be undertaken to elaborate empirically the conceptual framework (discussed in chapter 2) in a comparative context. Principal attention should be given to assessing the effects of information processing, "stakes," social networks, and institutional forces in particular markets, governmental settings, and the law (as discussed in chapters 4, 5, and 6) on private and public sector responses to various human hazards and risks.

8. Research on the development of regional interindustry/econometric modeling techniques (discussed in chapter 4) should be supported to

improve these techniques for assessing the effects of earthquake predictions and of other hazard phenomena.

These three recommendations should receive high priority, since they pertain directly to the problems of putting into effect the projects listed in recommendations 1 and 2.

9. Experimental research on decision making under conditions of uncertainty (discussed in chapters 2 and 3) should be undertaken to assess theoretical relationships between the dimensions of uncertainty implied by earthquake predictions and projected behavior.

10. Research on the relationships between science and government in the development and implementation of scientific knowledge about human hazards (discussed in chapter 7) should be undertaken to document the institutional forces and constraints that impinge on these relationships.

Recommendations 9 and 10 are of lower priority than recommendations 6, 7, and 8 because they relate less directly to the pivotal problem of developing monitoring research techniques. All, however, bear on the general question of dealing with earthquake predictions.

11. Comparative research on government and community responses to various hazards and large-scale disasters should be continued. Particular attention should be given to documenting institutional constraints on the development of disaster mitigation and preparedness programs and to establishing empirical relationships between these programs and postdisaster responses.

Studies of disasters analogous to earthquakes, and of ways to reduce such hazards are germane, but this project was ranked lowest in priority because of the range and diversity of research that has already been done on the subject.

POLICY ANALYSIS

All of the preceding recommendations contribute to policy analysis. The studies outlined in recommendations 1–3 should be initiated when earthquake predictions are judged to be imminent in order to provide essential data for policy evaluation research. In the interim, the studies outlined in recommendations 6–8 should be undertaken to provide the theoretical and methodological groundwork for subsequent research to monitor the

effects of earthquake predictions. The monitoring research on the earth sciences and the mass media outlined in recommendations 4 and 5 should be undertaken to formulate policies related to the development and dissemination of earthquake predictions and warnings. The basic research on decision making and on science-government relationships outlined in recommendations 9 and 10 and the traditional disaster research outlined in recommendation 11, although of lower priority, should be undertaken to formulate earthquake and other hazard mitigation programs.

Also of lower priority are the specialized policy problems reviewed in chapters 4 and 6. These include the following:

12. Research on the problems of marketing earthquake insurance programs (discussed in chapter 4) should be undertaken in preprediction periods for possible use in the development of model insurance programs.

13. Surveys of the diversification of banking assets (discussed in chapter 4) should be undertaken in preprediction periods to determine bank vulnerability to mortgage default.

14. Traditional legal research (discussed in chapter 6) should be undertaken to assess the liabilities of scientists and public agencies in developing earthquake prediction and warning systems.

1 Introduction

Recent technical advances have brought the long-sought goal of earthquake prediction within reach. Geophysicists and geologists now believe that with adequate funding and worldwide effort, reliable short-term and long-term forecasts could be made within a decade. At the same time it is widely recognized that constructive use of this new prediction technology will depend to a considerable extent on the accuracy and reliability of our knowledge about how people and organizations will respond to these predictions and warnings. Indeed, as the recent experience with swine flu immunization indicates, inadequate attention to the social consequences of using a particular technology may have counterproductive results and even vitiate the technology altogether.

At present our knowledge of the social effects of earthquake predictions is derived largely by analogy from experience with predictions of other types of disaster. But as we shall see, earthquake predictions differ from these other cases in some fundamental respects, and the analogies are thus a rather poor guide. It is therefore important to develop a systematic and empirically grounded body of knowledge about earthquake prediction itself. Such an effort should begin now.

This report by the Committee on Socioeconomic Effects of Earthquake Predictions is part of a long-standing program of the National Academy of Sciences–National Research Council (NAS-NRC) concerning natural and man-made hazards and disasters. The report is intended for the use of the Applied Science and Research Applications Directorate (formerly RANN) of the National Science Foundation and of federal, state, and

local government agencies that must deal with earthquake predictions and their consequences. The Committee also hopes to reach members of the social science research community who may not be aware of the social science aspects of earthquake predictions and of the interesting and important research opportunities our topic suggests.

This chapter will set the context of the Committee's recommendations by describing the technology of earthquake prediction and its possible consequences and by assessing the current state of social science research in this area, with particular reference to the work of previous NAS-NRC committees.

THE NATURE OF EARTHQUAKE PREDICTIONS AND THEIR CONSEQUENCES

ASSESSMENT OF PREDICTION TECHNOLOGY

The social and economic consequences of an earthquake prediction obviously depend on the nature of the predictions made. If a prediction states that there will be an earthquake of magnitude 8 in space *S* in a day or two (the same advance warning as for a river flood), the consequences will be mainly related to immediate effects and the problems of evacuating people from dangerous buildings and areas in the predicted impact area. If, on the other hand, the prediction holds that a major earthquake will probably occur in a given locality within the next 5 years, the consequences will be very different. Accordingly, we must have some idea of what kinds of predictions are likely to be made and what the salient features of these predictions are from the social and psychological point of view before we can know what kinds of consequences to anticipate.

The state of the art of earthquake prediction is depicted in the brief statements that follow. Extracts from the summary of the 1976 report of the Panel on Earthquake Prediction support these statements.[1]

1. *In a limited way, scientific earthquake predictions have been made:*

Anomalous physical phenomena precursory to some earthquakes have been clearly identified. . . . Some small earthquakes have been predicted in a scientifically credible way and most researchers are optimistic that we will eventually be successful in predicting larger earthquakes as well. . . . (Several large, damaging

[1]See Panel on Earthquake Prediction of the Committee on Seismology, *Predicting Earthquakes*, pp. 1–2.

earthquakes may already have been predicted in the People's Republic of China. . . .) A scientific prediction will probably be made within the next five years for an earthquake of magnitude 5 or greater in California. With appropriate commitment, the routine announcement of reliable predictions may be possible within 10 years in well instrumented areas, although large earthquakes may present a particularly difficult problem.

2. *Nevertheless the technology is still in the research stage:*

Neither the present state-of-the-art nor the present distribution of instrumentation permits socially useful predictions on a routine basis. Therefore, at this time, an expression such as 'area of intensive study,' as used in Japan might reflect more accurately the confidence level of interpretations of the observed phenomena in some areas than would an actual prediction. . . . The apparent public impression that routine prediction of earthquakes is imminent is not warranted by the present level of scientific understanding.

3. *The physical phenomena preceding earthquakes are not well understood:*

The physical nature of precursory phenomena is complex, and current models to explain them are crude; improvement of these models will require considerable effort in the field and laboratory, as well as in theoretical studies. . . . Of about 10 types of recognizable phenomena thought to be precursory to earthquakes, some may, in fact, be due to other causes and yield false alarms. Successful routine prediction will probably require the use of several techniques.

4. *Predictions will accordingly be probabilistic, and false alarms and failures to detect will be unavoidable:*

Predictions of earthquakes should specify time, magnitude, place, and probability. However, even a statement that does not specify time or magnitude, or a statement that an earthquake will not occur in a particular place or at a particular time, would be beneficial. . . . During the development of an earthquake-prediction-and-warning capability there will be unavoidable errors and false alarms. The public must be made aware of this prospect, and the development of any procedure to issue warnings must accommodate it. Even the ultimate system probably will not be infallible.

The authors of this report also envisage the possibility that *there will be disagreements between scientific experts* (not to speak of nonscientific predictions) on the interpretation of the evidence, disagreements arising partly from use of different instrumentation and partly from the complexity and probabilistic nature of the situation. To cope with this problem, the panel holds that

until formal procedures for issuing predictions have been established, predictions made by responsible scientists should be accompanied by sufficient backup data for full evaluation by the scientific community.

The panel also recommends that a formal procedure should now be established for evaluating earthquake predictions and for advising relevant agencies and groups concerning their validity[2]:

The scientific and technical aspects of earthquake prediction have advanced to the point at which the development of systems for associated societal response should be addressed promptly in a formal manner. A prediction capability will be of little value if societal response procedures are not formulated concurrently.

CHARACTERISTICS OF PREDICTIONS

Given this assessment of the technology of earthquake prediction and the kinds of predictions now being made, we can specify the main features of the predictions whose consequences we intend to discuss. As noted above, the kinds of consequences we examine depend on the nature of the prediction, and if some major breakthrough in prediction technique should occur overnight, many of our conclusions might become moot.

First, predictions will not specify precisely the place, date, or magnitude of the predicted event. At best, a range of magnitude, a general area, and a time interval may be given, and the limits might be quite broad. Of course the limits will be narrow enough that one should be able to say a "prediction" has been made, but the line between a prediction and a nonprediction is itself not an entirely clear one. In these respects,

[2]Currently, the State of California has an Earthquake Prediction Evaluation Council. The U.S. Geological Survey also has an Earthquake Prediction Council to review predictions made within the USGS and to advise the director as to appropriate action. The Working Group on Earthquake Hazards Reduction of the Office of Science and Technology Policy has recommended that the membership of the USGS Earthquake Prediction Council "be formally expanded to include non-governmental scientists so that the panel can be free of conflicts of interest, imagined or real, and can provide broad-based objective scientific evaluations." Under this plan the council would become the National Earthquake Prediction Evaluation Council, consisting of 5–10 specialists from the USGS and a comparable number from outside the government. The council would not issue disaster warnings but would advise the director of the USGS on the scientific validity of the methods used in the preparation of specific earthquake predictions and the reliability of the resulting predictions. This information, in turn, would be used by the director as a basis for communicating an evaluation of the threat to the governor of a seemingly threatened state. The issuing of warnings would be the responsibility of the governor and local officials. See Working Group on Earthquake Hazards Reduction, Office of Science and Technology Policy, Executive Office of the President, *Earthquake Hazards Reduction: Issues for an Implementation Plan*, 1978, pp. 28–36 and 105–107.

earthquake prediction will differ significantly from flood and hurricane predictions, which are relatively precise as to time, place, and magnitude.

Second, predictions will be highly probabilistic in nature, because of the complexity of the phenomenon and our lack of knowledge of it (point 3 above). In this way, earthquake predictions will be more like long-term weather forecasts than flood warnings. Only probabilities can be specified. Also, as stressed above, there will be false alarms and failures to detect. As noted later, this lack of certainty in prediction will turn out to be very important.

Third, legitimate disagreement is likely between scientific experts on whether a prediction is warranted. Thus it will not be clear whether the prediction is credible or whether any action should be taken. While the panel of scientific experts recommended by the NAS-NRC Panel on Earthquake Prediction may ameliorate this situation somewhat, it is unlikely, given the state of knowledge, that any review board will be able completely to resolve legitimate disagreements. Thus earthquake prediction is likely to be controversial. In addition, the public at large has little basis for making any independent judgments because, unlike floods, hurricanes, and tornadoes, earthquakes are preceded by no easily detectable external signs. The rarity of major earthquakes only adds to public uncertainty.

Fourth, earthquake predictions may have much longer warning times than the times typical of disasters previously studied. In the case of potentially disastrous earthquakes, it is assumed that there may be months and even years of advance warning, whereas for other disasters the elapsed time between prediction and occurrence consists of hours, days, or, at most, weeks.

SOCIOECONOMIC CONSEQUENCES OF PREDICTIONS

These characteristics of earthquake prediction have obvious implications for the kinds of socioeconomic phenomena to be studied. The differences between earthquake predictions and predictions of other kinds of disasters highlight the extent to which new research is needed.

First, the long lead times between prediction and event make it possible to carry out a variety of long-range policy measures whose efficacy must be studied. More importantly, the long lead time also permits changes in relatively broad and slow social processes (e.g., changes in land use and local labor markets and changes in migration patterns). Thus in the interim between prediction and event, the prediction may produce a number of direct, indirect, and cumulative effects.

Second, the long lead time implies that there may be consequences stemming from the prediction itself as well as from the anticipated event.

The distinction between consequences of the prediction and consequences of the event is underscored by the possibility of false alarms. As the Panel on the Public Policy Implications of Earthquake Prediction stated: "Under the worst combination of an inaccurate prediction and an inappropriate response, the prediction and quake together might even be more costly than an unpredicted quake would have been."[3]

Third, the uncertainty of the prediction, the low probability of earthquakes of high magnitude, and the lack of external signs compounded by the scientifically controversial nature of prediction give rise to a set of interesting psychological, social, and political processes that have little analogue in other natural hazards. Perhaps a better analogy would be to nuclear accidents, which also need intensive study. As we shall see, most people have difficulty dealing with probabilistic situations, particularly with low-probability events. Organizations are often no better equipped to deal with such uncertainties.

Finally, it is usual in studying social and economic consequences to distinguish predictions from warnings. In the words of the report on *Earthquake Prediction and Public Policy:*

> A *prediction* is a statement indicating that an earthquake of a specified magnitude will probably occur at a specified location and time, based on scientific analysis of observed facts. It is strictly information; it says nothing about how people should respond and takes no account of the consequences that may follow from the issuance of the prediction. . . . A *warning* on the other hand is a declaration that normal life routines should be revised for a time . . . (and) not all predictions will be followed by warnings.[4]

In the case of floods and other natural hazards, the relationship between prediction and warning is simple. In the case of earthquakes, however, the problematic relationships between prediction and warning, between information and policy, is a source of problems.

[3]See Panel on the Public Policy Implications of Earthquake Prediction of the Advisory Committee on Emergency Planning, *Earthquake Prediction and Public Policy,* p. 3.
[4]*Ibid.,* p. 7.

STATUS OF RESEARCH ON THE SOCIAL AND ECONOMIC CONSEQUENCES OF EARTHQUAKE PREDICTIONS

REPORT OF THE NAS-NRC PANEL ON THE PUBLIC POLICY IMPLICATIONS OF EARTHQUAKE PREDICTION

A major step toward anticipating the consequences of earthquake predictions was taken by the Panel on the Public Policy Implications of Earthquake Prediction, chaired by Ralph H. Turner. Its report (1975) was designed "as a basis for the formulation of public policy relating to an expected earthquake prediction capability." Its main aim was to alert decision makers to the issues, and it recommended actions warranted in the light of existing knowledge. At the same time the panel was aware of major gaps in our knowledge of the effects of earthquake predictions, and it offered a few "carefully selected recommendations for research" in particularly important areas:

> The future success of any earthquake-prediction and earthquake-warning system depends largely on whether public officials, business executives, and the populace assign high credibility to earthquake predictions and warnings. We have too little understanding of how the usual difficulties in securing public acceptance of disaster warnings will be intensified by . . . unusual features of earthquake prediction. . . .
>
> *Research Recommendation 6:* Circumstances influencing the credibility of earthquake predictions and warnings, and techniques for improving their credibility, need more careful study.
>
> *Research Recommendation 7:* Research is needed on how people process information regarding low-probability disasters and how this processing changes when a prediction alters the probability. It is important to gain more understanding of how people establish acceptable levels of risk in such instances.[5]

In keeping with its charge the Panel on the Public Policy Implications of Earthquake Prediction did not try to formulate any of these problem areas in any detail, nor did it try to establish priorities among proposed topics for research. This report is intended to take this next step—to define the unknowns in enough detail so that research priorities can be set and specific proposals invited.

SOME CURRENT RESEARCH

Research on the social and economic effects of earthquake prediction is in its infancy. Nevertheless, some interesting research (either recently completed or in progress) provides a starting point for future studies.

[5] *Ibid.*, pp. 11–12.

Although they did not collect new data, two previous technology assessments of earthquake prediction attempted to identify possible societal impacts. Jones and Jones present five sets of factors likely to affect societal responses to early earthquake predictions: (1) community characteristics of the prediction area, (2) design and administration of the prediction system, (3) magnitude of the earthquake predicted, (4) relative accuracy of the early predictions, and (5) degree of professional consensus supporting the official predictions.[6] The authors illustratively combine these factors into three scenarios in order to estimate impacts under varying conditions and suggest a number of policy issues that relate to these estimates. Weisbecker and his associates focus on decision options in the public sector in their assessment.[7] Although they conclude that there is no reason to deviate from the current U.S. approach featuring earthquake engineering as the basic defense against the earthquake threat, they also see no reason not to continue scientific inquiries into the art of prediction. Their report recommends preprediction planning at the regional level as opposed to separate state and local levels. Toward that end they present a general framework to facilitate the selection of strategies for mitigating the hazard.

To date there have been two major empirical studies dealing with the socioeconomic aspects of earthquake prediction, one recently completed and the other in progress. Haas and Mileti used two scenarios of predicted earthquakes in detailed interviews with 1,000 representatives of 200 business and governmental organizations in California to identify possible reactions to what they term credible predictions.[8] Executives in these organizations indicated that the reputation of the prediction source, the expressed consensus among recognized experts regarding the validity of any prediction, and the probability that the predictions would materialize were more important to credibility than the content of the prediction per se.

A sample of 246 families was also included in the study to determine possible individual and additional aggregate community effects. Haas and Mileti's findings suggest that if a damaging earthquake were to occur roughly as suggested by their prediction scenarios, both the human toll and the property damage would be less than those expected in an unpre-

[6]See M. V. Jones and R. M. Jones, *Scientific Earthquake Prediction: Some First Thoughts on Possible Societal Impacts,* 1975.

[7]See L. W. Weisbecker, W. E. Stoneman, and S. E. Ackerman, *Earthquake Prediction, Uncertainty, and Policies for the Future: A Technology Assessment of Earthquake Prediction,* 1977.

[8]See J. E. Haas and D. S. Mileti, *Socioeconomic Impact of Earthquake Prediction on Government, Business, and Community: Research Findings, Issues, Implications for Organizational Policy,* 1976.

dicted earthquake. However, these data also suggest that when the period between the issuance of the initial prediction and the occurrence of the earthquake is extended, the affected community may well experience social disruption and a decline in its economy. They point specifically to such possible economic trends as a prohibition on the sale of new earthquake insurance policies, a sharp reduction in construction, and a decline in the sale of durable goods.

As the Haas-Mileti project entered its final phases of data analysis, a new 3-year study under the direction of Ralph H. Turner, entitled "Community Response to Earthquake Threat in California," was in its initial stages.[9] Beginning in February 1976, reports of a substantial uplift along the San Andreas and associated faults and other possible premonitory signs of a potentially destructive earthquake were announced to the Southern California community. Although no formal prediction has yet been issued, this is the first approximation of a long-term prediction in the United States. The Turner study will provide base line data about community response to this and subsequent earthquake prediction information. The data will include a sample survey of 1,600–1,800 residents of Los Angeles County, periodic follow-up telephone interviews, direct monitoring of the mass media, and repeated interviews with selected leaders in the public and private sectors. On the basis of the survey data the study will assess (1) popular reception and understanding of reports of earthquake danger, (2) steps people take to cope with the threat, (3) the extent of altruistic concern for prospective victims and groups as contrasted to self-interest, (4) disposition to cooperate with hazard reduction programs developed by officials in the public and private sectors, (5) the process by which people make up their minds on these matters, and (6) the patterns of changing response in relation to developing events. Turner will also prepare and analyze a history of media and organizational response.

The next chapter presents a framework designed to point the way toward additional lines of research on the consequences of earthquake predictions.

[9]This description is based on personal communications between Ralph Turner and the Committee on the Socioeconomic Effects of Earthquake Prediction, 1977.

2 Conceptual Framework

The framework set forth in this chapter is designed to give a broad perspective on the research problems and policy issues to be formulated in the rest of the report. The framework presents in general terms the processes connecting earthquake predictions and warnings with potential social and economic consequences, identifying both the factors that should be studied and the relationships among them.

APPROACH TO THE PROBLEM

The framework is designed to develop the "anatomy" of an analysis of the consequences of predictions, that is, to specify those classes of factors most relevant to studying the problem. It offers a context within which the specific problem areas discussed in subsequent chapters can be placed. It also defines terms used throughout this report. Some general remarks here about the framework and its rationale may help orient the reader to the rest of the report.

First, the framework focuses on *process* and is designed to accommodate the possible short- and long-run effects. The process focus follows directly from the long lead times that may intervene between prediction and event and from the possibly broad interval (*time window*) within which the earthquake is predicted to fall. It allows for immediate effects of predictions (e.g., contraction of mortgage money, emotional re-

sponses) as well as the broader and more indirect effects on community organization, population redistribution, and regional economic structure alluded to above. Of particular importance is the role of feedback and aggregative effects.

The focus on process here supplements the more convenient way of grouping research problem areas in terms of the specific persons, organizations, and institutions involved. Legal constraints, for example, are discussed primarily in chapter 6 but are also noted in other chapters because they impinge on homeowners, earth scientists, firms, government agencies, mass media organizations, and markets. Our framework shows that in analyzing the responses of any of these actors or organizations the legal situation should not be ignored. Moreover, at different stages of the process, depending on the specific consequences we want to study, several individuals, organizations, and institutions will play a role. For example, in assessing the impact of a prediction on the real estate market (an institution), homeowners, buyers, and builders (individuals), banks and regulatory agencies (organizations), capital markets, and the regional economy (other institutions) will all have to be studied. Any given discipline-based project, however, might investigate only some of the behaviors and interactions involved.

Second, the framework is meant to be useful in the evaluation and construction of a wide range of social *policies* designed to ameliorate and control the effects of predictions and of earthquakes themselves. Again, the long lead time allows policy options that would not be considered in connection with other disasters. Moreover, we do not feel that the consequences will be so diffuse as to be outside the reach of policy, nor so specific as to dictate the best instruments to be employed.

Third, the framework is designed to analyze the behavior not only of individuals but of *organizations*, *laws*, and *social institutions* (markets, regulatory instruments) as well. Many policy issues concern the appropriate kind of organizations and institutions for achieving a given result (e.g., public versus private, the proper role of the government, market versus nonmarket mechanisms, the most effective means of legal intervention). Moreover, such organizations and institutions are to a large extent the medium through which the indirect and aggregate effects of individual responses are produced.

Fourth, *information* plays a key role in the analysis. A prediction is, after all, new information. Its consequences will depend on how the information is perceived and processed, a question strongly affected by the unusual nature of an earthquake prediction—probabilistic, nonspecific, perhaps controversial information about an uncontrollable event with potentially disastrous consequences. Moreover, as we shall see,

information processing is a very important determinant of the performance of individuals, organizations, and institutions.

Finally, the framework permits a *comprehensive view* of the effects of predictions and clarifies how various effects relate to one another. We are unlikely to be able fully to understand one or another set of consequences in isolation from the rest of the picture. While prudent research strategy may suggest considering the problems separately, especially in the initial stages, it is well to keep the larger picture in mind.

OVERVIEW OF THE FRAMEWORK

Figure 1 depicts an overview of the processes connecting predictions and their effects. The boxes represent key sets of variables, and the arrows important functional relationships between them. The problem is to document the determinants (boxes 1–6) of adjustments to earthquake predictions and the short-term as well as long-term consequences of these adjustments (feedback loops). Two-headed arrows signify joint effects. Arrows and paths are referred to below by the numbers of the boxes they connect.

Factors which are either uninfluenced by the variables represented in the figure or which can be treated as constant over a long time span (say, 15 years) are taken as exogenous determinants of the process. These include the sophistication of the prediction technology; the physical and geological events, such as changes along a fault or actual earthquakes, that would occasion predictions; aspects of the legal system, such as the constitution and the common law, that constrain policy; and the general social, economic, and governmental situation in the United States and the world as a whole, which affects community structure, policy, and decisions. The exogenous factors, of course, have an important impact on predictions and their consequences. We do not try to explain them, however; we only note their effects.

Turning, then, to the variables we do try to explain, we see that the consequences of a prediction depend on three predetermined factors: the nature of the prediction (box 1), the structure of the community or region in which the prediction is made (box 2), and the legal and political constraints (box 3) that limit the responses of individuals, organizations, and institutions. The last two factors are relatively slow to change. We want to understand their effects and determinants and perhaps ultimately reshape them through policy decisions. Community and regional structure includes the social and demographic composition of the population, income distribution, economic base and infrastructure, community

organization and resources, land-use patterns, political culture, and the like—in short, all of those aspects of the community and region that may be changed by a prediction or actual earthquake. Legal and political constraints refer to law and government policies—such as property rights assignments, liability rules, regulatory instruments, capital budgets, and intergovernmental division of labor—that affect the community and can be used to control the potential effects of predictions or earthquakes but that require large investments of time and effort to change.

The structure of the community and the political and legal constraints together determine the stakes and opportunities of individuals, firms, and others in the private sector (box 5). By *stakes* we mean the investments, broadly conceived, in the locality for which an earthquake is predicted. These include not only the economic and human capital of firms and households, but other kinds of "sunk costs"—in social networks, personal attachments, and knowledge—that are hard to replace or exchange. *Opportunities* refers to the courses of action available, along with the costs attached to them.

Legal and political constraints and community structure also affect the relatively easily changed policies and actions of various governmental agencies (box 4), such as building codes, local budget items and subsidies, and disaster preparedness measures. Boxes 3 and 4 represent the policies with which this report is centrally concerned. The involvement of various levels of government in generating and issuing predictions and warnings (including any controls of the mass media) is signified by the two-headed arrow connecting box 4 and box 1.

The way in which the prediction is presented and interpreted, as filtered through the mass media, informal social networks, governmental agencies, and other information channels, will affect the perceptions of its consequences and the consequences of the event itself (box 6). These perceptions will also be shaped by the ability of firms and households to process the data. Some information will be actively sought, while other data will be passively received. (The same information processes apply to government officials in box 4.)

The actual responses of individuals and groups in the community (box 7) will be jointly determined by their stakes and opportunities and by the information they have available about possible consequences to them. The adjustments in turn may affect any of the other variables in the system in the short or the long run (arrows 7-6, 7-5, 7-4, 7-3, and 7-2). To a large extent, consequences will be determined by interactions between the different groups involved. Social networks, neighborhood organizations, and labor and real estate markets may change if households and firms move out. Scientists may refine the prediction, partly on the basis of new

information and partly as a result of reactions of individuals to previous predictions (arrow 7-1). The government may pass new laws and institute new regulations for coping with consequences (arrow 7-4 primarily).

ELEMENTS OF THE FRAMEWORK

We will now comment in more detail on the different boxes and arrows that make up the conceptual framework depicted in Figure 1. In doing so we will illustrate the concepts and ideas with specific examples, which chapters 3–7 elaborate on. These comments are meant to suggest the kinds of questions that will form the basis for future discussions rather than conclusions already in hand.

NATURE OF THE PREDICTION (Box 1)

The kinds of consequences that might ensue will depend on the nature of the prediction that will be made. The research priorities stressed below are predicated on the assumption made in chapter 1—that predictions are likely to probabilistic, controversial, and nonspecific as to time, place, and magnitude. Should the technology turn out differently—for better or for worse—all the problems we note might become moot. We concen-

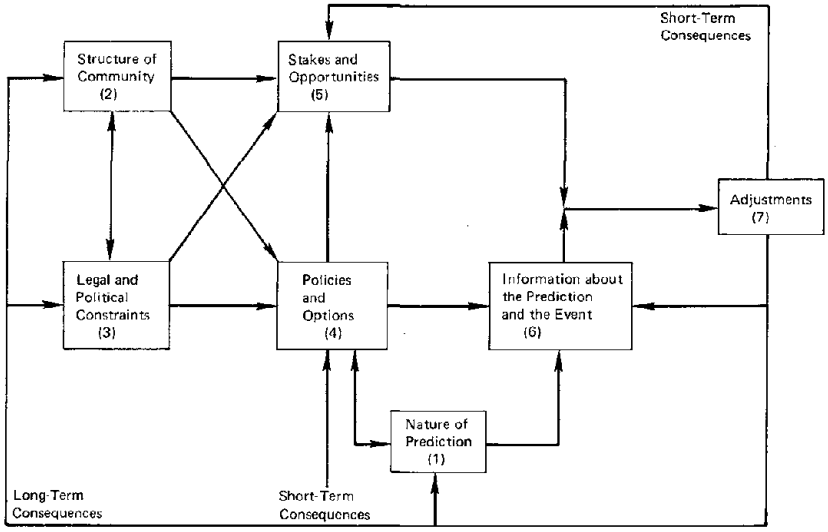


FIGURE 1 Conceptual framework for earthquake prediction problems.

trate below on scientifically based predictions produced by earth scientists, but other sources should not be ignored. The distinction between predictions and warnings already cited should also be borne in mind, as the path from box 1 to box 4 implies.

When one is considering the subject of earthquake prediction, it is important to distinguish between objective information and the subjective image produced by the data. Seismologists and engineers know that an earthquake of magnitude 7.4 is likely to damage bridges and freeways more than wood frame structures, yet homeowners residing in these structures may perceive the potential loss to their property from such an earthquake to be quite severe.[1] Their image of the loss will be largely determined by how the mass media and scientific community interpret the prediction (arrow 1-6 and box 6).

Similar problems of interpretation are likely to arise with respect to the uncertainty of the prediction and the timing of the predicted event. Considerable evidence from field and laboratory experiments suggests that people have an extremely difficult time dealing with uncertainty. Specifically, they are likely to use limited data and exhibit systematic biases in making decisions about probabilistic events.[2] The problem will be compounded if the scientific community disagrees about the validity of the prediction.

We expect that the prediction will change before the event occurs, both because of new physical information and conditions and as a result of the reactions of individuals, community groups, and firms (arrow 7-1). Such feedback will be discussed further in chapter 7.

STRUCTURE OF THE COMMUNITY (Box 2)

Community structure refers to all those characteristics of the community or region which might be affected by a prediction or which influence individual and organizational responses. A great variety of factors enter here, depending on the specific research problem we have in mind. Surely a given prediction might have quite different effects in one community than in another.

[1]Data from a field survey suggest that over 75 percent of the homeowners interviewed in California expect more than $10,000 damage to their wood frame homes from a severe earthquake. See H. Kunreuther *et al., Disaster Insurance Protection: Public Policy Lessons,* 1978.

[2]See A. Tversky and D. Kahneman, "Judgment under Uncertainty: Heuristics and Biases," *Science,* vol. 185 (1974), pp. 24–31, and P. Slovic, H. Kunreuther, and G. White, "Decision Processes, Rationality and Adjustments to Natural Hazards," *Natural Hazards: Local, National, and Global,* 1974, pp. 187–205.

The socioeconomic characteristics of the community (i.e., age distribution of the population, income distribution, and educational level) will modify the impact of the prediction on behavior. If the threatened community contains a high proportion of young and highly educated people, then residents might be much more willing to move to another area than in the case of a community composed primarily of older people. If so, then real estate values for a young mobile population are more likely to decrease if the prediction is taken seriously than they are if a more stable population is assumed. Communities with active social groups, such as neighborhood associations, may help stabilize the real estate market by pressuring residents to remain in the area to preserve the community structure.

The types of businesses and firms in the threatened community will also affect the consequences of an earthquake prediction. For example, if a large manufacturing plant is the primary source of employment for residents of the community, then the prediction will have a serious negative impact on the area if it causes the firm to contract its operations. In such a community there would be a close interdependence between the consumer and the business sector; the firm would be concerned with outmigration of households, while residents would be worried about the firm's relocating in another area. Conversely, communities with a business sector consisting primarily of retail stores and services would suffer a much less serious economic impact from a prediction of an earthquake than would the one-company town.

Actions in the public sector, comprising government agencies at the federal, state, and local levels, will be affected by the composition and effectiveness of political pressure groups representing the business and residential sectors (arrow 2-4). Thus neighborhood associations may demand special property tax relief to homeowners as an inducement to stay in the area. Similar lobbying efforts exerted by associations such as the Chamber of Commerce may result in special relief for firms and corporations, regulatory measures such as land-use restrictions, or building codes to reduce potential losses.

LEGAL AND POLITICAL CONSTRAINTS (Box 3) AND POLICIES AND OPTIONS (Box 4)

Boxes 3 and 4 comprise the policy options and institutional constraints affecting the prediction and its consequences. As noted earlier, there is no sharp distinction between these boxes, the difference depending on how easily the policies may be changed. For example, one may want to

know whether modifying a building code is likely to be easier than requiring earthquake insurance or changing liability rules. Such information will be important in formulating policies. Studies whose time horizon is short might well ignore the second two options as objects of analysis. Both boxes have similar impacts on the other components of the framework, however.

Studies concerned primarily with policy and governmental actions will raise both normative and behavioral questions. We want to know not only how state agencies perform their duties, but also whether there are alternative arrangements that might be more effective. Similarly, we do not want to study regulations, subsidies, tax instruments, and licensing in the housing market in the abstract without asking which of these instruments is likely to be the most effective in achieving a given policy end. Such studies should contribute to the revision of legal and political constraints over the long term (arrow 7-3).

The effects of a policy will depend on the nature of the prediction, on how well the policy can be implemented by various levels of government (boxes 3 and 4), and on its impact on individuals, firms, and other organizations in the private sector (arrows 3-5, 4-5, and 4-6). For example, local government's decisions to utilize land-use regulations following a prediction, will in part be determined by the time window associated with the prediction. If the earthquake is forecast to occur within the ensuing 2 months, officials may decide that it would take too long to implement effective controls. Then, too, state and federal governments may cope with economic disruption following a prediction through tax incentives, regulation, and insurance. The policies they choose will depend on their ability to enforce their decisions, on the behavior of individuals and firms following a prediction, and on the pressure exerted by these groups for change.

Policy instruments will differ in the extent to which the behavior they are intended to produce is voluntary or required, in the amount and kinds of information the affected parties need to respond appropriately, and in the kinds of monitoring they entail. Thus information processing on the part of households, firms, and government units is of central importance in determining policy effectiveness. (See paths 4-5-7 and 4-6-7.) Regulatory action, such as mandatory earthquake insurance or building codes, may reduce the information dissemination and processing costs (banks will now demand such coverage as a condition for mortgage, building inspectors may now impose certain conditions for a structure to remain open), but those policies entail enforcement costs and require a new set of institutional arrangements. In the case of mandatory earthquake coverage, the insurance industry may be concerned with the

effect of a severe loss on its financial solvency and hence will need a special governmental organization to provide reinsurance against catastrophic disasters. Clearly, research at many levels will be required to determine the relative cost and benefits of such policy alternatives.

STAKES AND OPPORTUNITIES (Box 5)

A prediction will affect the stakes of households and firms both because of damage the earthquake itself might produce and because of the existence of the prediction per se. To illustrate the first case, households and businesses will take stock of the potential physical and financial losses to their property should an earthquake occur. In making their assessment, they will focus on their subjective estimates of the loss, which, as we pointed out above, may be different from what was forecast by the scientists who issued the prediction. To determine the stakes associated with such a loss, one must know the contractual arrangements with respect to property. Residents of the community who rent their homes or businesses that lease their plants have considerably lower financial stakes from an earthquake than those who own the property outright.

Firms and households may also have to worry about noneconomic losses such as injuries and fatalities from an earthquake. From a legal point of view, there may be a price tag associated with these effects. For example, if firms were held responsible for any injuries in their plant should a predicted earthquake occur then they would have to consider the potential economic loss before keeping their businesses open.

The stakes associated with the prediction itself are more subtle but nonetheless of great importance. They are best illustrated by the plight of a firm that is highly dependent on local demand for its product and employs many workers in the community. Such a business will be concerned with the effect that the prediction has on area households. If many of them decide to move, the firm will lose an important part of the market for its product as well as part of its work force. In this case its stake depends on the ease with which it can shift to other markets and the cost of hiring and training workers to replace those who have voluntarily left. The problems faced by households are parallel. If they conclude that their employer will locate his business elsewhere, they have to determine what other employment options exist should they decide to stay or whether it would be better to relocate.

From the above examples it should be obvious that stakes are greatly influenced by policies and regulations in effect both before and after a prediction has been made (arrows 3-5 and 4-5). If earthquake insurance is required as a condition for a mortgage, then firms and households will be less concerned with the financial impacts of an earthquake itself and

may decide to ignore the prediction. In this case, housing values and employment opportunities in the area will be unaffected. Special forms of tax relief to businesses and firms may achieve similar effects.

In addition to such constraints on households and businesses we must also consider their opportunities for change. In a broad sense these opportunities are limited by the fixity of capital of firms or households and uncommitted resources such as liquid assets or cash. The term "resources" is used here in the broadest of contexts to include human, social, and material aspects. A firm with heavy equipment, such as a steel mill, will have limited opportunities to change its location after a prediction, while banks and financial institutions will have much greater flexibility. The steel mill will thus have a greater stake in the community than the bank or financial institution. Among households, a college-educated bachelor in his mid-twenties will have fewer family and community ties than a middle-aged couple with two teen-aged children. In the latter case, social investment in the community, the cost of relocating, and the problem of establishing a new set of friends and finding a job limit the opportunities to move. Such a family would then have a high stake in the community.

INFORMATION ABOUT THE PREDICTION AND THE EVENT (Box 6)

We have already noted the importance of information processing and dissemination in choosing between different courses of action. That we have given information handling a separate place in the framework (box 6) is not surprising, since a prediction constitutes new information. Among the kinds of information people have is, first, the prediction itself and the chances of its being realized (arrow 1-6). Of particular importance here are the credibility of the prediction and the image of the event that it evokes. The mass media and informal networks such as friends and neighbors will be the primary sources for initial information on the prediction. For convenience, households may decide to rely solely on these sources for information. Firms with high stakes and sufficient resources may want to call on specialized sources such as public officials or scientists to obtain more accurate data on both the probability and the consequences of the event. The greater the uncertainty associated with the prediction, the more useful such specialized information can be to the recipient, and such foreknowledge can benefit these insiders at the expense of others.[3]

[3]See J. Hirshleifer, "The Private and Social Values of Information and the Reward for Inventive Activity," *American Economic Review,* vol. 61 (September 1971), pp. 561–574.

Second, advertising, the mass media, and other sources will provide considerable information on what others are doing (arrow 7-6). Individuals may reach conclusions about the housing market by examining "For Sale" signs in their neighborhood; newspaper or television reports may provide information on employment changes. If individuals construe such information incorrectly, serious problems may follow a prediction. For example, if people observe several "For Sale" signs in the region where an earthquake is forecast and falsely conclude that homeowners are attempting to sell their property because of the prediction when in fact the turnover is due to normal causes, major dislocations in the housing market may ensue. Clearly, the relative accuracy of the various information channels needs to be assessed.

Personal contact with other individuals in the area will be another important source of information on what others are doing. Here again the data collected will be imperfect, since households and firms are likely to find out about the reactions of others through the social networks established in the community. People are more likely to believe information acquired through personal sources than mass media statistics. The knowledge that a friend was laid off as a result of the prediction will have more impact on a household than will impersonal statistics on actions taken by firms in a news story.

A third kind of information concerns the appropriate response that should be made following a prediction. Some individuals, households, firms, and governmental units may deem their present course of behavior satisfactory or decide that no better course may be available at the moment. They may reach this conclusion because they are not threatened by the prediction or because they cannot afford to take different actions (e.g., relocating). Others may adopt a new course of action.

If similar choice situations are any guide, the decision process for individuals, firms, and government agencies will be characterized by limited search for data,[4] reliance on informal contacts such as colleagues, friends, and neighbors,[5] and such systematic biases in processing information as uncertainty avoidance and selective perception.[6] As a result, the action taken will be influenced primarily by factors other than the comparison of costs and benefits.

An example related to earthquake prediction illustrates this point. After an April 20, 1976, forecast by James Whitcomb that a quake of

[4]See J. G. March and H. A. Simon, *Organizations,* 1958, and H. Kunreuther, "Limited Knowledge and Insurance Protection," *Public Policy* (Spring 1976), pp. 227–261.
[5]See J. Coleman, E. Katz, and H. Menzel, *Medical Innovation: A Diffusion Study,* 1966.
[6]See, for example, A. Tversky and D. Kahneman, "Belief in the Law of Small Numbers," *Psychological Bulletin,* vol. 76 (1971), pp. 105–110.

magnitude 5.5 to 6.5 would occur in the San Fernando Valley within the next year, an Allstate agent remarked: "We've seen a hell of an increase in the last couple of weeks. Many have been calling and just saying, 'Add it.' They don't even inquire about the price."[7] The chances are that these individuals had not even considered the limited damage that a quake of such magnitude would cause to their property, nor did they have any understanding of the 5 percent deductible on their insurance purchase.

If this general characterization of information and decision processes is correct, a number of research problems arise that will be formulated more precisely in the next five chapters. These include the following:

1. What are the heuristics and biases employed by individuals and organizations in coping with the earthquake threat and alternative courses of action?
2. To what extent do individuals and organizations (e.g., firms and government units) differ in their decision making and information processing? What accounts for variations among them?
3. What impact will the behavior of other firms and households have on a given actor, if personal influence is so important?
4. How is the efficiency of institutional arrangements (e.g., free versus regulated insurance markets) affected by such decision making and information processes on the part of individuals and firms?
5. What role can local, state, and federal governments play in disseminating information to the private sector? What legal mechanisms are available for coping with the problems likely to arise?
6. What role can the scientific community and the mass media play in the information dissemination process? How should scientists and the media be related to various levels of government?

ADJUSTMENTS TO THE EVENT AND PREDICTION (Box 7)

If individuals or organizations decide to act on the basis of a prediction, a number of ways of diminishing the threat of damage from the event or socioeconomic disruption from the prediction are open to them. Such measures can range from efforts to dissipate the forces of the natural events, that is, *modifying the cause of the hazard*, to moving one's residence or place of business in response to the threat, that is, *reducing the loss potential*. Between these extremes may be found a number of other options, including structural improvements and efforts to spread losses over time and among others.

[7] *New York Times*, 15 May 1976, p. 8.

TABLE 1a Adjustments (Given a Prediction) to the Events

		Reduce Loss Potential		Distribute Loss	
	Modify Cause	Land-Use Management	Structural Improvement	Insurance	Bear Loss
Individuals (consumers)	Do nothing	Individuals outside community do not move in; those inside wish to move out	Spend to reinforce residence	Try to purchase insurance	Do nothing
Firms	Do nothing	Move out or not move in	Spend to strengthen	Diversify holdings	Do nothing

TABLE 1b Adjustments to the Prediction

	Modify Cause	Reduce Loss Potential	Distribute Loss
Individuals (consumers, workers)	Ignore potential for decline in property value	Find jobs outside the site of prediction; hoard money	Default on mortgage; seek tax reduction
Firms	Release information to counter prediction	Diversify holdings[a]; stop selling; diversify activity	Diversify; apply for aid

[a]Reduce the number of mortgages at risk.

This adjustment scheme has been used widely to describe actions taken in response to a number of geophysical hazards but has never been drawn into the analysis of socioeconomic losses.[8] For example, the decision of a firm to shift its source of supply to less vulnerable regions represents an attempt to reduce loss potential; the losses envisioned, however, are not physical but economic. The firm seeing the potential for disruption of its manufacturing operations may well opt to insure an uninterrupted flow. Table 1 lists some of the adjustments that households and businesses may select to cope with the earthquake threat. The choices, including the decision to do nothing, will be determined by the way they are represented in the information processes described above (arrow 6-7), by the stakes an individual or company has in the community, and by the opportunity for change (arrow 5-7).

Firms and households with a large investment in economic and social capital and with resources for taking action are likely to adopt protective measures. They would investigate insurance and pursue options for making the structure and contents of buildings more earthquake resistant. The policies adopted by the government will play an important role in defining these adjustments (paths 4-5-7). For example, if low-interest loans were made available for investing in earthquake-resistant measures, then the adoption of such actions would be accelerated. If the government imposed certain building code regulations on existing structures, then money would have to be found to make the necessary changes. Table 1a illustrates the options available for coping with the event.

The prediction itself may stimulate other actions, as shown in Table 1b. These include attempts to dampen imagined secondary losses and to diminish effects stemming from the adjustments made by others. For example, savings and loan institutions may curtail lending in the forecast area, not because of the threat of financial loss but because of a decline in economic activity caused by the prediction. Businesses may move out of the area or shift markets. They do so not only because of the threat of damage, but because they are adjusting to the actions taken by others. Individuals attempting to reduce their potential losses may seek to move out of the threatened community. Businesses experiencing a decline in sales base adjust by attempting to change the public image of the event (modify the cause of loss), changing their location and market (reduce loss potential), or applying for special tax relief (distribute losses).

The range of adjustments open to the government can also be classified by using the scheme as depicted in Table 1 for firms and households.

[8]See G. F. White and J. E. Haas, *Assessment of Research on Natural Hazards,* 1975, pp. 57-67.

New policies can be adopted to modify either the cause of the event itself (e.g., pumping fluids into faults) or the effect of the prediction (e.g., deciding whether or not to have the Earthquake Prediction Council, if there is one, endorse the forecast). Other actions can reduce the loss potential from either the earthquake (e.g., enforcing zoning regulations or building codes) or from the prediction itself (e.g., providing tax incentives for encouraging economic activity in the area). Policies can also distribute the loss should a quake occur (e.g., requiring insurance as a condition for a mortgage) during the period between the prediction and the event (e.g., providing federal aid to local government should its taxes decline).

CONSEQUENCES OF A PREDICTION

Many of the potential consequences of a prediction and the problems to which these give rise have been implied in previous subsections. We noted that both short-term and long-term consequences are of interest to us. Furthermore, we distinguished the losses that would be experienced in the aftermath of a disaster from the costs associated with the forecast itself. A decline in housing values may reflect expected damage to come and as such cannot be considered a cost of prediction. On the other hand, if people overestimate the damage and hence have an image of the loss significantly higher than that suggested by the objective data produced by scientists, then the decline in housing values will be due primarily to the prediction itself.

It is worth emphasizing that some important consequences of earthquake predictions are those borne by individuals or firms not as a direct result of their own actions (like changes in profits that might result from the relocation of a firm) but rather as a result of the actions of others. Each individual adjustment looked at in isolation appears relatively harmless, but the transmittal of this information to others and their subsequent reaction may produce serious changes in the local and regional economic and community structure. For example, suppose a homeowner sells his or her home and moves elsewhere in the light of the earthquake forecast. This information will be transmitted to other families in the neighborhood. Some may be induced to sell their own homes and thereby lower property values, reduce the supply of labor to the business community, and reduce the demand for goods and services, thus causing firms to revise their stakes in the prediction. Previously, firms may have considered remaining in the region threatened by a quake, but now they may be sufficiently unsure of maintaining their work force and the

market for their products that they will either move or reduce the scale of their operations. These movements will reduce tax revenues and may necessitate curtailment of public services. The existence of such externalities and aggregation effects is of great interest to policy makers, since it is one of the main justifications for government intervention in the free market and other unconstrained social processes.

NOTES ON CHAPTERS 3–7

The next five chapters in this report formulate systematically the problems just outlined. Although considerable interdisciplinary work is suggested, the chapters follow disciplinary organization fairly closely. Chapter 3 deals primarily with the behavior of individuals, households, and social groups. It concentrates on the arrows leading in and out of boxes 5, 6, and 7 of the framework. Chapter 4, which deals with economic issues, is concerned primarily with boxes 2, 5, and 7, and the long-term and short-term dynamics affecting them. Insofar as economic structure is modified by policy, it takes account of some of the connections of boxes 3 and 4. Chapters 5 (government) and 6 (legal) are concerned primarily with policy (boxes 3 and 4), and they detail many of the problems mentioned here. They are concerned with both theoretical and applied questions, and insofar as these depend on the behavior of individuals and organizations (lawyers, government officials, and agencies, etc.), they tend to deal with boxes 6 and 7 as well. Chapter 7, on the seismological community and information channels, is primarily concerned with box 1 and the arrows leading into box 6. Box 1, the prediction, is particularly interesting because the possibly large size of the prediction time window allows both long-term and short-term feedback to have effect.

Pieced together, these chapters cover the whole framework we have developed. Chapter 8, which recommends specific research priorities, returns to the more comprehensive view taken above.

3 Individuals, Households, and Social Groups

This chapter proposes research on the reactions of individuals, households, and social groups to earthquake predictions. The importance of the topic scarcely needs pointing out: The combined responses of individuals and households to such predictions can clearly affect the ability of a community to react constructively. For public policy purposes, the reactions of community residents to predictions are important to know. The ways in which predictions are issued by public officials and the sources they are attributed to might have important effects on how residents react. Public policies providing the proper amounts and kinds of information about earthquakes and their effects or about the meaning of probability statements associated with predictions may change untoward resident reactions to more constructive ones. If possible declines in real estate values are of considerable concern to householders, then public policy may be altered to attempt to bolster the real estate market.

Although the language of this chapter may lead the reader to believe that we are primarily concerned with the reactions of individuals, it should be stressed that this apparent emphasis is mainly a convenience of language. Most persons in any but very unusual communities are members of households that act largely as units in important decisions involving moving, the acquisition or sale of major property and real estate holdings, employment, and even voting. The processes of making decisions within a household may vary from family to family, but it is likely that few major decisions are made by a household member without at least taking into account what the other members want. Thus statements

in this chapter that use the individual as their frame of reference should be read as if we were referring to families as well.

We will also be concerned with organizational forms larger than households in this chapter. In particular, voluntary associations (other than firms and governmental units, dealt with explicitly in other chapters), ranging from scarcely organized social clubs to fraternal societies and churches, will be discussed in terms of their roles in affecting public reactions to earthquake predictions. Less organized collective activities such as temporary coalitions and social movements will also be discussed, as they represent an outgrowth of individual reactions to predictions and as they affect such reactions. Particularly interesting are what are called "emergent associations," temporary associations and coalitions that sometimes arise in response to unusual situations. An earthquake prediction, particularly one that predicts a very serious tremor, might well be serious enough to produce such collective phenomena. For example, a religious sect with apocalyptic themes in its ideology might well seize upon an earthquake prediction as confirming its ideology and suddenly acquire members and publicity.

TYPES OF PREDICTIONS AND THEIR EFFECTS

In this chapter it is important for the reader to keep in mind that the nature of the prediction itself—the width of the time window, the length of lead time, the size of the predicted earthquake, and the probability of occurrence—can affect public reaction. Indeed, for some parts of the United States, such as California, a prediction has already been issued (the *standing prediction*), since every seismologist expects that a severe earthquake will occur in that area. The time window is very wide, covering tomorrow and possibly as far as into the next century. Although it is almost certain that a severe earthquake will eventually occur in California, there is no indication whether the probability varies at any point along the entire, wide time window. Hence the currently expected probability of occurrence at any point is uncertain.

The predictions this report is concerned with differ markedly from the standing California prediction. Time windows will be narrower and probabilities higher. Specification of magnitude will most likely include seismic events that can be expected to accomplish great damage. Even within these limits, however, predictions can be expected to vary. We can be sure that reactions to the prediction will also vary with these characteristics.

We can also expect that predictions will change over time, as the seis-

mologists acquire more information. A prediction may be superseded by another statement that changes the magnitude, probability, or time window of the expected earthquake. The effects of such changes, especially those that involve radical departures from the original statement, might be to reduce the credibility of the prediction source. Or a series of predictions that increase in severity and probability might give rise to an expectation that even more drastic announcements are on their way.

Nor is there any reason to expect that an earthquake prediction, even when issued by the most authoritative source, will go unchallenged. For some time to come, earthquake predictions will probably be, at least in part, judgment calls. Some seismologists will make other judgments, and the media might find it useful to exploit the contradictions.[1] Counterpredictions may arise from a variety of sources motivated by wishful thinking, desire for publicity, and so on. In any event, one can anticipate that alternative predictions will be made. People will have to choose which predictions to believe. Markedly different predictions from presumably credible sources may neutralize official predictions and impair public acceptance of any predictions.

Hence we should bear in mind that some of the major determinants of private and public reactions to predictions lie in the characteristics of the predictions themselves. It is a safe bet that most individuals are ignoring the current California prediction. If a prediction were to be issued tomorrow warning that an earthquake of Richter 8.0 would be likely to occur with a probability of .8 around January 1979, plus or minus 2 months, reactions would be quite different. The discussion that follows assumes official predictions of severe earthquakes occurring with relatively short lead times.

A second consideration to keep in mind while reading this chapter is that the main effects of an earthquake prediction are indirect effects that stem from the impact of the collective reactions of other individuals, households, firms, and governmental units. The direct effects of an earthquake prediction that operate through anticipated losses of property and damages to persons are also important, especially for those who are close to the predicted epicenter, but for most individuals and households, such direct effects can be expected to be small. The dilemma of a household is that its own reactions aggregated with those of the rest of

[1]Indeed, there are good reasons to believe that alternative predictions will be sought out by the mass media and perhaps by others. The media can be expected to ask a wide variety of "experts" to certify or question the official prediction. Clearly, challenges would be more newsworthy than confirmation. Similarly, some public officials may be hesitant to take drastic measures; in such a case, the mayor of a city, bolstered by his "experts," could dispute the predictions of a governor and his official experts.

the residential population of an area along with the reactions of its major institutions are the source of much of what can happen to it as the result of a prediction, whereas its own reactions will affect the aggregate very little. It contributes to what is community response, but there is little it can do alone to alter community response.

THE DIFFUSION AND ACCEPTANCE OF EARTHQUAKE PREDICTIONS

There can be little doubt that were an earthquake prediction issued that differed significantly from the standing prediction, the message would spread widely and quickly. Media attention given to amateur predictions indicates that even predictions with very little backing from the scientific community and public officials will receive considerable attention. Hence we can expect that official predictions made by recognized scientific organizations and endorsed by public officials will receive even greater attention. Except for the completely isolated individual or persons with special disabilities, some version of an official prediction will be received by nearly all persons within a matter of hours or days.[2]

The issues surrounding the reception of a prediction consist of how accurately it is received and whether it is believed. While these may not be important immediate issues for predictions about events that lie some months or years into the future, they may be quite important for warnings on which immediate action such as evacuation should be taken.[3] In any event, if a program of prediction is to be of some use in mitigating the potential losses from earthquake occurrences, it is clear that the predictions have to be understood properly and believed soon enough for action to ensue.

We can expect public knowledge of a prediction to increase in accuracy and detail with time, as by repetition in the media and in conversation. Hence we are mainly concerned here with how quickly knowledge coalesces into an accurate version.

[2]The news concerning President Kennedy's assassination reached almost everyone in the United States within 4 hours. See B. S. Greenburg and E. B. Parker, *The Kennedy Assassination and the American Public,* 1965.

[3]A possibly important area for research may be stated as "When is tomorrow?" or "How close must a predicted event be to produce a sense of immediacy on the part of the receiver of the message?" For example, does a prediction for an earthquake next month bring about a sense of immediacy in the receiver, whereas a prediction for 6 months hence merges into a time frame that puts the event into the far distant future? Answers to this question have implications for policies concerning when to issue predictions.

It is important in this connection to distinguish between knowledge of the prediction and knowledge about appropriate individual reactions to it. Individual reactions are as diverse as the situations in which people may find themselves and hence cannot be so easily diffused by the mass media and by more informal means. Indeed, it is this diversity of response that is at issue in this chapter. It is difficult to suggest in advance what public policy should be on household responses. A good case could be made that public policy should emphasize actions that almost all could take (e.g., provide directions for making crude risk assessments of residential structures), but equally good cases could be made for issuing only general statements along the lines that residents should not be worried, since public agencies are implementing adequate prevention and preparedness programs.[4]

At least some variations among individuals may be viewed as consequences of the predictions themselves. Thus a prediction issued by a self-styled seismologist is likely to be perceived generally as less accurate than one issued by a scientific review committee. We can also expect that a prediction that has a narrow extension into the future will be more easily acted upon than one framed in terms of a more distant future.

Some variations among individual reactions, of course, can be expected to stem from characteristics of the individuals. Highly intelligent and/or well-educated persons are likely to perceive a prediction more accurately than is the average person. Similarly, those who have had some experience with earthquakes may be more attentive to the prediction and more able to understand it.[5]

People near the predicted epicenter may be expected to want more complete information about the prediction—and to want it more quickly—than will people farther away.

The more heavily tied the individual's stake is to the fate of the community, the more likely the person is to acquire accurate knowledge. (*Stake* is explained more extensively later in this chapter.)

Although the discussion above has employed the active voice to describe the process of information acquisition, we can expect so much information to be poured into a community that people will learn about any prediction without taking much direct action. Passive learning will be as important as or more important than active learning. Indeed, we

[4]This clearly suggests a line of research that would test the impact of predictions accompanied by varying numbers of prescriptive statements about appropriate household actions. Such research might take the form of laboratory experiments that would serve to assess potential impact and of policy analyses searching for prescriptive statements.

[5]A contrary expectation is that those who have had experience with mild earthquakes may discount the prediction of a more serious event.

can expect that an index of importance of the prediction to an individual would be the extent to which active learning predominates over passive learning.

Summarizing, we can expect the following characteristics to affect the speed with which individuals achieve accuracy in their knowledge of the content of a prediction:

1. *Characteristics of the prediction.* The shorter the time to the predicted event and the greater the magnitude of the predicted event, the more quickly will individuals acquire accurate knowledge concerning the content of the prediction itself.
2. *Cognitive abilities.* Highly educated individuals and those with the ability to handle abstract concepts and technical terms will develop accurate perceptions of the predictions more quickly than will persons with less education.
3. *Exposure to risk.* Individuals located close to the predicted epicenter or inhabiting vulnerable structures will more quickly develop accurate perceptions of the predictions than will persons living at a distance or in less vulnerable buildings.
4. *Stake in locality.* Individuals with larger and more extensive stakes in their localities will be more likely to develop earlier and accurate perceptions of the prediction than will persons with fewer or lower stakes.

Although the content of a prediction may be accurately perceived, it need not be believed. Obviously, belief is not an all-or-none matter; an individual may believe the prediction in every respect except the magnitude of the anticipated quake, or the probability of it, or some other element of the prediction. A special problem arises out of the probabilistic nature of predictions: Although the announcement may phrase the prediction in terms of probability, the individual still has to decide whether to accept the prediction as indicating that the event will or will not take place. How individuals convert probability statements about sets of events into predictions about single instances has been a subject of laboratory research but not of field research. We simply do not know how much a probability statement has to depart from .5 in either direction for the preponderant single event prediction to be perceived as either zero or one.[6]

[6]This problem suggests a subject for laboratory experimentation in which probability statements are systematically varied in a choice situation presented to individuals, possibly with additional variations in areas (health versus automobile accidents) as well as in other relevant factors.

Even given a high probability, a prediction of catastrophe initially has to overcome the bias toward normality that exists in us all. After all, the best prediction we can usually make is that the near future will not be very different from the present. Indeed, this bias lies at the heart of everyday life, making it possible to plan ahead even though we cannot know the future. Thus any prediction is subject to some degree of discounting, at least at first.

Many of the same factors that affect accuracy of perception can be expected to affect credibility of a prediction. Thus an important element is likely to be the nature of the prediction and its sponsorship. A prediction issued with scientific and political endorsement may be more believable than one issued without either. Another important factor would be unanimity among "elites" concerning the credibility of the prediction. A prediction that does not have unanimous support from scientists or politicians can be expected to be less credible than one that does.[7] Similarly, predictions in which the probability statements are around .5 can be more easily discounted than ones in which the probabilities are close to unity.

The factors that influence the believability of an earthquake prediction are similar to those we think affect accurate perception. But, the direction of the influence is not easy to anticipate. Thus an individual who owns property and has strong social ties in a community might be prone to believe a countervailing prediction because the anticipated threat to this life may be greater than what he is willing to face. Alternatively—since he has so much to lose if a quake comes—he may be overly eager to accept a prediction and take proper precautions to protect his stakes.

In outline form, here are some of the major factors we expect to play a role in the credibility of a prediction:

1. Characteristics of the prediction
   a. Credentials of persons and organizations issuing the prediction
   b. Degree of acceptance of the prediction among the scientific community
   c. Degree of acceptance of the prediction among elites
   d. Timing, probabilities, and magnitudes associated with prediction
2. Characteristics of persons responding to prediction
   a. Experience with earthquakes

[7]Indeed, some analysts have considered that the reason fluoridation referendums sometimes fail when opposed by a vociferous minority is that a large proportion of the electorate loses faith in the arguments of both sides and decides on a conservative strategy of endorsing no change, rather than a change that might lead to untoward outcomes. Credibility is lost under the circumstances of rancorous conflict. See R. Crain, E. Katz, and R. Rosenthal, *The Politics of Community Conflict,* 1969.

b. Stake in locality
c. Intelligence and education
d. Exposure to risk

Social scientists who have studied how public opinion is influenced have postulated a "two-step" flow, in which messages broadcast by the media are initially picked up by "opinion leaders"—persons with above-average interest in an area who tend to serve as sources of advice for their peers—and then relayed through the opinion leaders' circles of acquaintances. Although we can anticipate that the mass media will feature any earthquake prediction so prominently as to attract almost everybody's attention, the credibility of a prediction may follow more closely the two-step model. People will look to their trusted and knowledgeable peers for clues on how to evaluate a prediction.

In addition, we must consider the impact of prevailing opinion in an individual's social environment. Thus someone whose friends, co-workers, kin, and neighbors believe in the prediction is more likely to accept the prediction than is a person in a social environment with opposite characteristics. Indeed we may expect the credibility of a prediction for a single individual to be, in part, a function of the rate of acceptance of the prediction among that individual's contacts.[8]

THE RANGE OF INDIVIDUAL AND HOUSEHOLD RESPONSES TO EARTHQUAKE PREDICTIONS

Beyond the question of whether people will believe in a prediction there is the question of what people will do about it. The repertory of responses is limited by three main factors. First, individuals and households vary in the extent to which their actions must take into account the preference of others. For example, a household in which there are several working adults is less flexible than a single-earner household.

Second, the more resources an individual or household has and the more liquid those resources are, the larger the response repertory of the

[8]The role played by interpersonal contacts in the formation of beliefs and perceptions is an important but secondary phenomenon. We know that how an individual votes is strongly affected by the voting preferences of those persons whom he knows. Although opinion climates accelerate movement toward unanimity within a subgroup, the driving forces for change have to be considered as coming from within individuals or from outside events. Thus some kinds of individuals may be likely to accept some kinds of predictions, and the prevailing level of acceptance within the social networks of those individuals will add an extra boost or apply the brakes to tendencies already at work within the individuals. Furthermore, each individual is a member of several subgroups and may be able to choose the climate that most closely suits his natural proclivities.

individual and household. Thus a wealthy family with its main cache of assets in certificates of deposit can more easily pull up stakes than can a less affluent family whose assets are tied up in physical plants and real property.

Finally, there is the question of the costs associated with each possible reaction. Some households may find that moving from a threatened locality can be accomplished cheaply, while for others the financial and personal costs may be more than can be borne or justified. The costs involved are not merely cash outlays for moving or modifying one's home but also the more intangible costs associated with modifying one's life-style or leaving behind satisfying relationships with friends, neighbors, and kin. The strength of household attachments to localities and social relationships is not very well known. We do know that since the late 1940's approximately 20 percent of the American population has been moving each year, a level of mobility that suggests that these ties are not very strong. Yet when we also note that young people entering into the labor market or marriage (or leaving both) contribute disproportionately to this appearance of restlessness, we suspect that for some portion of the population moving may be a traumatic, wrenching experience. Older persons whose careers have peaked and whose daily lives are comfortably surrounded by supporting networks of kin and friends may be those whose social relations are most threatened by an earthquake prediction.[9]

The possible range of responses to an earthquake prediction may be classified under the following categories. The first possible response is to do nothing at all, a choice that involves in effect making a bet that the earthquake will not occur and that the actions of others will not affect one's life significantly. Doing nothing at all may also be based on a decision that the costs of doing something will exceed the costs of the predicted quake. For some types of predictions, such a reaction may be the most appropriate, if the household has considerable flexibility in resources and if low costs would be incurred if the bet is lost. Thus a prediction of an earthquake of major magnitude 2 years into the future may be met best, at least at first, by doing nothing. Indeed, the normality bias alluded to earlier in this chapter suggests that typical first responses would be to do nothing, perhaps in the hope that "everything will turn out all right" or in the expectation that counterpredictions will provide good reasons for heavily discounting the bad news. In addition, it takes time to gather information on what other individuals and households are doing and on what reasonable alternatives exist.

[9]P. H. Rossi, *Why Families Move,* 1955.

This earliest period, immediately following the issuance of a prediction, might turn out to be extremely critical both for policy making and for setting the tone for public response. Policy statements that set forth clearly the alternatives open to individuals and the appropriate measures to be taken by public agencies and large firms may do much to reduce the levels of public uncertainty and anxiety. Similarly, adverse public response in this period, such as an inundation of "For Sale" signs on property, sets a pattern of panic from which it may be difficult to recover.[10]

A second set of responses involves undertaking loss mitigation measures while remaining in the locality. Thus a household might undertake to strengthen its house or move to one less prone to failure under earthquake stress. Or, people might support investment of public funds in strengthening public facilities and structures, and stronger building codes for factories, stores, and other places where large numbers of persons may gather.

Public officials can be expected to be deluged with requests for information on loss mitigation measures. Since the development of a set of such measures does not need to wait for an actual earthquake prediction to occur, it seems appropriate for federal agencies to arrange for the development of handbooks—outlining points of vulnerability in structures and what can be done to strengthen them—for officials and for direct distribution to the public.

We can also anticipate that firms will be set up to meet the demand for information and action. "Earthquake vulnerability assessment" will undoubtedly be offered, one hopes by qualified firms. The same entrepreneurs and others will also most likely offer remodeling services intended to strengthen structures and lessen vulnerability. State legislation and local ordinances might be drafted to attempt to keep exploitative practices to a minimum. Public information campaigns can also be designed to provide households and individuals with information on how to verify the qualifications of such business services. Such information campaigns should be pretested to make sure that they are comprehensible and that they provide appropriate information.

A third set of responses may involve attempting to spread the costs of loss mitigation measures or of potential earthquake damage over a larger base. Examples are calls for subsidized earthquake insurance available to

[10]These considerations suggest a program of research on this earlier period after the prediction. Laboratory experimental studies might be designed to study the different reactions to prediction messages containing varying amounts of information on appropriate early responses. Field studies on responses to actual predictions might be focused profitably on the immediate postprediction period.

residents or for standby legislation providing relief and rehabilitation expenditures. Obviously, such moves are largely political, since they involve the use of government authority and the change or reinforcement of government policy. Equally obviously, most people cannot by themselves take such steps to mitigate losses. Such reactions imply the existence of collective actions involving joining with others in political movements.

Political entrepreneurs—persons seeking to strengthen their political followings or to develop such followings—can be expected to find in these issues opportunities to expand their followings. Public officials with the responsibility for issuing or certifying earthquake predictions will most likely try to neutralize this area as a source of political issues by attempting to co-opt their political opponents. While such moves may take the predictions out of the arena of normal state and local politics, this action may provide the opportunity for nonestablishment groups to obtain followings. Neighborhood associations and coalitions of neighborhood associations might become especially active, along with splinters from the radical right and left. Of course, the mass media, ever alert for newsworthy items, will provide free publicity for such political entrepreneurs.

A fourth set of reactions is also political in character, but here the attempt is to control through collective action the indirect effects of earthquake prediction. Movements to strengthen ties to a locality, to attract new residents to an area, to lower turnover rates in residents and real property, or to convince businesses and factories not to relocate elsewhere are all examples of participation in movements of this sort.

One can expect that local civic organizations that specialize in noncontroversial community issues will attempt to provide leadership of this sort. Campaigns to strengthen attachments to the locality will undoubtedly appear to be appropriate for Kiwanis and Rotary clubs, chambers of commerce, local councils of churches, social agencies, and the like.

A fifth set of reactions involves leaving the locality of presumed risk, or not moving into it. Decisions by outsiders not to move into the locality can be devastating.[11] A drastic decline in in-migration could easily lead

[11]Obviously, property values are maintained by having some degree of correspondence between a body of buyers and a body of sellers, just as the population stability within a locality is maintained by an appropriate balance between out-migrants and in-migrants. Indeed, a community can easily go into population decline by experiencing a steady out-migration rate and a decline in in-migration that would supply replacements for those who have left. In this connection, the study of the diffusion of information and rumor outside the area affected by an earthquake prediction is of interest. For example, it would be useful to know what Bostonians (and persons from other U.S. cities) believe about earthquakes in the San Francisco area.

to an equally drastic decline in sale prices for homes or rents for rental units.

The actions described above involve specific adjustments by households and businesses. One may also consider reactions involving stress symptoms, anxiety, fears, and the like. It is easy to imagine that persons who are currently struggling with a high level of anxiety might react to an earthquake prediction by becoming more anxious or that the prediction could play a role in the fears of persons who are currently suffering from psychological impairments of some kind.[12] More important, however, may be the impact on the mental health of individuals who have been functioning normally. Whether worries, fears, and anxieties arise from anticipation of the earthquake itself or indirectly from anticipated disruptions of community, job, or some other valued aspect of the locality cannot be clearly predicted in advance, nor is it clear that such changes are to be expected at all. Research on the effects of earthquake predictions should monitor this area of human behavior as well.

Finally, we may consider the appearance of other types of collective phenomena. Existing associations—for example, neighborhood associations and churches—can be expected to become concerned with the prediction and to attempt to rally their members around whatever issues arise. One may also expect that new organizations whose existence centers on the prediction may arise. For example, a religious sect may announce that the coming earthquake has some apocalyptic significance and thereby attract attention and new members.

Of the responses outlined above, some are mutually exclusive—obviously, one cannot move out of the area and do nothing simultaneously—but even those that are mutually exclusive can be undertaken sequentially. Thus a household's initial response may be to do nothing, but it may take action later on. Other responses can be carried on simultaneously. While preparing to sell one's house and leave, an individual may also join neighbors to petition public officials to strengthen local public school buildings. In short, responses may be multiple, and they may vary over time.

Nor is it reasonable to expect all people to react in the same way. Their circumstances vary in ways that can affect their responses, a topic we shall take up in detail later.

The uncertainty of response to earthquake prediction is of considerable policy concern. Untoward, dysfunctional responses that subject a locality to unacceptable losses may be minimized by appropriate policy measures

[12]This possibility suggests a research strategy in which persons under psychiatric treatment are monitored for the effect of the prediction on the course of their treatment and on the symptoms they display.

and constructive, functional responses from others. Of particular importance are policies on how the prediction is issued and what kinds of information it provides.

THE ROLE OF INFORMATION IN INDIVIDUAL AND HOUSEHOLD RESPONSE

Given an earthquake prediction, it can be anticipated that individuals and households will seek to gather information. Of course, the media and public officials will respond. Experts will be interviewed and asked for their assessments of the prediction and its consequences; citizens will be asked what they believe and how they intend to react; surveys of the sort we suggest will be undertaken (with considerable pressure placed on researchers to reveal results as quickly as possible); public officials will issue statements and will be asked for statements; and so on.

The information people seek may be viewed as falling into three categories: information on the meaning of the prediction, information on appropriate responses to the prediction, and information on how others are reacting to the prediction.

It will be especially difficult for people to get unbiased information from personal contacts. Since we can expect social networks to be partial in their coverage of major population types in a locality, the information gathered by a household will conform primarily to the responses of its own subgroup. People are more likely to know about the reactions of others like themselves—those of the same socioeconomic level, neighborhood, and age group—than about what the full range of the local population thinks. To some extent, such partial information can be supplemented by the mass media, but direct personal contacts still tend to be more credible.[13] Thus the knowledge that several neighbors are selling their houses may be persuasive evidence of out-migration despite assurances from the mass media that few families are leaving.

We can expect that the extent to which different people seek information will vary, as will the efficiency of the search and the quality of the information obtained. This variation will depend in part on the same individual characteristics that condition other responses to earthquake prediction. The next section of this chapter takes up those differentiating characteristics in detail.

[13]Indeed, it is the great persuasiveness of interpersonal influence that accounts for the ability of political candidates to win victories when the mass media have strongly favored their opponents.

FACTORS DIFFERENTIATING HOUSEHOLD AND INDIVIDUAL RESPONSES

If we have learned anything about human behavior through empirical field research in the past 30 years, it is that although such behavior is variable, it usually follows certain patterns. The circumstances in which people find themselves, their intelligence, their social attitudes, and the ways in which they are connected to other people all can be expected to affect how they perceive, understand, and respond to problems. There is no reason to think that facing an earthquake prediction will be different.

We have classified the factors differentiating households and individuals into two broad categories: (1) stake in the locality and (2) resources with which to gather information and respond to a prediction.

STAKES

The concept of "stake" covers household or individual "investments," broadly conceived, in the locality for which an earthquake is predicted. Investments encompass possessions, attachments to persons, organizations, and social networks, and even less tangible conditions such as "community standing" that require expenditures of time, effort, and other resources to acquire. The investments of particular concern here are, of course, those attached to locality that either could not be separated from locality or could be moved only with great difficulty or loss. The most obvious stakes are economic, but noneconomic stakes may be just as potent in affecting reactions to an earthquake prediction.

Real property ownership is a primary economic stake. Nationally, about three out of four households own the dwellings they occupy. The stake represented by an owned dwelling consists of the equity invested in the house and the obligations represented in mortgages and other liens on the property.[14]

Some households also own rental property. Most dwelling units offered for rent are owned and managed by persons who own fewer than three such units. Outside the major metropolitan areas, there are few major landlords who own or manage many dwelling units. The usual pattern of renting is for a household to own a two-apartment building, one unit occupied by the owner and the other by a tenant. In addition, of course, there is real property rented out to businesses and industries. Although households holding business rental properties are only a small proportion of property owners, their economic well-being and their strategic

[14]Close to 85 percent of the dwellings occupied by owners are mortgaged to some degree. See Bureau of the Census, *Annual Housing Survey: 1975,* 1977.

involvement in public affairs provide them with considerable influence on community actions.

An earthquake prediction threatens the real property stake of owners in two ways: The earthquake itself might damage the building, and the announcement of the prediction might lower the market value of the property, either by increasing supply or lowering demand. Of course, the owner need not realize a loss if he chooses not to sell his house. For those who have to put their houses on the market for reasons other than fear of earthquake, declining real estate values may mean an actual loss.[15] Even if they do not sell, property owners may still feel deprived of the full value of their property, since drops in value may hinder their ability to move or to obtain financing for repairing or strengthening the structure. For those who own rental properties, a drop in rental prices can be quite serious and quickly felt. Landlords suffer drastic losses in income when units remain vacant and hence can be expected to be particularly sensitive to market fluctuations.[16]

For these reasons we can expect those who own real estate to be especially attentive to news concerning earthquake predictions and to seek out information on the meaning of the prediction and on what other people are doing about it. We can also expect such persons to support public policies that distribute losses widely and that discourage abandoning the locality.

Employment is another type of economic stake. Businesses can move away to avoid losses or reduce activity to draw down inventories; customers may seek other, more reliable sources of supply or avoid a store because of possible injury. The actions of firms under an earthquake prediction are discussed in greater detail in a later chapter. What is relevant here is that an earthquake prediction may threaten a person's job.

The ease with which people can replace their jobs with equivalent positions elsewhere affects their stake in the locality. Those who are largely dependent on the locality for customers—e.g., doctors, public officials, lawyers, retailers—have high stakes there. Like landlords and property owners, people in these jobs can be expected to be especially alert to information about the prediction. In contrast, those whose occupations

[15]Loss would have to be computed with respect to the expected value of the unit if an earthquake had not been predicted.

[16]This is especially serious for landlords who rent one or two units. A vacancy means the loss of revenue of 50 or 100 percent, whereas a high vacancy rate for owners of large numbers of units may mean a much smaller drop in the percentage of rental income. For this reason, land economists think of the small landlord as loss minimizers rather than profit maximizers.

allow them to find jobs easily in other localities have a lower stake in the area covered by an earthquake prediction.[17]

Other assets constitute a third type of economic stake. Savings bank depositors have a stake in the local real estate market, since their banks are ordinarily the largest source of mortgage money. Although such deposits may be insured under federal or state insurance schemes, the failure of a savings bank does not mean that depositors will immediately receive their funds. Liquidation of assets and processing insurance payments often takes many months, clearly jeopardizing the liquid capital of depositors. Investments in local businesses or municipal bonds may represent other assets whose value might be threatened by an earthquake prediction. Ordinarily, only a small proportion of households hold assets in the form of investments and bonds, but a much larger proportion have savings accounts.

The noneconomic stakes individuals have in a locality may be just as important as the economic ones but harder to measure. To begin with, friends, relatives, and other personal contacts can be of considerable importance. Such ties may consist of simple social contacts, or perhaps of stronger patterns of mutual aid and support. For those who have grown up in a locality and lived there many years, no substitution for these relationships exists.[18] We can therefore expect that those who are part of such networks will want to learn about earthquake predictions and to make responses that tend to preserve their ties. It should also be noted that persons in such networks may be provided with a considerable amount of information thereby.

A second kind of noneconomic tie may be local social status, of a type unavailable elsewhere. To be a doctor in a small town may mean very little in the national ranking of doctors and their specialties, but to be any kind of physician may be very important within that town. Similarly, to be known in one's neighborhood as a hardworking, honest person may be the outcome of years of residence—a reputation difficult to achieve as a stranger in some other community.[19] Obviously, status would be more important as a stake in an independent community, where jobs and residences are both present, than in a bedroom suburb.

[17]It should be noted that older workers, women, blacks, other minority members, and workers with physical or mental disabilities would have a stronger stake in the locality where they already have a job than other workers in the same occupations.

[18]At least one observer has noted that those displaced by urban renewal projects show a set of symptoms similar to bereavement. See M. A. Fried and P. Gleicher, "Some Sources of Residential Satisfaction in the Urban Slum," *Journal of the American Institute of Planners,* vol. 27, no. 4 (1961), pp. 305–316.

[19]This is apparently the reason few workers beyond the age of 40 take up transfer offers when industrial plants are relocated in another community.

A third type of noneconomic stake may be associated with the life cycle stage of the household. As a household progresses from marriage, to the stage of childbearing and child rearing, to a period when the older couple are once again without children, to the final dissolution through death of one of the partners, the household's dependence on the locality changes. In the earliest stages, households are perhaps least locality dependent (this is the period of highest migration rates); the period of highest dependency would be the stage when children are attending school and mothers are relatively closely tied to the housewife role. While the post-child-rearing period appears to involve a lessening of community dependence, other factors come into play, especially the networks and social status considerations mentioned earlier.

Stakes tend to be interrelated. For example, homeownership is related to the holding of other economic assets and reaches a peak in the child-rearing period as do ties to networks of friends and neighbors. Hence stakes tend to accumulate and reinforce each other.

RESOURCES

A family's resources can also be expected to affect its responses to an earthquake prediction. Clearly, some of the stakes discussed in the preceding pages can also be counted as resources, depending on their liquidity. Thus the same household characteristic may be either a resource or a stake, depending on how bound it is to the locality.

Income and wealth are perhaps the most important of all resources. The loss of a dwelling or its decline in value may not mean as much to a wealthy household as it would to a household whose entire wealth is bound up in its home. For economic resources and stakes it may be the ratio of the amount of money invested in the locality to total wealth that matters. Wealth or income independent of locality is obviously less threatened by either an earthquake or a prediction.

Occupational skills that are easily transferable or in demand in other localities represent a resource that in a sense liberates the household from the impact of a prediction or an earthquake. These economic resources provide the individual or household with the ability to absorb the impact of a prediction or to avoid its consequences entirely.

Other types of resources, primarily noneconomic, also help. As already noted, intelligence enables a person to absorb more information more accurately concerning earthquake predictions. Thus we may expect people with high levels of formal education (a proxy for cognitive skills) to respond to the predictions more intelligently than will less well-educated persons.

Personal health may also be regarded as an important resource. The energy available to individuals, their mobility, their span of attention, and other physical conditions all affect individual abilities to cope with change. The ability to deal with earthquake predictions should be no exception.

DESIGNS FOR RESEARCH ON HOUSEHOLDS AND INDIVIDUALS

The preceding sections suggest the following research. First, since we expect that reactions to predictions will vary according to the nature of the predictions issued, it is clear that we learn more by observing a number of predictions than by studying only one, even if it is the first one. However, since it is unlikely that many different types of predictions will be issued within a short period, it may be best to simulate them under controlled conditions and observe how credibility varies with the nature of the prediction and the authority issuing it. Such research may be carried out under laboratory conditions or in a field survey based on hypothetical events. It may be quite productive to ask people to rate or rank the credibility of a number of different predictions, describing the issuing authority, the scientific credentials of the persons making the prediction, the degree of consensus in the scientific community, and the nature of the prediction itself (time window, probability, magnitude, etc.). Of course, no description of a prediction can capture the circumstances that would accompany the real thing. Hence research along these lines can at best yield only very rough approximations of actual situations, where the effects of mass media and social networks may be very strong.

Second, we expect that after the initial announcement the reactions to a prediction will change with the passage of time, for several reasons. The prediction itself may change; issuing authorities may expand on it, and countervailing predictions may be issued by other experts. Furthermore, people can be expected to gather information in the aftermath of the prediction and to yield somewhat to the climate of opinion characteristic of their social groups. Therefore, learning that a company is leaving town may render the prediction more believable than will merely learning that a group of scientists have endorsed it.

These considerations obviously call for longitudinal research in which people are studied at intervals after the issuance of a prediction. It is not clear, however, what the intervals should be, nor whether a panel design (in which the same households or individuals are studied over time) or repeated cross sections should be used. Panel designs are relatively expen-

sive and difficult to execute, but cross-sectional designs are statistically less efficient in detecting changes.

Third, the research design should compare localities. Localities vary in socioeconomic mix; they may be urban, suburban, or rural; they may be relatively independent or closely interlocked with the surrounding area; and their social networks can vary in cohesiveness—for all these reasons, responses to earthquake predictions should vary accordingly.

Finally, although there are some mechanical advantages to assigning equal probabilities to each population unit sampled, a more efficient sampling strategy may be one that maximizes the variance in pertinent characteristics. Thus if we expect households to vary mainly according to the stakes they have in the local community, then it makes sense to oversample high-income people, since only a few will appear in the equal probability sample. Furthermore, high-income households are likely to have breadwinners who manage or own significant business enterprises—persons whose reactions to earthquake predictions are therefore of special interest.

The next chapter takes up the questions of how such business firms may react to earthquake predictions and what the corresponding effects may be on local and regional economies.

4 Economic Consequences of Earthquake Predictions: Business Firms and the Regional Economy

Some people express concern that earthquake prediction will result in severe economic disruption. Others counter with the assertion that predictions will go unheeded. Will businesses strengthen their workplaces and meet commitments to those who rely on them for products and employment, or will they attempt to avoid the threat of damage by moving outside the forecast vicinity? How much flexibility will they have in choosing courses of action? What other factors will limit their behavior? At a broader level, what are the possible effects of predictions on housing, employment, and capital markets? How will the regional economy respond? We cannot now predict with confidence what will actually occur; rather, the purpose of this chapter is to provide the theoretical foundation for the study of these and related questions.[1]

It is tempting to view the economic consequences of earthquake predictions from an equilibrium perspective, that is, to assume that a prediction disturbs the normal patterns of trade within a region but that a new equilibrium will eventually emerge. But by looking only at the beginning and the end we will ignore the behavioral dynamics of the transition. The material to follow tries to avoid this pitfall by placing considerable emphasis on what happens during the period of disequilibrium and by measuring the consequences that follow.

[1]Useful background information for this chapter is contained in the report by the Panel on the Public Policy Implications of Earthquake Predictions of the Advisory Committee on Emergency Planning, *Earthquake Prediction and Public Policy,* chap. 8, "Economic Implications of Earthquake Prediction," pp. 67–80.

The chapter is divided into four parts. A discussion of business firm behavior serves as a point of departure and covers the range of adjustments open to firms and the internal and external organizational conditions likely to influence those adjustments. The second section reviews the role of markets in economic adjustment processes, and the third offers methods for understanding how the combined choices of firms translate into regional economic consequences. The final section outlines specific research topics that emerge from the material in the preceding sections.

BEHAVIOR OF THE FIRM

Chapter 2 discussed in a general way the determinants of the adjustment behavior of individuals, households, firms, and governmental agencies. Given that these responses are influenced by the characteristics of the earthquake prediction, the relevance of the following discussion of business behavior is obviously greater for longer-range predictions than for short-term ones.

ADOPTION OF ADJUSTMENTS

Building on the discussion of adjustments found in chapter 2, we note that responses by the business sector range from active measures aimed at insulating the individual firm from events surrounding it to the passive alternative of doing nothing. Thus an industrial organization may respond by strengthening buildings, depleting inventories, diversifying production activity, or seeking insurance. Banks may reduce the number of mortgages at risk. Insurance companies may restrict or increase earthquake insurance sales. All these firms may formally evaluate predictions with their own resources, perhaps for purposes of countering official predictions. Each of these responses represents active attempts to mitigate expected damage from earthquakes or economic disruption resulting from the prediction. At the other extreme, firms may respond by simply ignoring the threat and doing nothing about it. The choice of active or passive responses rests ultimately on a complex set of forces.

The nature of the prediction and information about alternative courses of action will be of fundamental importance. But perhaps equally relevant are the economic and human capital (stakes) the firm has invested in the community. For example, if a corporation has fixed assets in the community and no way of moving or liquidating them, active responses will require other forms of protective action. Conversely, large and

highly diversified companies will have an advantage in the number of options open to them because their human and material resources and range of operations provide them with considerable flexibility.[2] Thus the choice of adjustments is obviously influenced by the impact on the firm's capital value. The predicted event will either damage physical capital (structures and production equipment) or interrupt the flow of income. Either occurrence will diminish a firm's capital value, and the firm will probably try to find ways of combating the loss. By comparing capital losses due to the predicted quake with the loss caused by making adjustments, the firm can select the strategy least threatening to its survival.[3]

The location of a business's primary market influences the way it adjusts. A restaurant whose market is confined generally to the immediate community has most of its capital value tied up in its local reputation; therefore it is likely to stay in the area. Nationally recognized restaurant chains, however, are much less affected by local reputation and hence are more flexible. Finally, the concept of capital can also be extended to the firm's work force—in this relocation example, it includes the degree of specialized knowledge the employees contribute to the organization. Assembly or service tasks requiring only common skills can readily be shifted. If, however, the work force consists of professionals with skills essential to the functioning of the entire operation, then a decision to move is strongly influenced by the choice of the work force to stay or leave.

The above example illustrates the role of stakes in influencing firm behavior. Knowledge of stakes, of the nature of the prediction, and of the alternative courses of action available is a starting point for a description of business behavior. But there are many other facets of adjustment behavior, several of which spring from sociological perspectives about organizations.[4]

[2]A productive enterprise with its capital firmly "riveted to the earth" will not be able to modify its losses by moving to a more secure region. There is no way that a small steel firm could profitably move its furnaces and coke ovens; the high cost of relocating is sufficient to eliminate such an option from serious consideration. However, a small final assembly plant with a routine set of tasks can readily shift operations elsewhere. This option would be even more attractive if all equipment and work space were leased annually.

[3]This search process has been stated in a somewhat positive tone, but business decision making may not be quite so rational. Yet the survival of profit-making organizations often hinges on their ability to adjust to new environments, so such a description may not be unreasonable.

[4]This point has become axiomatic in the literature on organizations. See, for example, March and Simon, *Organizations;* P. M. Blau and R. W. Scott, *Formal Organizations,* 1962; R. M. Cyert and J. G. March, *A Behavioral Theory of the Firm,* 1963; and A. Etzioni, *A Comparative Analysis of Complex Organizations,* 1976.

ORGANIZATIONAL CONDITIONS

Organizational behavior involves decision processes and networks of social relationships. Adjusting to a prediction involves a complex interplay of formal (administrative control) and informal (power and bargaining) processes within and between interdependent organizations. These processes are admittedly difficult to document empirically, but assessing them is important for explaining patterns of adjustment behavior. In effect, business firms are not free to behave as they wish, regardless of need. The fixity of capital has already been suggested as one factor that limits a firm's ability to adjust to hazards. There are others, both internal and external.

Internal Conditions The internal structural characteristics of a business influence its behavior. By structural characteristics, we mean activity patterns—both the formal division of labor (task and control structures) and the informal social arrangements that invariably emerge. These patterns define and limit the firm's basic functioning.

The important empirical requirement is to determine the regular basis for organizational action. How does the firm normally produce a product or provide a service? How does it monitor its environment? How does it process new information? Although some organizations are more adaptive than others,[5] all have a tendency to respond to new situations in terms of established routines.[6] If that fails, of course, innovation is required; but even then, the link to previous practice is never totally severed.[7] Thus if we want to account for the readiness to seek and use information about predictions and possible responses, we must examine the structure of business activity.

For example, a firm with very rigid work roles and procedures may be less able to have its staff take on new assignments, such as assessing the consequences of earthquake predictions, than will a firm that is more flexibly organized. The speed with which a firm responds therefore will be directly related to its flexibility in work roles and procedures. Routine patterns of decision making in the firm will also strongly influence adjustments. Some firms have established patterns of deliberation at vari-

[5]For a review of the literature on organizational innovations, see G. Zaltman, R. Duncan, and J. Holbek, *Innovations and Organizations,* 1973.

[6]See T. Burns, "The Forms of Conduct," *American Journal of Sociology,* vol. 64 (1958), pp. 137–151.

[7]This point is made with regard to disaster behavior by G. A. Kreps, "The Organization of Disaster Response: Some Fundamental Theoretical Issues," *Disasters: Theory and Research,* 1977.

ous hierarchical levels. The options to be considered tend to proliferate in such a structure, and decisions to adopt adjustments will probably be made slowly. Once adjustments have been determined, however, their implementation may be expedited because of the active involvement of people throughout the organization in the decision-making process. Other firms have highly centralized systems through which decisions can be made more quickly. Adoption of a policy, of course, does not guarantee rapid implementation; this is a special example of the general problem of organizational control.[8]

The organizational structure of a firm cannot be discussed as if it were distinct from the people who comprise it, particularly when the problem is about decision making under conditions of uncertainty. Those persons that routinely serve as links between the firm and the general social environment are likely to be gatekeepers of information about earthquake predictions and responses. Previous research suggests that what such people know enhances their influence on organizational decision making, even to the extent of allowing them to transcend their position in the firm's hierarchy.[9] In general, it is clear that human skills vary from one organization to the next and that variation affects a firm's ability to cope with changing circumstances.[10]

Finally, material resources are an obvious determinant of organizational action.[11] Some companies may have a full year's operating budget totally committed at the time a prediction is issued, whereas others have flexible financial reserves. Profit margins vary. The existence of some financial slack allows a firm to spend money on gathering information and responding to a prediction.

To summarize, the structural characteristics and human and material resources are the internal conditions that will affect the degree to which a business assimilates earthquake prediction information, the range of adjustment options it considers, and the speed with which it acts on its adjustment decisions.

External Conditions The firm's environment also plays a role. Again, the research problem is to document structural patterns—in this case the degree of interdependence between the firm and its market, the various

[8]See A. S. Tannenbaum, *Control in Organizations,* 1968.

[9]See, for example, H. Wilensky, *Organizational Intelligence,* 1967.

[10]See, for example, T. Burns and J. M. Stalker, *The Management of Innovation,* 1961.

[11]See, for example, P. White, "Resources as Determinants of Organizational Behavior," *Administrative Science Quarterly,* vol. 19 (September 1974), pp. 366-379.

governmental and legal structures that control it, and the private groups and organizations that impinge on its activities.[12] Businesses vary in the extent to which they are subject to government regulations, in their dependence on other organizations for sources, in their vulnerability to local public opinion, and, of course, in their need to respond to local markets. In other words, firms operate within complex social, economic, political, and legal relationships that may affect their responses to earthquake predictions.

In discussing such relationships, it is important to note that businesses are not simply passive agents that adapt to changes in their environments; they are also aggressive social actors capable of altering external conditions. Any successful firm or corporation is skilled at both adaptive and opportunistic behavior. We suspect that a long-term earthquake prediction will result in significant social disruption, which may very well lead to opportunism by highly aggressive businesses. Thus there may be attempts to increase profits rapidly, to increase shares of markets, to reduce government controls, and, more subtly, to increase social and political influence.

It has been argued that a complex business environment makes managerial decision making costly in several ways. First, it may be difficult to plan for an adequate supply of intermediate products. Second, it may be difficult to procure capital if the lender needs information that the borrower may not want to reveal. Third, the organization may be vulnerable to opportunism, especially if there are few suppliers or competitors. Such opportunism by other businesses may take the form of empty threats or promises, or, more seriously, strategic manipulation of information and misrepresentation of intentions. Contracts could theoretically be negotiated to cover such contingencies, but the costs of enacting them would be great. A traditional alternative has been for firms to eliminate many

[12]Although interest in organization-environment relationships is relatively recent among organizational analysts, the matter is being given increasing research attention. In fact, some analysts argue that conditions outside organizations are primary determinants of organizational behavior. See, for example, the following: F. E. Emery and E. L. Trist, "The Causal Texture of Organizational Environments," *Human Relations,* vol. 18 (February 1965), pp. 21–32; W. Evan, "The Organization-Set: Toward a Theory of Interorganizational Relations," *Complex Organizations and Their Environments,* 1966; S. Terreberry, "The Evolution of Organization Environments," *Administrative Science Quarterly,* vol. 12 (March 1968), pp. 590–613; H. Turk, "Interorganizational Networks in Urban Society: Initial Perspectives and Comparative Research," *American Sociological Review,* vol. 35 (March 1970), pp. 1–19; R. Corwin, *Reform and Organizational Survival,* 1973; R. N. Osborn and J. Hunt, "Environment and Organizational Effectiveness," *Administrative Science Quarterly,* vol. 19 (June 1974), pp. 231–244.

of these uncertainties by integrating both horizontally and vertically.[13] By bringing suppliers under the corporate umbrella, for example, information distortion is reduced, predictable sources of supply secured, internal prices guaranteed, at least in the short run, and financial resources amassed.

The degree to which firms can minimize these transaction costs is, of course, determined by the nature of their economic activity, their internal structure, and the organizational makeup of the surrounding business community. Conglomerates and holding companies are a common response, even during periods of relative quiet. Under the disruptive influence of an earthquake prediction, existing economic uncertainties may worsen, thus encouraging the growth of such organizational arrangements. In a region where a substantial amount of business conglomeration has already occurred, the prediction of an earthquake may engender only slight changes in market conditions. But in areas where small, independent firms predominate, the same prediction may provoke substantial fluctuations in prices and incomes. Hence the potential for market disruption is likely to be governed by the preprediction structure of business activity.

Public policy should be sensitive to market conditions but not misled by them. Thus an accelerating sense of uncertainty in the private sector may result in the emergence of new organizational arrangements. In one sense these arrangements should not be viewed with alarm; they are efficient institutional solutions to such problems as high transaction costs. Yet markets may convey inaccurate information as a result of problems of information processing or of the existence of integrated firms with an internal pricing apparatus invisible from the outside. The general point is that the advantages of public policy versus solutions from the private sector should be carefully evaluated.[14] Businesses affect each other, the public, and the government. The importance of any firm in the general scheme of things depends to a great degree on rational economics. Analysis of regional interdependencies is therefore crucial for assessing the socioeconomic effects of earthquake prediction.

[13]For a discussion of these issues in the economics literature, see O. E. Williamson, *Markets and Hierarchies, Analysis and Antitrust Implications: A Study in the Economics of Internal Organization,* 1975. For a discussion of these issues from the organizational literature, see J. D. Thompson, *Organizations in Action,* 1967.

[14]Admittedly, social scientists have just begun a comparative study of institutional structures, with markets as one means of accomplishing given ends. The normative issues inherent in such research are not readily resolved analytically. It is clear that economists are generally hesitant to sacrifice market forces for other institutional arrangements, except where problems of equity are at issue.

THE ROLE OF MARKETS

Markets embody and reflect economic processes generated by earthquake predictions and thereby convey information that shapes the adjustment behavior of various economic actors.[15] Of course, market information may be an unreliable guide, especially if it reflects economic actions prompted by imperfect information concerning the earthquake or the actions others are contemplating.

Economists have long argued that market prices and incomes convey information about the extent to which consumers value different products and how costly the products are to make. This is not to suggest that the market would be an accurate record of a rational business response to an earthquake prediction. For example, the price of housing may plummet far below what a realistic assessment of damage would warrant. Prices are composites of many individual choices. If such choices are not based on accurate information—as in the case of panic selling—then market prices do not reflect an awareness of the true picture of loss. Of course, a lack of recorded change may indicate that homeowners are operating under a normality bias. As of now it is not known whether overreaction or underreaction is most likely. There is some assurance, however, that the active search for information will be affected by price and income changes.[16] Social scientists are not yet sure how various markets will respond to earthquake predictions, nor are they sure how the resulting market effects (prices and incomes) will influence public reaction. Much depends on the results of the research recommended in this report. Some reasoned speculation as to how important markets will fare follows.

HOUSING

It is likely that the housing market will reflect estimated losses at an early stage. For example, if one could be assured that property damage would not exceed 10 percent of a dwelling's value, then it seems unlikely, at least from the standpoint of damage alone, that housing values will drop

[15]Most individuals are likely to learn about an earthquake prediction from impersonal sources such as the mass media. Some will then search for more data on the prediction. The literature on innovation suggests that the adoption of adjustments, if it occurs, will be confined initially to this relatively small group of individuals and firms. As knowledge about their behavior spreads, similar or different adjustments may be adopted rapidly by others. For a thorough review of the subject, see E. Rogers and M. Shoemaker, *Communication of Innovations,* 1971.

[16]Much of the decision-making literature assumes that once people are aware of a problem they will actively seek out information about the losses and range of feasible adjustments. Thus even though a person may ignore an earthquake prediction, he may not be immune to a decline in the value of his home or to the notice of an impending layoff.

by more than 10 percent. This drop mirrors the decline in value that occurs after the event. The only difference is that with a prediction the market is reacting to an estimate.

Several factors may induce a decline in excess of that which reflects a realistic set of losses. First, the imagined damages may be much in excess of those warranted by the prediction. Second, buyers may be scarce because of diminished job opportunities in the forecast region or because of reluctance to move into the area. Although the average damage expected is 10 percent, a few structures will be totally destroyed. And since most individuals cannot self-insure, the problem of risk will influence selling prices. This potential decline may, however, be a temporary phenomenon. Once the event materializes and the damages are repaired or once the threat is past, values could approach that of the predisaster trend (see Figure 2a).

This speculation hinges on a few plausible assumptions. First, the prediction does not permanently impair the regional economy. Second, the earthquake or threat of an earthquake will render many existing structures—older apartment buildings, for example—uninhabitable. The resulting tight supply along with a steady demand should buoy housing values after the quake. If either assumption proves false, then housing values may stay depressed. Under a peculiar set of circumstances—that

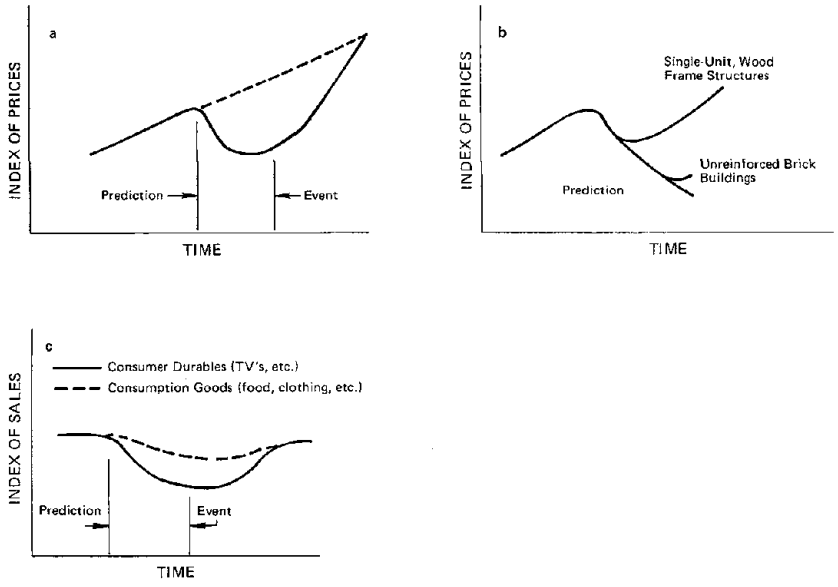


FIGURE 2 Probable response of different markets.

is, if employment in the region increased after the event at the same time older structures were designated unsafe—values may even recover and surpass the preprediction values.

Related to this last point is the likelihood that values will fall in a very uneven fashion in the postprediction period, because some classes of building are less susceptible to damage than others. Single-unit, wood frame dwellings are by far the safest, while unreinforced brick apartments are the most susceptible to collapse. The market may eventually reflect this information as shown in Figure 2b. Unreinforced structures will most likely lose value in comparison with wood frame houses.

EMPLOYMENT

Other markets will also reflect estimates of loss, but these changes are more complicated than are those of the housing market. There is a good indication that certain types of disasters generate substantial secondary effects for local and regional economies. Recent severe winters in the Northeast and the 1977 Johnstown Flood are sufficient reminders of this. Disruption of sensitive productive sectors will cause unemployment not only for those immediately affected, but also for industries that rely heavily on the impact area for their source of supply. If, for example, the semiconductor industry in San Jose, California, were decimated, it could be a matter of *years* before the supply of semiconductors could be fully reestablished. Supply shortages would be quickly felt by electronics firms that use semiconductors in production. Without these ingredients the output of intermediate and final products would decline. Employment would fall, both in these electronics plants and in other plants that use their products.

In some ways, businessmen would realize the potential for such a cascade of effects, and layoffs and declining business values might ensue. There is some reason to believe, however, that unemployment will exceed what the anticipation of disaster-induced dislocations would dictate, because firms must contend with adjustments to the physical elements of the hazard as well. For example, people might postpone buying durable goods. This action would diminish damage sustained after earthquake, but it would also diminish sales before the earthquake.

Such a recession could be only a temporary one (at least for some industries), however, and it could be followed by a boom, fueled by abnormally high levels of savings. This potential, combined with the damages generated by the quake, could further stimulate demand for durables in the postquake period. Sales then could reflect the trend shown in Figure 2c. One could argue that over the entire time span, aggregate sales will probably be uninfluenced by the prediction. This is

not to say that the drop and rise shown would not lead to problems; marginal businesses would most likely fail under such pressure.

Analysis of the traditional unstructured labor market will provide only a partial explanation of what happens to labor during the adjustment period. Just as businesses tend to internalize transaction costs, job training is increasingly tailored for the specific task and firm. Such training has the advantage of discouraging turnover and reducing the costs of coordinating highly specialized departments. Given that this kind of training is time consuming, however, it is unlikely that firms relying on it will be quick to lay off their workers. If any cuts are made, they will tend to be peripheral. In summary, employment effects will be governed by an amalgam of forces, related both to the unstructured labor market and to the organizational makeup of the predominant firms.

CAPITAL

A prediction could influence the market for capital even more than the other markets. As suggested earlier, an uncertain business environment makes managerial decision making generally more costly, and this uncertainty would be compounded in the wake of an earthquake prediction. In the case of capital markets, the availability of external financing for firms would decline under such conditions. In general, banks and other lending institutions are hesitant to make long-term capital commitments when price changes cannot be anticipated. Recent concern about inflation illustrates this point. Because an earthquake prediction will probably increase uncertainty about future prices, a shortage of external finance capital may result.[17] Such a shortage would, of course, choke off investment for those firms that depend on borrowing for investment purposes. Organizations that have developed their own internal markets for capital can continue investing, if they want to.

ADJUSTMENTS VIEWED FROM A REGIONAL STANDPOINT

A perspective on organizational response remains just a study of *individual* adjustments unless some way is found to weave these responses

[17]It will be particularly difficult for service industries to obtain external financing. This is because the capital value of such firms is tied up in the skills of its managers. Since such human assets are highly mobile, a lending institution is generally reluctant to support concerns depending on such assets—a reluctance that would probably increase in a postprediction period.

into a pattern. The importance of any one decision can be measured only in relation to the whole. In fact, many of the responses cannot be known until the extent to which different organizations are interdependent is established. The environmental conditions mentioned above and a firm's market hinge on such relationships.

HOW THEN, WILL THE REGIONAL ECONOMY RESPOND?

The local economy will be reshaped as households and businesses adjust to the damage and disruption they anticipate. The depth and duration of this transition depend on such factors as shifts in buying patterns of both consumers and producers, possible relocation of businesses, and the ability of local governments to sustain revenues and services. Because the performance of the local economy is a key to the success of dealing with the earthquake prediction, it is important to estimate the economic links between consumers, producers, and local government. There are two methods by which this could be accomplished: by regional interindustry analysis or by regional econometric models that measure aggregate economic conditions. Each has its advantages, but before discussing them in detail we will first explain how these models can be used.

A basic question regarding which of the regional models is most suited to this problem is this: How much will the economic output of an area change if the mixture of final demands is somehow altered? The focus of interindustry work is on the links among industries—who ships what to whom and who demands how much of the final product? With these data, tables capturing the flavor of a region's economic interdependence can be constructed. Input-output tables, as the name implies, indicate how much of an industry's output is used as input to the production of other goods and services and how much is exported from the region or bought directly by consumers or government. By manipulating the data within the table, the impact of any change in final demand on a region's total output can be determined.[18] The total output change reflects not only the direct effects but all the indirect effects as well. That is, if final demand for housing shrinks as a result of a prediction, then not only will the output for housing decline but so will sales of lumber, glass, appliances, and other components related to new home construction. In turn,

[18]The total production of goods less those goods used in the production of other goods defines what remains for final consumption. In matrix form, $x-Ax=y$ (where x is total output, A is the input-output matrix, and y is the vector of final demands placed by households and government) $x-Ax=y$ is equivalent to $(I-A)x=y$. Solving for x, we see that $x=(I-A)^{-1}y$. $(I-A)^{-1}$ captures the direct and indirect effects on output of a change in final demand.

these reductions translate into diminished demand for inputs used by this expanded array of industries. The whole process, replete with feedback effects, is captured within the interindustry approach. An understanding of these interindustry links can translate the effects of an altered pattern of consumer or business behavior into an overall decline in business activity.

This piece of analytical apparatus links the adjustments described above to the social and economic consequences flowing from a prediction. Moreover, the approach gives some insight into how stakes may change during the preevent period as incomes and employment fluctuate in response to a stream of individual and corporate adjustments. Figure 3 illustrates these interactions.

The type of analysis suggested here begins with a regional interindustry table. The adjustments made by individuals and businesses alter the array of final demands placed on the region's productive and service activities.

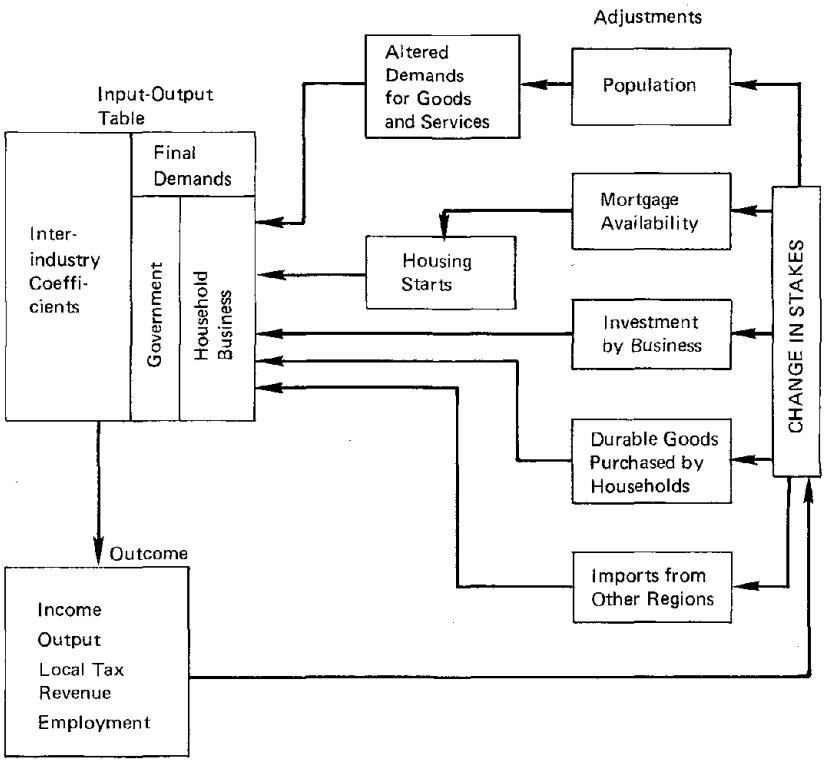


FIGURE 3 Interindustry analysis of economic response.

TABLE 2 Business and Income Multipliers for Selected Counties and Regions in California[a]

Region or County	Construction (General Contracts)		Trade (Wholesale and Retail)		Finance (Banking, Insurance, and Real Estate)		Services (Hotels, Auto Repair, and Personal Service)	
	Business[b]	Income[c]	Business	Income	Business	Income	Business	Income
San Francisco Bay region[d]	2.48–2.66	1.85–2.51	2.84	1.69	2.80–3.10	2.07–2.15	3.19–3.28	1.99–2.20
Santa Barbara County[e]	2.43	1.90	2.94	1.59	2.73	1.79	2.38	1.61
Lassen County[f]	1.75	—	1.98	—	1.52	—	1.77	—
Glenn County[g]	1.97	1.94	2.26	1.40	2.06	1.59	2.21	1.54
Santa Cruz County[h]	2.44	2.19	2.47	1.44	1.81	1.51	2.41	1.53

[a]The multipliers shown were obtained by vertically summing the Leontief coefficients for each region or county.
[b]Represents the direct, indirect, and induced change in regional output for a one-dollar change in demand for the sector indicated.
[c]Defined in the same way as the business multiplier; change in income, however, is the focus of attention.
[d]G. Goldman, unpublished table, 1977.
[e]L. T. Wallace *et al., Economic Impacts of Resource Use,* 1975.
[f]C. W. Rimbey *et al., Economic Impact of the Lassen College Community on Lassen County 1973–1974,* 1976.
[g]D. McLeod and G. Goldman, *Glenn County Economic and Resource Use Study,* 1975.
[h]E. Nickerson and G. Goldman, *Economic Impact Analysis: A Framework for Santa Cruz County,* 1976.

These choices translate into declines in local business activity, in income and employment, and in revenue collected by local and state governments. The extent to which these impacts are felt depends upon the following:

1. The altered buying pattern of households. What kind of purchases will be postponed?
2. The decision of businesses to reduce investment. Are inventories alone cut back, or will new capital expansion as well as routine replacement be curtailed?
3. The income level of those who decide to leave. Will the higher-income households with marketable skills opt to migrate, thereby depressing demand disproportionately within the region?
4. The altered export picture. Will firms outside the region shift to suppliers believed to offer a more secure source of product?
5. Decisions on the part of local businesses to relocate. Will businesses actually move out, and if they do, how much of the void they leave will be made up by those who choose to stay? How much of what was produced within the region must now be imported?

The answers to these questions will define the severity of any prediction-induced recession. It should also be apparent that the extent of the contraction in a particular area will depend heavily on the area's degree of self-sufficiency. Regions that import much of what they use from neighboring areas will find their economies less disrupted than will those regions that produce, process, and sell what they use. Table 2 suggests the variability that might be expected in different regions of California.[19] The numbers displayed are the direct, indirect, and induced changes to the value of the gross regional product and income, given a one-dollar change in the final demand.

As the table indicates, the change in final demand on the total production of goods and services can cause very different effects in different places. A $10 million decline in retail/wholesale trade on San Francisco's economy translates into a $28.4 million reduction in total activity. Yet a similar decline in trade in Lassen County would cause a contraction approximately one-third smaller, $19.8 million. Why is this the case? Lassen County, like many agriculturally based areas, imports much of what it consumes. Hence a change in final demand does not stimulate or dampen local employment in Lassen County so much as does a change in an urban area where the economic ties are more complicated. In the San

[19]The specific numbers in Table 2 are used only to illustrate the technique. No implication about future effects of earthquake predictions can or should be drawn from these numbers.

Francisco Bay economy, for example, imports still exist, but a higher percentage are semifinished. As a result, a decline in demand affects not only wholesale and retail trade but light manufacturing as well.

It is equally important to understand how local income and employment will respond to such changes. Government policy will be directed more toward the change in the income position of individuals than toward alteration in output. The second column labeled "Income" in Table 2 illustrates the sensitivity of local income to demand. If demand for residential construction, for example, declined in Santa Barbara County by $10 million, income would fall by $19 million. This reduction captures both direct losses in employment and indirect and induced losses. The indirect impacts stem from diminished purchases made by contractors for semifinished and finished products. The induced impacts occur because unemployment reduces household income; reduced household income results in less demand for consumer goods. Reduced consumer spending then sends ripples through the economy, swelling the numbers of unemployed even further.

If the federal government intervenes, the economic contraction just outlined will probably not proceed so far as the income and employment multipliers indicate. Unemployment insurance will, at least for a short time, buoy spending. If the area is recognized as a pocket of high unemployment, these payments can be extended for over a year. Studies conducted on the relationship between multipliers, both including and excluding this inducement effect, conclude that income changes without inducement are 65–78 percent of those with inducements.[20] If the Santa Barbara example is used, this means that income may fall by as little as $12.35 million to $14.82 million.

The regional model just described is equally useful in determining how different public programs would fare in stabilizing a crippled economy. For example, one could ask how much "predisaster repair" would be needed to counteract any decline in investment and purchases elsewhere. As shown in Table 2, the reduction in income induced by a decline in the purchase of durable goods referenced by the column labeled "Trade," is less than that occurring in construction. Hence a lesser stimulus would be required in the construction sector to offset any such shift in business and consumer spending.

Other possible policies or occurrences can be incorporated in an equally straightforward way. What would happen if out-migration was encouraged? What would happen if businesses were guaranteed a continuing

[20]See J. E. Bradley and J. P. Gander. "Input-Output Multipliers: Some Theoretical Comments," *Journal of Regional Science,* vol. 9 (1969), pp. 309–317.

market or if government contracts were to provide assurance to producers within and outside the region? These are only a few of the possible questions which could be answered with the approach sketched in Figure 3.

Interindustry techniques have just been highlighted, but as mentioned earlier, there are other approaches—econometric models, for example—that are potentially useful in forecasting how a regional economy will respond. A few of these are currently operational in California, namely, the University of California (Los Angeles) forecasting model and Hall and Licari's model of Los Angeles.[21] These approaches have at least three advantages over interindustry analysis. First, because in the econometric method many of the productive and service sectors are collected into a few categories, this method is a more manageable tool with which to work. Second, econometric models incorporate elements often missing from the other approach, such as wages, prices, and interest rates, to mention a few of the more important ones. Third, although this report does not compare the costs of different research techniques, it should be noted that interindustry input-output models may require the collection of substantial amounts of primary data. If this is the case, the costs of using these models will be much greater than those associated with aggregate regional econometric models. These advantages are somewhat counterbalanced by one significant disadvantage. The high degree of aggregation may make the tool less useful for gauging the economic consequences of earthquake predictions. The study of adjustments may focus on a disaggregated set of business activities, thus complicating the problems of combining results with this method of forecasting. The purpose here is not to select a strategy for the researcher but to indicate the need for some form of forecasting and to raise the advantages and disadvantages of the traditional approaches.

The economic processes measured by these techniques are partly affected by the institutional forces described earlier. Excess supply of goods gives rise to accumulating inventories, which in turn induce unemployment. In addition, markets will reflect in price changes the adjustments that individuals make. The movement of prices and incomes will reflect how the imagined event is being acted upon. The market for

[21]Others that have been developed include Philadelphia, Ohio, and Mississippi. For a discussion of the Philadelphia model, see N. J. Glickman, "An Econometric Forecasting Model for the Philadelphia Region," *Journal of Regional Sciences,* vol. 11 (1971), pp. 35–47. The Ohio model is discussed by W. L. L'Esperance, G. Nestel, and D. Fromm, in "Gross State Product and an Econometric Model of a State," *American Statistical Association Journal,* vol. 64 (1969), pp. 787–807. See G. F. Adams, C. D. Brookings, and N. J. Glickman, "On the Specification and Simulation of a Regional Econometric Model: A Model of Mississippi," *Review of Economics and Statistics,* vol. 57 (1975), pp. 286–298.

housing will be particularly sensitive to the image of loss. Whether these markets provide useful information to individuals or whether they complicate the adjustment process is not yet known.

To summarize, the prediction of an earthquake initiates a sequential choice process. If businesses do not view a disaster forecast as a significant threat to them, then no new strategies or adjustments will be forthcoming. If, however, some members of the business community perceive the threat of damage or economic disruption with a sense of urgency, then they will search for more information and ways to cope with that threat. Each region will respond according to the makeup of its productive and service sectors. Currently, it is not known whether a constructive or passive set of adjustments would be forthcoming. The most active responses are those which result in the reduction of loss potential by strengthening, relocating, or changing the makeup of production or service activities. Firms that do not have these options open to them may attempt to modify the threat by disseminating information that contradicts the prediction or they may attempt to spread losses among others. As adjustments are undertaken, a chain reaction is set in motion, growing in an exponential fashion as more and more individuals and social units are touched by the unfolding events. The depth and breadth of these impacts depend on the types of business activities in the forecast area.

Regions with considerable self-sufficiency (high multipliers) are particularly vulnerable to a prediction. This vulnerability is amplified if the production base operates on leased equipment, is not regulated, does not depend on specialized skills, and sells its products outside the forecast area. The economic and social health of such a community depends on the decisions of businesses to stay or leave. The policy options in such a situation are few; they revolve around financial incentives, public pressure, and regulation. The choices of households in this situation are of secondary importance.

At the other extreme there are regions like the farmbelt areas that are dependent upon activities that are not movable. Rural economies are almost entirely dependent upon the fortunes of agriculture. They expand and contract in relation to the incomes generated from the most recent harvests. The prediction of an earthquake for such a region would probably have little impact on the local economy, for any movement of services (restaurants, retail and wholesale trade) from the area would not directly influence employment. Additional capacity would most likely be found in those establishments electing to ride out the threat. In addition, these rural areas do not tend to be centers of rapid growth; hence any diminished demand for construction would not result in significant eco-

nomic dislocations. Concern about a prediction-induced recession is much less pressing for such an area. The most appropriate focus for public policy in rural areas therefore is on the event itself, that is, how to accelerate the adoption of protective measures.

By identifying those communities and regions with slowly or quickly adjusting businesses, public policy makers could tailor policies in different areas to the speeds at which changes are likely to take place. Those areas that adjust quickly will need immediate attention, while areas that adjust slowly can be attended to later.

The speed with which a region responds to a prediction becomes more important as the lead time lengthens. Predictions of events far in the future may stimulate economic hardships, but increasing the time window also creates opportunities for businesses to undertake constructive actions. To capitalize on a lengthy forewarning, policy makers should balance the need to maintain a stable economic and social order before the event against the need to reduce risk to life and property. As the warning time diminishes, of course, the focus of policy needs to shift toward the problem of risk reduction.

RESEARCH RECOMMENDATIONS

The preceding discussion suggests attention toward the following two types of research: (1) studies of the behavior of firms and of the market and other institutional forces that affect such behavior and (2) analysis of regional economic responses in terms of economic modeling techniques.

STUDIES OF THE BEHAVIOR OF FIRMS

The economic and social consequences of earthquake prediction hinge on the adjustments that the productive and service sectors of the economy undertake to protect themselves from primary and secondary losses. The responses discussed above range from doing nothing to moving away. Doing nothing may be quite effective in diminishing disruption before the event, but it exposes life and property to earthquake risks. Moving away insures a diminished exposure to risk of damage and injury, but it throws the community into a state of economic and social disruption. Both courses of action have negative consequences, but both also contain the opportunity for intervention to lessen these risks or impacts. For this reason it is recommended that research be focused on these adjustment choices. What will they look like? How did they come about? And what

can be done to aid organizations in selecting adjustments so as to reduce dislocation and avoid injury and damage?

Study of Information Processing The role of information in directing how firms behave is paramount. The kinds of information of concern can be generally distinguished in terms of direct (earthquake-induced) and indirect (prediction-induced) effects. Of course, both kinds of information can be received from others or generated by the firm itself.[22] In studying the role of information in organizational decision making, particular attention should be given to identifying the sources of information, to defining the content of information transmitted and received, to determining the accuracy of the information transmitted and received, and to documenting the interpretation of the information by organizational decision makers.

Study of Adjustments Information processing will clearly influence the choice of adjustments. However, as has been noted, the final mix of actions will be heavily influenced by organizational characteristics. To better understand the economic impact of earthquake prediction, it is necessary to understand how these other factors influence adjustment choice. Empirical answers to the following questions will help forecast how businesses respond:

1. *Internal organizational conditions.* How flexible is the work process with regard to products and timing? What is the amount of finance capital available, and how flexible is the firm in using it? How does the formal and informal social structure of the firm affect the timing and implementation of various adjustments?
2. *External organizational conditions.* How much autonomy does the firm have over decisions to make adjustments? How flexible is the firm in its choice of adjustments given its primary market?
3. *Stakes.* How much does the firm stand to lose from the physical destruction resulting from an earthquake? In effect, what is the value of buildings, equipment, and materials at risk? How much profit does the firm stand to lose from the disruption of production as a result of an earthquake? What are the perceived production loss and market loss? What does the firm stand to gain from the consequences resulting from a prediction?

[22]Information can also take the form of obtrusive indirect effects on a firm that occur through normal business channels as a result of the prediction. For example, there may be fewer clients buying products or making service requests.

REGIONAL ECONOMIC RESPONSE

The development of regional models provides a mechanism for integrating the decisions of individual firms. Questions about the impact of adjustment choice on income and tax revenue, for example, can be addressed with econometric or interindustry techniques, as can the impact of reduced consumer spending or capital availability. The following research projects, some of which are models and some related studies, address the problem of regional economic response.

Regional Interindustry/Econometric Models Regional economic models should be developed for those areas thought to be particularly vulnerable to a prediction. Whether an interindustry or econometric approach is more desirable depends on the ability to merge the findings of either technique with the results flowing from behavioral studies. There are a number of models currently in operation including those at the Water Resources Department of California, at the University of California at Berkeley, and at the University of Washington.

Until a prediction is made, it may be unwise to fund detailed studies of specific locations. Interindustry models in particular tend to need much attention in order to maintain their predictive ability. Instead, a more modest effort is recommended: Existing models should be updated and used to determine which areas of the state are most economically vulnerable. Such reconnaissance work need not be supported entirely by funds earmarked for earthquake hazard reduction. Models of the sort just described are just as useful in studying the effects of drought or altered government spending.

Survey of Household and Business Spending Plans Since the health of the local economy is linked with the spending plans of households and businesses, the firm studies discussed in this chapter and the previous one should assess the types of purchases, if any, that would be postponed as a result of predictions. Of course, it will be important to know who is doing the postponing, and why.

Analysis of Market Effects Because of the uncertainty of relying on market signals in choosing a course of action, the role of markets in conveying correct information should be examined in the context of household and business studies. As already noted, markets may provide misinformation in the postprediction period. This hypothesis needs some attention, especially with reference to alternative arrangements for disseminating information. If market prices prove to produce misleading information, what can be done about the problem? What are the impli-

cations of government intervention, and under what conditions would it be warranted?

Survey of Bank Vulnerability Much like the insurance industry, the financial community will probably be concerned with the potential consequences of a prediction. The surveys of households (discussed in chapter 3) should assess under what conditions, if any, residents would default on existing loans. Concurrent studies of bank vulnerability should be undertaken to find out how diversified banking assets are and how extensive mortgage default would have to be before local and nonlocal banks would be threatened.

Research on Model Insurance Programs One possible outcome of earthquake prediction is the cessation of all earthquake insurance sales. In effect, this action may be necessary to protect those who have already purchased insurance. Since the prediction changes the situation from one of risk to one closer to certainty, it is possible that further sales might be banned. On the surface, this appears to be a reasonable stand, yet a closer examination suggests that some modified form of insurance may still be desirable. First, even though the earthquake may be predicted with certainty for a community, the particular structures within the quake area that will be damaged are impossible to pinpoint. In San Fernando, for example, quake damage was sporadic; in some instances, similar houses standing next to one another sustained different degrees of damage. Ground shaking is influenced by soil conditions; structures on loose alluvial soil will sustain more damage than those on bedrock. Figure 4 shows the distribution of damage simulated for two earthquakes in the San Francisco Bay region.

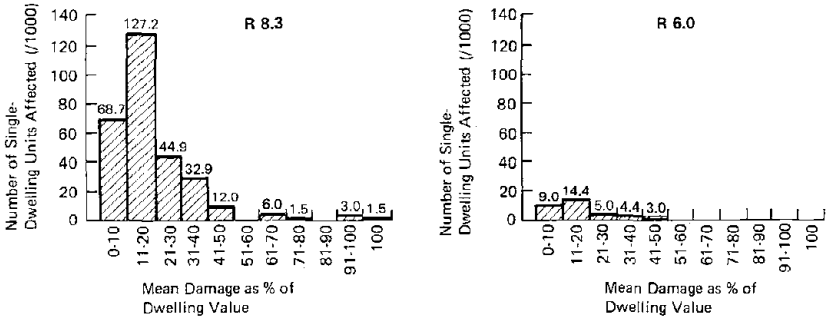
The mean damage is shown to be less than 10 percent of a dwelling's value. If 10 percent damage is assumed to be typical of less severe earthquakes, then one could develop an insurance program for the community, even in the postprediction period. Given a 3-year lead time, a normal 5 percent deductible, and an average structure value of $30,000, monthly premiums should be less than $40. This assumes that the predicted quake is certain to occur. Research might be undertaken on methods to market such insurance. Could it be administered through a property tax collection scheme? Would the government stand behind such an effort and provide for reinsurance? How would private insurers react? It seems reasonable to conduct research on various possibilities to establish a set of model programs that the local community could adopt.

The behavioral studies of businesses and the development and refinement of regional economic models should receive strong emphasis for both theoretical and policy analysis purposes. It will be crucial to know

how firms adjust to the first scientifically credible earthquake predictions. Properly timed and broad-based surveys can identify these adjustment patterns, and intensive case studies can determine how the decisions were made. The business and household studies outlined in this chapter and the previous one should, of course, measure financial plans and behavior and assess the role of market forces in adjustment patterns. Economic modeling then provides a set of useful techniques for exhibiting the results of these studies.

Research on bank vulnerability and the development of model insurance programs are also important for analyses of the regional economy, but we suggest that these topics receive somewhat lower priority for the following reasons: first, the responses of the banking and insurance industries will become quickly known; second, both industries are heavily regulated by a set of uniform rules; and third, regulating agencies such as the Home Loan Bank Board, the Federal Reserve Board, and state insurance commissions are well staffed to do research and to take actions to counteract responses that are not in the public interest.

Even though social science research on these two important industries is deemphasized here, it is clear that the recommended research on households and businesses will provide important data for these industries. Banks need to know how homeowners will respond. Will they default on their mortgages? How far will housing values fall? How will savers respond? Will they withdraw all deposits? Will bank deposits dwindle because unemployment is forcing people to live off their savings? All of these questions deserve some attention. The results of these studies will be incorporated into the regional economic models discussed above. Once these data have been collected, of course, the findings will need to be disseminated to the banking and insurance industries.



Source: Harold C. Cochrane, *Natural Hazards and Their Distributional Effects.* Boulder, Colorado: University of Colorado, Institute of Behavioral Science, 1975.

FIGURE 4 Distribution of damages in simulated San Francisco earthquakes of Richter 8.3 and 6.0 magnitudes.

5 Government

Government will clearly play a central role in earthquake prediction and its consequences. Governmental actions shape communities and, to an extent, the stakes that individuals and firms have in them. Governmental actions will influence the promulgation of predictions and warnings and the social consequences that ensue. Governmental organizations also are responsible for preparing for earthquake disasters and responding to them when they occur. In short, the involvement of government in the problems associated with earthquake hazards is diverse and essential. Taken as a whole, government will have a role in responding to most aspects of the consequences—both positive and negative—that may flow from the technology of earthquake prediction. Thus many of the issues discussed in the chapters on individuals, firms, and the economic and legal systems are intimately related to potential governmental actions.

This chapter discusses policy issues and recommends research on the role of government in mitigating earthquake hazards. The first section provides an overview of government's domain of responsibilities. The second discusses the tasks these responsibilities imply and also the barriers government may meet in performing them. The third discusses analytical approaches to research on earthquake-related governmental action. The final section of the chapter recommends research projects to pursue.

The recommended research reflects three major considerations. First, the role of government is inescapably intertwined with the development and implementation of policies toward earthquake disasters and their pre-

diction. A crucial set of research problems is concerned with the processes of creating and implementing useful policies. Second, it is necessary to evaluate which among the many research topics related to governments and earthquakes are most feasible and useful. The recommendations include both applied projects to monitor the effects of public policies regarding earthquake hazards, and basic research on policy processes, disaster mitigation and preparedness programs, and disaster responses. Third, the research recommendations are tempered by an assessment of the current status of policy and social science knowledge that can be applied to governmental responses to earthquake hazards.

EARTHQUAKE HAZARDS AND THE DOMAIN OF GOVERNMENTAL ACTION

The National Research Council's Panel on the Public Policy Implications of Earthquake Prediction classifies governmental action in three broad categories: (1) authenticating and issuing earthquake warnings, (2) controlling and offsetting detrimental side effects of the predictions, and (3) implementing emergency preparedness measures and enacting a hazard reduction program to minimize community disruption and loss of life and property when the earthquake occurs.[1] It is safe to assume that government will act in each of these areas.

AUTHENTICATING AND ISSUING WARNINGS

In view of the scientific complexity of earthquake predictions and the consequent uncertainties surrounding them, both the Panel on Earthquake Prediction[2] and the Panel on the Public Policy Implications of Earthquake Prediction have recommended that the government organize groups of scientists to review the technical merit of any predictions. The state of California has already appointed an Earthquake Prediction Evaluation Council for just this purpose. Although scientists will make the earthquake predictions, the warnings and advice based on them falls within the purview of government, as does responsibility for disseminating information to those who are affected.

[1]See Panel on the Public Policy Implications of Earthquake Prediction of the Advisory Committee on Emergency Planning, *Earthquake Prediction and Public Policy,* pp. 41–45.

[2]See Panel on Earthquake Prediction of the Committee on Seismology, *Predicting Earthquakes.*

SOCIAL CONSEQUENCES OF PREDICTIONS

Whether a prediction accurately foretells an earthquake or not, it may have a wide range of consequences, many of them adverse—social disruption, redistribution of population, dislocation of housing and insurance markets, migration of business and industry, and loss of local tax revenues. It is conceivable that the consequences of some predictions may be worse than those resulting from an actual earthquake. It is quite likely that government at every level will attempt to avert unwanted consequences of earthquake prediction.

HAZARD MITIGATION AND DISASTER PREPAREDNESS

Government has the responsibility for mitigating earthquake effects and responding to the effects that cannot be avoided. The advent of earthquake predictions is likely to prompt new interest in measures to reduce the severity of earthquake damage and prepare disaster agencies for more effective responses.

Local authority, usually enabled by state legislation, is the traditional means of reducing various hazards through building codes and land-use regulations. Local authority could also reduce earthquake hazards through such regulations both before and after a warning. Planning and training programs can improve preparedness in the divisions of local government—police, fire, utilities, public works, welfare, health, and others—that have important responsibilities in disasters. Measures to improve disaster responses will probably touch not only most local governmental organizations, but many higher governmental organizations as well.

STAGES OF GOVERNMENTAL ACTION

Changing circumstances will affect the timing of these anticipated governmental actions and, consequently, the appropriate timing of different research projects. A simplified, but useful, way of summarizing these circumstances is to view them as stages in the development of earthquake prediction technology and the evolution of public policy. There are three such stages: (1) governmental action to hasten the development of earthquake prediction technology, to anticipate its social consequences, and to prepare for earthquakes[3]; (2) development of earthquake prediction

[3]These efforts have already begun, and existing federal legislation insures their acceleration in the immediate future. See footnote 14 for details on Public Law 95-124, the "Earthquake Hazards Reduction Act of 1977."

technology to a point at which warnings are issued; and (3) occurrence of actual earthquakes in the United States.

The timing of the second and third events is now unforeseeable. In fact, earthquake prediction technology may not mature soon. Governmental activities, and therefore appropriate research strategies, will differ with the order and timing of these three events. If, as seems likely, the currently legislated efforts to prepare for both earthquakes and the social consequences of earthquake predictions substantially predate the maturation of earthquake prediction technology, research will be most needed on policies to lessen earthquake hazards and improve preparedness. When earthquake predictions are actually issued, the range of relevant research broadens to include a study of governmental adjustments to new, perhaps unparalleled, situations, including the possibility of false alarms. If an earthquake occurs, either before or after authorized predictions, different situations for research obtain. Obviously, research priorities will vary according to the stage of earthquake prediction technology and the timing of earthquakes.

THE ROLE OF GOVERNMENT: ANTICIPATED TASKS AND PROBLEMS

Social science research permits a general outline of the probable tasks and problems governmental organizations will face in handling preparedness measures, earthquake predictions, and actual earthquakes. The tasks and problems outlined below are based on speculation. It may be argued that some of these tasks are more important than others and that some of the problems are more likely to develop than others. However, past research can supply neither normative prescriptions about how governmental organizations should proceed nor precise predictions of what they will do. Thus what follows is neither an inventory of suggested governmental measures nor a definitive summary of earthquake-related governmental problems. Rather it is a summary of possible tasks and problems, which past research on government and disasters provides as a guide to appropriate future research.

Government may assume leadership to obtain the best possible benefits of earthquake predictions and to lessen untoward social consequences of predictions. Because of its responsibilities for public safety, welfare, and equity, government will also probably be accountable in some fashion for earthquake warnings and their effects. Although earthquake predictions themselves will be made by scientists, warnings that advise citizens how to respond to a prediction will involve government, thrusting upon

it tasks of assessing the credibility of predictions, acquiring information needed to advise potential victims, and warning them. The associated problems are discussed in chapter 7.

The tasks of government occasioned by an earthquake prediction, however, only begin with warning. It is likely that government will assume tasks designed to reduce the economic stagnation, social dislocation, population redistribution, and tax revenue losses that warnings may bring. If disregarded, such consequences could ultimately be worse than the effects produced by an actual earthquake.

It is possible that an earthquake prediction will produce significant economic disruption. Although these problems will be the object of extreme local concern, the resources of local governments will rarely permit independent action to avert them, and the federal government will probably have to assume the major burden. It is difficult to anticipate the details of federal intervention, but they are likely to include measures to guarantee insurance coverage, grants to offset loss of local tax revenues and to maintain essential public services, extended unemployment benefits, and regulation of financial institutions to stabilize real estate markets and capital flows.

The tasks assumed by government will undoubtedly vary with the precision claimed for the prediction with respect to timing, magnitude, and geographic area. At one extreme, short-term, precise predictions will seem to preclude all but the tasks of highest priority, such as saving lives. A long-term, tentative prediction will verge on the present situation—that is, the eventual likelihood of an earthquake of uncertain magnitude and timing. Long-term predictions will make a broader variety of government tasks feasible—such as the preparedness measures discussed below—but they will also reduce the urgency of response. Predictions that turn out to be false alarms will present an even more ambivalent context for defining governmental responses to subsequent predictions. Thus even when earthquake prediction techniques have developed to a point at which they are convincing to a significant segment of the scientific community, the range of tasks a prediction may lead government to assume is great, and the intensity with which government will pursue them is unpredictable.[4]

[4]It could be argued that the added specificity of timing, location, and magnitude provided by even a tentative earthquake prediction may reduce present barriers to earthquake preparedness and result in a significant expansion of earthquake-related governmental tasks. Even in areas where earthquake hazards have been clearly identified, preparedness now struggles against the burdens of indefinite location, timing, and magnitude. Predictions may revitalize governmental efforts to promote preparedness.

The recent passage of the Earthquake Hazards Reduction Act suggests renewed efforts by the federal government to improve the disaster preparedness of state and local governments. A good idea of the role that state governments may play in this field may be derived from Figure 5, which presents some of the earthquake-related legislation enacted in California in the last few years. Note that it is a mixture of state responsibilities and mandates to local governments.

Disaster mitigation and disaster preparedness activities of local governments vary considerably from community to community, and governmental programs in these areas are often difficult to implement. The mitigation of earthquake impacts involves a long-standing and difficult set of problems already within the purview of many local governments. These include the establishment and enforcement of land-use and building code regulations, which have always been controversial and which will become even more so with geographically precise predictions. Both of these hazard reduction programs require long lead times and sustained effort to be effective; both are often challenged by powerful, short-term economic and political demands. Disaster planning and preparedness programs must generally compete with routine nondisaster activities of local government. The result is often nominal compliance with the formal requirements for disaster planning, without effective anticipation of actual disaster conditions. Thus, even though disaster preparedness is not newly occasioned by earthquake prediction technology, it is as important and difficult to accomplish as preparation for the social consequences of predictions.

It is difficult to discuss the nature of governmental responsibilities apart from a total examination of the problems and responses of communities in disaster.[5] It is enough to note here that the government's role potentially touches every short-term aspect of human and community survival. Thus an understanding of the ultimate effects of earthquake predictions will depend on thorough knowledge of governmental responses to disaster. A recent comprehensive review of disaster response studies takes particular note of our lack of knowledge of the relationships between disaster mitigation and preparedness programs and responses to disasters.[6]

[5]See A. Barton, *Communities in Disaster: A Sociological Analysis of Collective Stress,* 1969; R. R. Dynes, *Organized Behavior in Disaster,* 1970; and D. S. Mileti, T. E. Drabek, and J. E. Haas, *Human Systems in Extreme Environments: A Sociological Perspective,* 1975.

[6]See E. L. Quarantelli and R. R. Dynes, "Response to Social Crisis and Disaster," *Annual Review of Sociology,* vol. 3 (1977), pp. 23–49.

Bill Number	Summary
Senate Bill 351 (1971-72)	Modified Section 63502 of the Government code to require that a Seismic Safety Element be prepared by each city and county and included in the general plan. The element is to consist of an identification and appraisal of seismic hazards and a definition of the risk for the community.
Senate Bill 479 (1971-72)	Section 15002.1 of the Education Code required geological and soil engineering studies for all proposed school sites to preclude the siting of a school in any location where the geologic/seismic characteristics are such that the construction effort required to make the site safe for occupancy is economically unfeasible. It also stated that no school building shall be constructed or situated on the trace of an active geological fault.
Senate Bill 519 (1971-72)	Senate Bill 519 (Section 15000 of the Health and Safety Code) established basic regulations for site evaluation, the design and construction of hospitals. In addition, a Technical Board was created which was comprised of licensed professionals in all of the involved and allied subject fields.
Senate Bill 520 (1971-72)	A fault hazard zone act which requires the examination of each site to assure that no structure of human occupancy is built astride or on an active fault. In addition, requires disclosure of the presence of the fault zone in all real estate transactions.
Senate Bill 1114 (1973-74)	Requires that any school building constructed on an active fault before 1957 shall be subject to replacement at another location in accordance with the Field Act. Remains in effect only until December 31, 1974.
Senate Bill 1729 (1973-74)	Created the Seismic Safety Commission which is responsible for encouraging research; gathering, analyzing, and disseminating information; coordinating governmental seismic safety activities; setting goals and priorities; and other activities in connection with earthquake hazard reduction.
Senate Joint Resolution 63 (1973-74)	SJR 63 requests the President and the Congress of the United States to assure the people of California that action will be initiated to establish a program for abatement of seismically hazardous federally owned structures in the State of California, and that the program will consider the elements of abatement programs in existence in California.

Senate Bill 2422 (1973-74)	SB 2422 amends the Alquist-Priolo Geologic Hazard Zones Act (SB520) to require the State Geologist to define "new real estate development" and "structure for human occupancy."
Assembly Bill 2615 (1973-74)	Permits continued use of school buildings which are not in compliance with the Field Act structural standards (earthquake safety) after June 30, 1975, if authorized by the State Allocation Board and the work on repair, reconstruction, or replacement of such buildings has commenced. Prohibits authorization for continued use of such buildings after June 30, 1977. An urgency measure.
Assembly Bill 4140 (1973-74)	Requires that buildings or structures be designed and constructed to resist earthquakes (and high winds) according to the Uniform Building Code, not as formerly called for in the California Administrative Code. Also allows the Division of Codes and Standards of the Department of Housing and Community Development to enforce the Earthquake Protection Chapter of the Health and Safety Code.
Senate Bill 1950 (1975-76)	Provides immunity from liability to a public entity or public employee acting in response to an earthquake emergency or whenever an earthquake emergency appears reasonably imminent.
Senate Bill 2059 (1975-76)	Abolished the State Building Standards Commission and replaces it with the Department of Building Safety, the Commission of Building Safety, and a Board of Building Regulation Appeals. Establishes the Commission as the sole state agency with authority to adopt building regulations. After July 1, 1977, no state agency except the Commission would be permitted to adopt any building regulation.
Assembly Bill 3684 (1975-76)	Waives the requirement under Senate Bill 479 for geologic and soil engineering studies prior to acquiring sites for school building purposes, except for sites within an Alquist-Priolo Special Studies zone or within an area designated as being hazardous in the local seismic safety element.
Assembly Bill 4278 (1975-76)	Gave the Governor emergency powers to deal with disasters, in accordance with the Federal Disaster Relief Act of 1974, upon his proclamation that an emergency exists. This bill gives him additional emergency powers if the President declares a major disaster exists.

SOURCE: Prepared by James E. Slosson, formerly California State Geologist, and William J. Petak, School of Public Administration, University of California, 1977.

FIGURE 5 Example of recent California experience in earthquake hazard reduction legislation (1971–76).

ANALYTICAL RESEARCH PERSPECTIVES ON EARTHQUAKE-RELATED GOVERNMENTAL TASKS

Five general considerations cut across earthquake-related governmental tasks, whether they pertain to predictions, mitigation and preparedness programs, or disaster responses. The first three of these are general perspectives that seem to be essential tools for informed research on the subject. These view the research in terms of *informational, policy,* and *organizational* considerations. The remaining general considerations hinge on the intergovernmental and political contexts of government in the United States.

The need for efficient and effective transfer and use of information in earthquake prediction and preparedness can hardly be doubted. Collectively, we are faced with a highly consequential, but uncertain, technology. Careful use of complex scientific knowledge and its clear transmission to the public is central to many earthquake-related governmental tasks. Governmental organizations can be thought of as originators and distributors of information and as facilitators of essential communication among others.[7]

In the case of novel, potent, and complicated information such as the information stemming from earthquake prediction techniques, communications and education are interwoven. In addition to the tasks of dealing with dissemination of information as part of the prediction and warning process, governmental organizations will undertake training activities, answer questions, and in general profoundly influence how warnings are received. Communications will flow in many directions between government, the public, and the scientific community, as well as between governmental organizations.

Although the mass media will be the major supplier of information to the public, government will usually be its ultimate source. Government will also probably be concerned with supplying information to people inadequately informed by standard media because of language difficulties, physical handicaps, or other reasons. Government's tasks may be affected by the media's selection and emphasis of what the media regard as newsworthy information and the distortions that may result. Government will find its tasks complicated if information provided through the mass media lacks sensitivity to the distinctive needs of individual localities and persons.

Public policy offers a second general perspective on earthquake-related government tasks. The whole of government's involvement with earth-

[7]See S. S. Skjei, *Information for Collective Action,* 1973.

quake hazards can be conceived of as a problem in policy making and policy implementation. Viewed this way, the tasks assumed by governmental organizations are shaped by the policy decisions of the several levels of government. Perhaps of greatest importance, the policy perspective illuminates the earlier question of how to formulate earthquake hazard policy. The policies themselves should not be taken as given. As will be pointed out in this chapter and in chapter 8, the organization of policy making and policy implementation deserves careful attention.[8]

A third perspective interprets the actions of government in organizational terms. An organizational perspective is useful because units of government are organizations, sometimes of considerable size and complexity. Research on the role of government in earthquake hazard mitigation should keep this fundamental point firmly in view. The nature of organizational action is complex and can be expressed in several ways. One observer has pointed out that organizational action requires coordination, integration, and control of diverse behavior by individuals.[9] Another writer, concerned with the dynamics of forming and implementing policies, has observed that organizational decision making is actually a complex bargaining process among interest groups within the organization.[10] A third has noted that organizations as structures of roles and status have continuity and inertia that transcend the personal character and tenure of the persons occupying these roles.[11] The implications of the organizational perspective, however, are more important than the way an individual chooses to define it.

Organizations are not persons. Neither conceptions of their natures nor explanations of their actions should unwittingly be confused with psychological interpretations appropriate for individual behavior. Organizational administrators may act in terms of psychological needs, stimulus-response mechanisms, and the like, but organizations do not. Psychological interpretations have their place in the analysis of behavior within organizations, but the actions of organizations *per se* will shape earthquake policy and its enactment.

A fourth perspective relates to the complexity of intergovernmental relations resulting from the familiar layering of local, state, and federal jurisdictions as well as the proliferation of special purpose agencies

[8]See Y. Dror, *Public Policy Making Reexamined,* 1968, and J. E. Anderson, *Public Policy Making,* 1975.

[9]See W. J. H. Sprott, "The Nature of Social Action," *Readings in Introductory Sociology,* 1972, pp. 53–61.

[10]See Thompson, *Organizations in Action.*

[11]See J. E. Haas and T. E. Drabek, *Complex Organizations: A Sociological Perspective,* 1973.

within levels. Coordination between governmental levels regarding earthquake hazards and predictions is made difficult because many organizations are likely to be affected by a single hazard area. The most important predictions will be for urban areas because of the greater likelihood of damage and threat to life in those areas. Virtually all such earthquake-prone urban areas in the nation are located in jurisdictions governed by many separate, independent governments. Los Angeles County, for example, has 77 cities and more than 200 independent special districts within its borders. Each government organization has particular expertise and responsibilities that often overlap and conflict.

When many government organizations are involved with a common problem, competition of two ironically different kinds can occur. On the one hand, there may be competition to capture the increased resources that are likely to accompany an earthquake prediction. On the other hand, because governmental responses to such predictions are bound to be controversial no matter what steps are taken, some agencies may compete to *avoid* responsibility.

There is at present an extraordinary proliferation of federal agencies that might be involved with earthquake predictions, and coordination among them will be difficult. There are over 100 federal agencies involved in emergency planning, research, and operations. The interplay among them will be a central aspect of responses to earthquake predictions.[12]

A fifth and final consideration relates to the political context within which governmental responses to earthquake hazards will take place. Government and politics are sometimes so intermingled as to be indistinguishable. The economic and political stakes riding on earthquake predictions and responses cannot help drawing governmental action into the political arena. Politics, in effect, makes earthquake policy highly sensitive to the response and participation of the public. In this context "the public" can refer to a variety of things, principally the contending interest groups created or mobilized to influence policy.

In another chapter the legal aspects of earthquake hazard mitigation are discussed. However, many of the issues touched on there do not rest solely on legal considerations. Within constitutional boundaries, what is legal depends on what the political process produces. To correct the absence of legal authority for some hazard reduction measure requires the enactment of a new law through a legislative process that is highly political. Different groups and individuals stand to gain and lose, depending on the precise measures legislated. Consequently, where stakes

[12]See C. E. Fritz, "An Inventory of Federal Government Agencies That Have Planning, Research, or Operational Functions Relating to Disasters, Emergencies, and Hazards," June 1977.

are substantial, vigorous political pressures shaping the legislative process can be anticipated.

Further political pressures on local enactment of earthquake policies and legislation can be expected. It is possible that earthquake predictions and policies will become politically sensitive and elected officials may avoid certain actions in fear of voter reaction. In turn, the electorate may view what elected officials do about earthquake hazards as an appropriate basis for judging their qualifications for office. To the extent that political officials make decisions and new policy in response to predictions, the adequacy of their behavior can become a topic for political debate and electoral controversy.

Resolution of many public issues requires achieving a balance between efficiency and equity. As with most social problems, the lower-income groups will find themselves most vulnerable to the adjustments that earthquake policies may call upon citizens to make. As usual, the political arena, with governmental organizations in full participation, will be the furnace within which the compromises between efficiency and equity are forged.

RESEARCH PERSPECTIVES

The general purpose of this final section is to outline research strategies from which specific recommendations can be derived. The approach taken here is based on possible governmental action as seen from the general social science perspectives discussed earlier. Although the topic of government permits a virtually unlimited range of research, a considerable degree of selectivity can be exercised by judging potential research in terms of its usefulness to governmental participation in earthquake problems and its relevance to basic theoretical issues in the social sciences.

GENERAL RESEARCH STRATEGIES

Ideally, complex social problems such as those associated with earthquakes would be addressed by several types of social science research. Many of these research strategies can be summarized as *developmental, inventory, monitoring,* or *basic* research.[13]

Developmental research is the social science analogue to engineering, which applies existing knowledge of the physical sciences to the solution of specific problems. In the case of earthquake-related governmental

[13]Developmental and inventory research are specific forms of applied policy research. A more thorough discussion of policy analysis is found in chapter 8 of this report.

problems, developmental research would use the findings of the social sciences to prescribe and evaluate specific policy options. It would also identify the most formidable barriers to effective policy implementation and suggest the techniques that might be used in overcoming them.

Developmental research depends on the maturity of basic research. Basic knowledge of the social processes and structures at issue must be refined enough not only to anticipate a broad array of possible policy-related difficulties, but also to select with confidence the ones that must be dealt with. In other words, developmental research requires more than minimal knowledge of the nature of, and causal relationships within, the social systems at question. Developmental research for purposes of prescribing policy making and policy implementation cannot be confidently recommended here. Relevant social science knowledge is sufficient to identify useful perspectives, but these perspectives have not yet yielded confident predictions or even clear descriptions of causal processes. Thus the myriad barriers to policy implementation that can be identified have not been narrowed to a manageable, precisely understood few.

Inventory research identifies and maps the distribution of important aspects of a pragmatic problem. With respect to earthquake disasters one might inventory the potentially important actors, their attitudes and social characteristics; the relevant social structures, such as political jurisdictions and relations between levels of government; and relevant material resources. Inventory research is useful where policy strategies are narrowed to a few alternatives and the most efficient and effective management measures are at issue. At present, the preliminary nature of governmental policy on earthquake hazards makes a recommendation of inventory research unwise. Policy alternatives are not defined sharply enough to justify inventories of the attitudes of officials about them. Nor are the distribution of responsibilities for earthquake hazard reduction among political jurisdictions and the allocation of resources sufficiently precise to warrant inventories.

Monitoring research, on the other hand, is entirely appropriate in these circumstances and is strongly recommended. While it is now difficult to anticipate when earthquake prediction technology will justify warnings, technical progress will not await a precise anticipation of its consequences by the social sciences. Moreover, national concern and activity on earthquake prediction and other hazard reduction measures will be spurred by the recent passage of the Earthquake Hazards Reduction Act of 1977 and the funding that it provides for new programs.[14] In these circumstances,

[14]Public Law 95-124, "The Earthquake Hazards Reduction Act of 1977," was passed on October 7, 1977. The purpose of the act is to reduce the risks of life and property from future earthquakes in the United States through the establishment of an effective earth-

one of the most important services the social sciences can render is to selectively monitor the results of public policy. Federal concern for, and financing of, preparedness for earthquake disasters and the social consequences of their prediction will not remain relatively high indefinitely. Since the problems to be encountered and the results to be expected from this episode cannot be precisely predicted, it is important not to squander opportunities for preparedness while they are available. The social sciences can at least identify some of the broad outlines of the social barriers these efforts will encounter, and through skillful monitoring studies can document the consequences of the earthquake hazard reduction policies that were chosen.

Finally, judiciously selected programs of basic research on the conditions affecting disaster mitigation, preparedness, and response will have the most long-term benefit. It is easy to imagine how much more effective preparations for earthquake predictions would be if policy could be guided by basic knowledge of critical barriers to preparedness and the ways to overcome them. If we knew more about the conditions affecting receptivity of governmental organizations to preparedness innovations and if we knew the relationship between various preparedness options and effective disaster responses, the kind of development research discussed above could be undertaken. Basic research has an uncertain bearing on the pragmatic problems of improving preparedness for earthquake hazards in the short term. However, without basic research we will continue to be ignorant of how to prepare adequately when our next opportunity arises. Both social scientists and policy makers need to know more about how governmental organizations respond to problems such as earthquake mitigation and preparedness and how these responses affect performance during disasters.

RESEARCH TOPICS

It is recommended that *political processes*, *policy studies*, and *organizational perspectives* be emphasized in both applied and basic research on government. The implications of earthquake predictions documented throughout this report signify the political sensitivity of many issues that

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quake hazards reduction program. The act authorizes the expenditure of over $200,000,000 during the 3-year period ending September 30, 1980, to develop earthquake-resistant design methods and procedures; predict earthquakes and characterize seismic hazards; develop model codes in cooperation with state and local officials and practicing professionals; and plan and prepare for, respond to, and recover from earthquake occurrences. For further information on the act and its implementation, see the report by the Working Group on Earthquake Hazards Reduction, *Earthquake Hazards Reduction*.

will arise, particularly at state and local levels. In the last section we mentioned the possibility that earthquake predictions and preparedness present potential political dilemmas for elected officials. Whether the actions of public officials become an election issue or not, their controversial potential is unlikely to be overlooked by the local and state officials who will shape policy. Research should be undertaken to assess the extent and effect of political pressures on earthquake preparedness and prediction measures.

Initially, this political research should monitor these pressures. This process would be applied research, but it would also provide the foundation for selected basic research. The applied research can provide information on political barriers to agencies promoting earthquake preparedness. Rapidly gathered and reported information may form the basis for adjustments in the measures being used by responsible agencies to promote preparedness. If monitoring of political processes indicates that governmental adjustments based on predictions have erupted into a publicly debated political issue, intensive research of the issue should be undertaken. Of particular interest is the opportunity to pursue basic research on the formation of interest groups and their participation in such controversies. Here knowledge of who is engaged in public controversies over earthquake hazard reduction, and of how they are organized, will help indicate the political dimensions of these programs. If monitoring indicates that political pressures are effectively influencing hazard reduction programs without public controversy, there may be the opportunity to study the operation of entrenched, but not publicly visible, interests such as have been found to affect public health care measures.[15]

There is also an opportunity to study a potentially useful analogue to the earthquake problem. Flood hazards create land management and building code issues that may be similar to those created by earthquake hazards. The political and local governmental responses of the last few years to the National Flood Insurance Program administered by the Department of Housing and Urban Development may be analogous to some of the political issues likely to be provoked by earthquake predictions. Basic research on the responses of local communities to this program may reveal the shape of future political impacts on earthquake reduction measures.[16]

[15]For a description of such barriers to attempted reforms of health care delivery in New York City, see R. R. Alford, *Health Care Politics: Ideological and Interest Group Barriers to Reform,* 1975.

[16]See E. J. Baker and J. G. McPhee, *Land Use Management and Regulation in Hazardous Areas: A Research Assessment,* 1975; D. E. Moore and R. L. Cantrell, "Community Response to External Demands: An Analysis of Participation in the Federal Flood Insurance Program," *Rural Sociology,* vol. 41 (Winter 1976), pp. 484–508; and J. C. Pierce and H. R. Doerksen (eds.), *Water Politics and Public Involvement,* 1976.

Finally, our basic knowledge of the political and social processes affecting governmental response to earthquake disasters is meager. A recent comprehensive review of the literature reports only two studies on the responses of government in disasters.[17] Because of the uncertain timing of the development of earthquake prediction technology, efforts to reduce earthquake hazards in the near future will concentrate on preparedness. It is important to shape preparations for earthquake responses according to conditions that affect actual governmental performance in disasters. Thus it is recommended that research on governmental responses to *any* type of disaster be undertaken. The basic knowledge gained may be useful in selecting realistic preparedness measures.

Policy formation and implementation should be the subject of both monitoring and basic research. As noted, the social sciences cannot now predict with assurance the most effective policies on earthquakes and predictions. Policy formation, however, will proceed. Present governmental sensitivity toward earthquake hazards assures this. Thus a suitable role for policy studies is to monitor the enactment of developing policies. Assessment of the successes and failures, with rapid feedback to policy makers, may allow adjustments of policy before the present episode of federal concern for earthquake hazards has run its course.

At the same time, more basic knowledge of the processes of creating earthquake policies is needed. As has been pointed out, many levels and agencies of government share responsibilities for earthquake hazard reduction. Research on the conditions affecting the policy-making process in which these diverse agencies are involved may yield basic knowledge of the problems faced by policy directed toward earthquakes and other hazards. Basic research of this type should be synchronized with developments in earthquake prediction technology. Policy issues, and therefore the processes and constraints affecting policy making, will undoubtedly change as this technology matures. An inescapable conclusion from an examination of the relation of government to natural hazards is that periodic concern on the part of the federal government is predictable, as is the periodic appropriation of funds to better cope with hazards. However, the governmental processes by which this concern is channeled and the funds expended are virtually unknown, as are the conditions affecting the implementation of policies.

Most of the recommended research will require an organizational perspective. It is, after all, organizations that will create policy and put it into effect.[18] Though government can be studied from the standpoint of individual officials and employees, it is strongly suggested that research-

[17]Quarantelli and Dynes, "Response to Social Crisis," pp. 23–49.
[18]*Ibid.*

ers who study the actions of government frame research questions and procedures with sensitivity to the organizational level of analysis.

From an organizational perspective, certain nuances of the recommended research are more easily seen. For example, governmental organizations are formal.[19] To a degree perhaps, even greater than in other types of organizations, governmental organizations have formally mandated jurisdictions and responsibilities. Most governmental organizations have everyday responsibilities far removed from the sphere of reducing earthquake hazards. Thus there is the problem of how innovations which implement earthquake policy measures will interact with and fit into existing organizational structures and domains.[20] The research studies should examine not only whether governmental organizations adopt the measures indicated by public policy, but also the more telling questions of how they do so. If (as in the case with many measures) they are formally adopted but given little attention, the effectiveness of the policies they serve will be diminished.[21] Serious pursuit of earthquake mitigation and preparedness policies by governmental organizations can be examined as a special case of the general organizational problem of control.[22]

Implementation of earthquake policies should be studied from another vantage point—as a problem of diffusion and organizational adoption of innovations. Monitoring research should chart the patterns of adoption measures indicated by emerging policies. Basic research should pursue a fundamental understanding of how hazard reduction innovations are adopted. The difficulty of inducing innovation should not be underestimated.[23] Typically, disaster-related innovations address matters quite marginal to the usual concern of governmental organizations. They are often adopted half-heartedly, if at all. While the literature on organizational innovations is growing in strength, we currently know very little about conditions promoting adoption of such measures.[24]

From an organizational perspective, even the formal decision to adopt earthquake measures cannot be seen as the action of an individual administrator. Instead, decision making has been found to involve complex interplay among coalitions of organizational interest groups.[25] Decisions

[19]See Blau and Scott, *Formal Organizations.*

[20]Thompson, *Organizations in Action.*

[21]See J. M. Weller, *Organizational Innovation in Anticipation of Crisis,* 1974.

[22]See M. Crozier, *The Bureaucratic Phenomenon,* 1964; and Tannenbaum, *Control in Organizations.*

[23]Weller, *Organizational Innovation;* and Mileti *et al., Human Systems.*

[24]See Zaltman, *et al., Innovations and Organizations.*

[25]See M. K. Moch and E. V. Morse, "Size, Centralization and Organizational Adoption of Innovations," *American Sociological Review,* vol. 42, pp. 716–725.

affecting adoption of such innovations and the vigor with which they are pursued by governmental organizations should be studied with this in mind. Once formally adopted, innovations are subject to subtle modification through "goal displacement" processes.[26] Studies of governmental organizations should assess how the implementation of new earthquake mitigation measures is affected by the day-to-day power and bargaining processes within the adopting agencies.

Finally, organizational researchers should consider complex governmental relations as sources of influence on the adoption and implementation of earthquake mitigation measures. Past research suggests that the initiation of local governmental improvements and programs is significantly affected by intergovernmental relationships of various types.[27] The media through which these intergovernmental influences flow, such as laws, administrative directives, seminars, workshops, specialty journals, and professional associations, should therefore be monitored on a continuing basis.

To reiterate, the emphasis given organizational research reflects a judgment on the essential nature of policy formation and implementation. In each case, the acting unit is typically a formal organization. It is true that one could study the attitudes of organizational leaders, but if this is done, these attitudes should be regarded as only one influence on organizational action. A similar argument—not so obvious, but equally important—can be made for studies of public response to earthquake issues. These responses could be studied as distributions of individual attitudes. However, such attitudes will not be consequential in the political arena unless they are promoted by public interest groups.[28] Some exceptions to this emphasis on organization—for example, in the study of political pressures on elected officials—could be justified. On the whole, however, it seems better to resist the lure of easier methodologies and the common tendency to reduce public issues to individual attitudes.

RESEARCH RECOMMENDATIONS

In summary, coordinated monitoring research and basic research on the actions of government are recommended. Each of these general research frameworks will be more fully discussed in chapter 8. The recommended *monitoring research* includes the following:

[26]Haas and Drabek, *Complex Organizations.*

[27]See C. B Marrett, "On the Specification of Interorganizational Dimensions," *Sociology and Social Research,* vol. 56 (October 1971), pp. 83–99; and R. L. Warren, S. M. Rose, and A. F. Bergunder, *The Structure of Urban Reform,* 1974.

[28]See R. H. Turner and L. Killian, *Collective Behavior,* 1972.

1. Monitoring the results of policy implementation in governmental organizations, with emphasis on earthquake reduction and preparedness measures.
2. Monitoring of policies and innovations strictly related to earthquake predictions and their consequences. Research should be synchronized with developments in prediction technology.
3. Monitoring of political pressures that affect measures related to earthquake predictions and hazard reduction.

Basic research on the following topics is recommended:

4. The processes of policy making and implementation with respect to earthquake reduction and preparedness programs and earthquake predictions and their consequences. The strategic research sites are to be identified by the monitoring studies listed under recommendations 1 and 2 above.
5. The impact of political processes on earthquake prediction and hazard reduction measures. The strategic research sites are to be identified by the monitoring studies listed under recommendation 3 above.
6. The responses of government organizations to major disasters of any type.
7. The study of policy making and policy implementation analogues (land management, building codes, insurance) in the federal floodplain management program.

A variety of methodologies are suitable for the recommended research. Monitoring surveys of government organizations will generally provide extensive, if superficial, information about the policies and innovations adopted and the problems encountered. However, because of the difficulty and dangers of assessing the organizational impact of policies and innovations entirely on the basis of formal adoption, intensive case studies of the integration of earthquake-related and other hazard reduction measures are needed. Case studies should also be undertaken to assess the *effects* of these measures in disasters. At this point there is hardly a suitable vocabulary to describe the variable impacts of policies and innovations in this area on the actions of governmental organizations. Intensive case studies can begin to build such a vocabulary and to discover conditions that may effectively shift marginal policies and innovations to a place of genuine concern and effectiveness within the organizations that adopt them. Intensive case studies are also suitable for the study of how public and special interest groups respond to hazard reduction issues.

6 Studies of Legal Problems in Earthquake Prediction

The legal problems of earthquake prediction, and the corresponding needs for research, can be approached from two complementary perspectives. One approach is to identify the key questions of legal interpretation that are likely to arise in the course of developing and implementing an earthquake prediction technology and to try to anticipate how these questions should be addressed in research. The second approach is more broadly concerned with the role that law plays in influencing human conduct.

The first approach was used by the National Research Council's Panel on the Public Policy Implications of Earthquake Prediction in its review of the legal implications of earthquake predictions.[1] Although this chapter will discuss some of the same issues as those contained in the panel's report, it will address these issues from the second, broader perspective of the role of law in influencing human conduct.

[1]See Panel on the Public Policy Implications of Earthquake Prediction of the Advisory Committee on Emergency Planning, *Earthquake Prediction and Public Policy,* chapter 6, "Legal Implications of Earthquake Prediction," pp. 81–95. The chapter discusses modifications in the existing concepts of social responsibility that a prediction capability will require. The issues include prediction-related liabilities (such as publicizing predictions or delaying public disclosure), aspects related to land-use control (including building, housing, and zoning codes), and problems connected with real estate mortgage markets.

A RECOMMENDED FOCUS ON LAW-RELATED RESEARCH

In approaching the study of legal problems in earthquake prediction, it is recommended that researchers, be they lawyers or social scientists, aim their inquiries at the relationships between legal rules and institutions on the one hand and individual and social conduct on the other. This recommended focus follows directly from the overriding theme of this report, which urges research relevant to policy. It must be assumed that policy makers attempt to be cognizant of the law and legal institutions within which they must function. The status of the law and legal institutions is indispensable information for this inquiry and for public policy formulation.

There are, of course, examples which show that policy makers have sometimes acted differently from the way they would have acted if they had understood the law; such action usually results from poor legal advice rather than from failure to acknowledge the importance of understanding the legal problems. If policy makers need better counsel on legal problems when making policy decisions relating to earthquake prediction, the solution lies in better legal counsel when they are making those decisions, not in reliance on a massive, independent examination of prospective legal problems. Otherwise the effort would be inefficient, since the status of the law varies over time and from place to place. Specific policy decisions require specific legal counsel. A general discussion of the status of the law as it relates to earthquake prediction must be viewed as a useful guide to the possible problems and as a warning of the importance of getting the specific answers to those questions when specific policy decisions are to be made.

In terms of the conceptual framework outlined in chapter 2, law-related research should (1) focus on the law and the legal institutional background as variables important to most research on the socioeconomic effects of earthquake prediction and (2) recognize that, like other variables, law and legal institutions will be variously perceived and therefore pertinent to the study of information generation, dissemination, and perception.

At the outset it is necessary to have some conception of the general function of law in human social existence. The natural world is made up of millions of factors, some of which are so highly predictable as to be absolute certainties for practical purposes, and others of which are highly unpredictable. That the sun will rise each day in the east is a practical certainty. That it will rain each day is an uncertainty that varies from place to place. There are human difficulties which result from the uncer-

tainties of rainfall, and man is slowly learning how to lessen those difficulties either by gaining some measure of control over the natural process of rainfall or by technologically lessening his dependence on regular and predictable rainfall.

Among the uncertainties of human life are those that result from human social existence. One who plants corn with the hope of harvesting a bountiful crop must worry not only about whether there will be sufficient rainfall, but also about whether someone will steal his corn or whether someone else's cow will stray into his field and eat his corn. Similarly, the person who is raising the cow must worry not only about its health, but also about whether some other person will steal it. There are some technological remedies available to both the farmer and the rancher. The cow can be either fenced in or fenced out, but then there will be the additional worry of whether or not the fence will hold, or whether the rancher might tear the fence down so that his cow can graze on the corn.[2]

It is a central function of law to limit social uncertainties such as these. By property rules, the law defines the relationship between the farmer and the rancher with respect to the corn and the cow. If the right of the corn farmer includes the right to exclude the rancher and his cow and further to collect damages from the rancher should the cow break through the fence and damage the corn, the behavior of the farmer is likely to be different from what it would be in the absence of these assurances.[3] The law, by limiting some of the uncertainties, modifies human behavior from what it would be without legal controls. A model based on a utilitarian conception of human behavior would suggest that with increased certainty there will be increased incentive to invest energy and resources in the improvement of one's situation. It is a theory of the role of law that has wide acceptance and that is supported by many general observations, but the understanding of the relationship between law-induced cer-

[2]Professor R. H. Coase uses a similar example in his article, "The Problem of Social Cost," *Journal of Law and Economics,* vol. 3 (1960), p. 1. A central point of Coase's analysis is that, assuming zero transaction costs, it makes no difference from a resource allocation point of view whether the rancher is liable for the damage done by his cow or the farmer is required to bear the costs associated with the rancher's proximity (e.g., trampled and eaten corn or the cost of constructing a fence). The implications of the Coase analysis for earthquake prediction are discussed in a later footnote.

[3]It is important to read this statement carefully. It does not say that the farmer's behavior is likely to be different if he has a right to be free from cow-induced injury as opposed to the rancher's having a right to be free from liability for cow-induced injury. The distinction drawn here is between the existence of defined and enforced legal rights as opposed to the absence of any such rights. It should be expected that human behavior will differ in these two situations.

tainty and human responses is extremely general.[4] Policy makers who seek to anticipate or encourage specific human responses to specific circumstances require considerable refinement in their understanding of the relationship.

A directly related point, particularly pertinent in the context of earthquake prediction, is that there must be readily accessible information about the law if it is to influence human conduct and provide certainty in place of the risks of unregulated human interaction. For example, once the law defines the relationship between the farmer and the rancher with respect to corn and cow, that relationship must be communicated to the rancher, the farmer, and others whose activities might conflict. This fact suggests an important realm of research on the dissemination of legal information and its processing by individuals, groups, and governments: From what sources do people acquire information about the law? How is legal information formally and informally communicated? What capacities do people have for comprehending the legal information to which they have access? The answers to these questions may suggest better means of disseminating legal information and modes of communication that will make it more understandable.

Given the fundamental idea that law is a means of encouraging productive decision making by eliminating some of the uncertainties of social existence, it becomes apparent that any sophisticated policy-making effort requires knowledge of how law operates to control uncertainty and influence human conduct. Specifically, if a policy maker anticipates that a likely response to an earthquake prediction for a particular area will be a decline in property values in that area, a desirable goal might be to minimize this negative impact. There are several possible legal actions that might influence property values, such as alteration of the property rights themselves, alteration in the tax structure, or alteration of the regulation of the insurance industry. All of these policy alternatives are based on some hypothesis about the anticipated human response. Researchers can do much to aid in forming policy by engaging in the theoretical task of hypothesis formulation and the empirical task of hypothesis testing.

A simple illustration follows. Assume that an earthquake prediction is issued for a particular area. Because of the officially certified prospect of an earthquake, property values decline. It might be concluded (1) that all

[4]One need not, of course, accept the utilitarian conception of human behavior as a natural, inalterable fact. Ashley Montague, for example, argues that man is naturally a social being whose modern obsession with self-satisfaction is the result of a corruption of innate characteristics. The utilitarian response is that when individuals act pursuant to an apparent social good they do so because they get more personal satisfaction out of contributing to that social good than from realizing some other private good. See A. Montague, *On Being Human,* 1967.

property holders who acquire their property after the prediction do so with the knowledge that their property is in an earthquake risk area and (2) that property holders have access to any existing information about the extent of that risk. Property holders will therefore have discounted their valuation of the property according to their estimation of the earthquake risk. Just as the property holder gets unexpected gain from discovery of previously unknown minerals under his land, so will he suffer unexpected losses from the discovery of earthquake faults under or near his land. But what if the official prediction is erroneous? In that case the diminished property value will not have been within the foreseeable expectations of the property owner. A decline of property values will result, and much in Anglo-American legal tradition suggests that the state should reimburse those injured by losses that result from the public pursuit of the public good.[5] Mitigating these losses may be accomplished by any of several means, including those suggested in the preceding paragraph. Possibilities include a moratorium on property taxes, provision of insurance after the issuance of a prediction, or transfer and purchase of injured property rights by the state. In addition to being concerned about "unjust" declines in property values—losses that could reasonably have been expected to be legally prohibited—the state may want to soften the impact of diminished property values for reasons relating to local employment and economic stability.

Problems of legal interpretation and problems of the relationship between law and human conduct involve different research strategies and interests. Problems of legal interpretation are the "stuff" of traditional legal research and, of course, important to the conduct of everyday legal affairs. Problems of the relationship between law and human conduct are not well studied by traditional legal research; rather their study requires the perspectives and methods of the social sciences. Although social science research is not common, the most frequently studied subject has been the economics of law.[6] Warren Samuels has reviewed much of the research on this subject.[7] The preeminent example is Richard Posner's economic analysis of law, which applies the methodology of economics to all the traditional categories of law and reveals the artificiality of much of the foundation for those categories.[8]

[5]Consider the "taking" or "compensation" clause of the Fifth Amendment to the United States Constitution.

[6]For a discussion of why the link with economics has been popular, see J. Krier, "Book Review," *University of Pennsylvania Law Review,* vol. 122 (1974), p. 1004.

[7]See W. Samuels, "Law and Economics: A Bibliographical Survey 1965–1972," *Law Library Journal,* vol. 66 (1973), p. 96. See also W. Samuels, "Legal-Economic Policy: A Bibliographic Survey," *Law Library Journal,* vol. 58 (1965), p. 230.

[8]See R. Posner, *Economic Analysis of Law,* 1977.

Other empirical studies of law include the Chicago jury study conducted by Harry Kalven and Hans Zeisel,[9] Martin Shapiro's *The Supreme Court and Public Policy,*[10] and a collection of studies of the social impacts of Supreme Court decisions edited by Theodore Becker and Malcolm Feeley.[11] There are a few others, but many questions are entirely unexamined.

Existing research on the relationship between law and human behavior, like the examples above, generally falls short of the type of research urged in this report. Studies in law and economics have generally involved theoretical formulation of hypotheses that are seldom empirically tested.[12] Much of what empirical work has been done has concentrated on criminal law, an important but narrow focus.[13] There have also been empirical studies of the behavior of legal institutions, an outgrowth of what Roscoe Pound called sociological jurisprudence. As Ronald Dworkin notes, "Some lawyers, like Jerome Frank and Pound himself, attempted to carry out this sort of study, but they discovered that lawyers do not have the training or statistical equipment necessary to describe complex institutions in other than an introspective and limited way."[14]

All this study notwithstanding, there is a need to examine in a general way the impact of law on society. Crime control is obviously important, as is the behavior of our legal officials, but the vast bulk of the law is addressed to the ordinary person, whose behavior it affects in some way. Policy makers, whether their concern is earthquake prediction or something else, cannot possibly hope to achieve their objectives fully unless

[9]See H. Kalven and H. Zeisel, *The American Jury,* 1966.

[10]See M. M. Shapiro, *The Supreme Court and Public Policy,* 1969.

[11]See T. L. Becker and M. M. Feeley (eds.), *The Legality of Supreme Court Decisions,* 1973.

[12]Law and economics theory has been tested in some historical studies. See, for example, T. A. Anderson and P. J. Hill, "The Evolution of Property Rights: A Study of the American West," *Journal of Law and Economics,* vol. 18 (1975), p. 163; G. Priest, "Law and Economic Distress: Sangamon County, Illinois, 1837–1844," *Journal of Legal Studies,* vol. 2 (1973), p. 469; and W. Hurst, *Law and Economic Growth: The Legal History of the Lumber Industry in Wisconsin, 1836–1915,* 1964.

[13]See, for example, H. Ball and L. Friedman, "The Use of Criminal Sanctions in the Enforcement of Economic Legislation: A Sociological View," *Stanford Law Review,* vol. 17 (1965), p. 197; W. Chambliss, "Types of Deviance and the Effectiveness of Legal Sanctions," *Wisconsin Law Review* (1967), p. 703; and G. Sykes, *The Society of Captives: A Study of a Maximum Security Prison,* 1958. For non-crime-related empirical studies, see, for example, H. Ball, "Social Structure and Rent Control Violations," *American Journal of Sociology,* vol. 65 (1960), p. 598; and A. Rose, "Sociological Factors in the Effectiveness of Projected Legislative Remedies," *Journal of Legal Education,* vol. 11 (1959), p. 470.

[14]R. Dworkin, *Taking Rights Seriously,* 1977.

they have an understanding of the social consequences of the various legal mechanisms and rules used in policy implementation.

Because of the primitive nature of our understanding of the relation between law and human conduct, initial inquiries must be at the level of what might be called basic research.[15] The questions to be asked will not be peculiar to the specific problem of earthquake prediction but that does not prohibit their being asked in that context.

The problem thus defined and recommended here as the type of law-related research that should be conducted can be separated into three parts: (1) an assessment of the processes by which individuals, groups, and governments acquire information about laws and institutions; (2) an assessment of how they interpret that information; and (3) an assessment of how they respond to laws and institutions.

For example, assume that in anticipation of future earthquake predictions and resultant negative impacts on property values, a state legislature enacts a law requiring insurance companies to sell earthquake insurance after the issuance of a prediction. The legislative hypothesis is that people will be encouraged to retain or purchase properties with the prospect of realizing a return on their investment in one way or another. The relevant questions for research in relation to this legal action are the following: (1) Have those whose conduct the action was designed to influence been informed of the law, and, if not, by what mechanisms or processes would they be informed in the future? (2) Do those the law was designed to influence comprehend the impact of the law? If not, how can such understanding be achieved? (3) How did the law affect the conduct of those persons it was designed to influence? In other words, was the legislative hypothesis correct, or must a new one be formulated?

THE ROLE OF LAWYERS IN THE RECOMMENDED RESEARCH

Lawyers are, with few exceptions, well able to collect and catalogue information about the status of the law. A principal focus of their formal training is on that very skill. Whether lawyers are also able to study inde-

[15] "Legal scholarship has not neglected the *outputs* of the system as thoroughly as the inputs (those factors which influence legal change and development). Rules and decisions are outputs, and most of the literature is about this subject. However, . . . the impact of output on the world outside is usually overlooked, assumed, or ignored." See L. Friedman, *The Legal System*, 1975, chapter 3. Friedman's book is the most significant contribution to the general question of relating law to human behavior. It is significant that Friedman wrote the book on the heels of his pathbreaking study, *The History of American Law*, 1973. That book is a history that repeatedly reveals legal changes based on policy carried out without an understanding of how the law would actually affect the human conduct that the policy sought to influence.

pendently the relationships between law and human conduct is less clear, and this question must therefore be a concern both of prospective researchers and of those considering the support of research proposals.

The methodology of traditional legal research—that is, research to determine the status of the law and for which the primary laboratory is the library—requires special skills with legal materials. More important, there are special skills needed to interpret and understand the information contained in those materials. For these reasons, it is imperative that any research effort in which the status of the law is a relevant variable include the services of a lawyer. For parallel reasons, lawyers will be, as a general rule, unable to conduct the research without the assistance of someone trained in the methodology of social science. The scarcity of such research, as evidenced by the dearth of reported results in the legal periodicals, is evidence not that lawyers are uninterested, but rather that they lack the methodological tools to conduct the research. There may be exceptions, but the burden must be on the lawyer to demonstrate methodological competence, which is not a requirement of formal legal training.[16]

The role of the lawyer, however, is not limited to cataloguing legal fact. There must be theories of human behavior in relation to the law from which models can be developed and tested. Lawyers, particularly academic lawyers, have both training and experience in legal theory and legal model building. This theoretical effort is central to understanding legal implications of the socioeconomic effects of earthquake prediction. There is no scarcity of such effort by lawyers, although none exists that addresses the legal implications of earthquake prediction. Those theories need testing, and it is that effort in which lawyers will generally require the assistance of social scientists.

PERTAINING TO POLICY

In contemplating earthquake prediction research that will assist in policy formulation, it is important to recognize the overriding limitations that arise from the basic nature of the American legal system. One can conceive of a theoretical solution to an anticipated legal problem, an exercise that may be both interesting and theoretically instructive. However, the realities of Anglo-American common-law jurisprudence dim the prospects for any significant social benefit from such theorizing. In the context of a research program seeking to influence policy in the short run,

[16]For a defense of this thesis, see J. Huffman, "Is the Law Graduate Prepared to Do Research?" *Journal of Legal Education,* vol. 26 (1974), p. 520.

legal scholars must recognize the inertia of a legal system with extensive and strong historical roots. Legal research that seeks to influence legal development and to facilitate public and private response to earthquake prediction technology must therefore address the changeable periphery of the legal system, and not its common-law core.

The implications of the assumption that the American legal system is slow to adjust to a changing world are important to developing a program for policy-relevant research on the legal effects of earthquake prediction. For example, a central issue is that of liability for injuries resulting from the prediction. There is much a legal scholar could consider about the effects of alternative approaches to liability, but a realistic research program must recognize the existing structure of public and private tort law and work around the system. Although the answer to any particular liability question may be unclear, the legal principles and rules on which the answer depends are relatively clear, as the discussion later in the chapter indicates.

Similarly, the constitutional factors that may have some relevance to the prediction process are fairly stable principles based on centuries of historical development. The specific constraints the Constitution imposes and the particular governmental authority the Constitution specifies may be unclear at times, but the underlying constitutional principles are unlikely to change in response to particularized social or technical developments.

In studying human responses to legal variables, it is first important to distinguish empirical facts and empirical hypotheses from legal hypotheses. Legal hypotheses are predictions about what legal officials will decide in particular situations. Research on formulating hypotheses is the daily work of practicing lawyers. As suggested above, publicly funded research should not, as a rule, be devoted exclusively to predicting legal interpretations. The exception is when such research is likely to lead to immediate policy action in the form of accommodating or altering legal constraints. For example, under the discretionary function exclusion of the Federal Tort Claims Act, the federal government may be liable for harm resulting from the negligent formation of the plan.[17] Assuming this legal hypothesis or prediction is likely to be correct, federal policy on earthquake prediction will benefit if it takes into account likely legal consequences. Alternatively, government policy might be advanced by altering the Federal Tort Claims Act and its judicial interpretations. For example, the act could specifically waive the government's immunity in the case of harm resulting from federal earthquake predictions, or it

[17]See the subsequent discussion of the Federal Tort Claims Act in this chapter.

could expressly assert the existence of such immunity.[18] Many states have similar tort claims legislation, and similar issues arise with respect to them.

Thus the formulation of legal hypotheses and the examination of such hypotheses is an appropriate subject for research unrelated to actual litigation, but only when government policy formulation depends on an informed prediction or legal hypothesis about what the law will in fact turn out to be after the courts have acted.

Empirical hypotheses and empirical facts are central to the kind of research for which this report calls. For example, the effects of a particular legal rule can be measured with varying accuracy that depends on the effects in question and the methodology available for measurement. This kind of empirical data is obviously important to policy making, since legal rules are both social variables and useful tools for policy implementation. Existing rules of liability no doubt influence human reaction to possible harm. If an individual knows that he will be liable for harm resulting from an erroneous official earthquake prediction, his response to that prediction is likely to be different from his response if he knows that the government will be liable for any harm.[19] The important problem for the policy maker is to determine what the responses to different liability rules will be and then to attempt to influence human actions in the desired direction either through manipulation of the liability rule or through other policies to counteract undesirable consequences of existing liability rules.

For legal research to be relevant to policy it must assist in coordinating hazard reduction measures with legal constraints. It must contribute to our ability to adjust the law for more efficient hazard reduction and to adjust our hazard reduction measures to conform to law. The law is a principal tool for policy implementation, but to use it effectively we must understand the probable consequences of particular legal measures. It is insufficient to call forth the policy power and impose theoretical hazard reduction measures. We must know whether or not the measure actually

[18]The Federal Tort Claims Act is a waiver of sovereign immunity with respect to certain types of suits. The problem involved in interpreting the act is determining whether the government remains immune from the particular suit at issue. See the subsequent discussion of this act in this chapter.

[19]Drawing upon Coase's analysis in "The Problem of Social Cost," referenced in footnote 2, Professor H. Demsetz, in "When Does the Rule of Liability Matter?" *Journal of Legal Studies,* vol. 11 (1972), p. 13, argues that the assignment of liability, again assuming zero transaction costs, will have no allocative effect. Two simple policy conclusions to be drawn from this and from the Coase analysis are that liability and property rights assignment may make a difference due to the reality of often high transaction costs and that rights assignment will have significant distributive as opposed to allocative effects.

has the anticipated effect, and we must know what the costs of the measure's implementation are in relation to its benefits.

THE STATUS OF THE LAW

Having recommended that research examine the relationships between law and human conduct, we must point out that both researchers and reviewers of proposals still need to acquire a general familiarity with the kinds of legal problems that may arise. The remainder of this chapter is a survey of prospective legal problems, with recommendations. There are three categories: (1) constitutional limitations, (2) tort liability, and (3) direct regulation.

Constitutional Limitations Numerous constitutional issues can be hypothesized in the context of public and private earthquake prediction, but few of them merit serious assessment as limiting prospective earthquake prediction activities. Should earthquake prediction and warning involve some type of self-activating warning device, concern will probably be expressed about potential violations of freedom of expression, invasion of privacy, and illegal search.[20] This concern would be based on the possibility of governmental misuse of home electronic devices, a threat which should not be entirely discounted, but which is unlikely to result in a constitutional prohibition on such warning devices. To be an unconstitutional constraint on free speech, governmental conduct must have a demonstrated chilling effect on the exercise of free speech.[21] The mere possibility of an invasion of privacy or of an illegal search has never been the basis for proscribing governmental conduct. Under existing First Amendment law, there should be no problem resulting from home warning devices.

Several due process issues might be imagined, some of which should be accounted for in policy formulation, but none of which requires extensive research.[22] The processes of prediction formulation and dissemina-

[20]"Congress shall make no law . . . abridging the freedom of speech . . ." United States Constitution, First Amendment. "The right of the people to be secure in their persons, houses, papers, and effects, against unreasonable searches and seizures, shall not be violated . . ." United States Constitution, Fourth Amendment. The right of privacy derives from the First, Fifth, Ninth, and/or Fourteenth Amendments depending upon one's preferences in judicial opinion. See *Griswold* v. *Connecticut, U.S. Reports,* vol. 381 (1965), p. 479.

[21]See, for example, *Laird* v. *Tatum, U.S. Reports,* vol. 408 (1972), p. 1.

[22]"No person shall be . . . deprived of life, liberty, or property, without due process of law . . ." United States Constitution, Fifth Amendment; ". . . nor shall any State deprive any person of life, liberty, or property, without due process of law . . ." United States Constitution, Fourteenth Amendment.

tion will likely be subject to any relevant due process requirements. For example, government hearings to determine the most effective dissemination system must, no doubt, comply with due process requirements of notice and right to be heard.[23] Similar due process requirements would certainly apply to government decisions formulated to respond to predictions. Depending on the administrative procedures adopted, the Administrative Procedures Act may or may not be a controlling factor.[24] However, the overriding justification for unusual governmental powers in the event of an emergency may limit, depending on the nature of the emergency, the applicability of normal due process requirements.[25]

Equal protection is a likely foundation for litigation.[26] The data collection system for earthquake predictions is not and certainly will not be of uniform benefit to the entire American population. Some may seek to challenge that the data collection system constitutes a violation of equal protection, on the grounds that others benefit from the official involvement in earthquake prediction while the complainant does not. If government prediction and warning services are provided to areas of high earthquake risk, however, as the Defense Civil Preparedness Agency's crisis relocation planning applies to areas with a high risk of nuclear attack, the government should have no difficulty overcoming equal protection challenges on this basis.

Other equal protection challenges might arise from the policies implemented as a means of mitigating the harm resulting from earthquake predictions. For example, the manipulation of rules of liability will probably be upheld if resulting classifications promote a legitimate state objective and if they do not arbitrarily discriminate against individuals or groups falling within various classes.[27] Lacking either of these character-

[23]See, for example, *Goldberg* v. *Kelly, U.S. Reports,* vol. 397 (1970), p. 254.

[24]*United States Code,* 5, section 551 and following; *Data Processing Service* v. *Camp, U.S. Reports,* vol. 397 (1970), p. 150.

[25]"The constitutional question presented in the light of an emergency is whether the power possessed embraces the particular exercise of it in response to particular conditions." *Home Building and Loan Association* v. *Blaisdell, U.S. Reports,* vol. 290 (1934), p. 398.

[26]"No state shall . . . deny to any person within its jurisdiction the equal protection of the laws." U.S. Constitution, Fourteenth Amendment. The provision may be interpreted to require the state to treat similarly those individuals who are to determine which people are similarly situated and when people are not being similarly treated.

[27]Under present standards, the U.S. Supreme Court applies a strict standard of review of legislative classifications based upon human characteristics—such as race, country of origin, and, according to some judges, sex, presumed to be illegitimate bases for legislative classification. Similarly, strict review is demanded when legislative classifications deny to some while granting to others a fundamental interest like voting or travel. Classifications

istics, any statutory classification will be upheld upon demonstration of a rational relationship to the government purpose of reducing earthquake harm.[28]

Other constitutional challenges may arise in the context of the Fifth Amendment taking clause because of land-use and building restrictions,[29] in the context of the contract clause to the extent that government regulation impinges upon existing contracts,[30] and in the context of violations of the right to travel to the extent that private movement is restricted. These are surely only samples of what the imaginative lawyer will contemplate, but none of them merits significant consideration at this point in policy formulation for earthquake prediction. Little can be done to prepare for such challenges, except to be cognizant of their likelihood.

Of course, high costs can attach to the resultant litigation, a factor that may justify action to discourage such suits. Experience suggests that in emergency situations, government is seldom kept from imposing limited restraints on constitutional rights. A critical issue, for which there is little precedent, is that of predicted emergencies in which the accuracy of the prediction is low and the lead time long. For example, can people be constitutionally forced to evacuate an entire city on the basis of a 50 percent probability of an earthquake's occurrence? And after evacuations based on two or three false alarms, will the court take a different view of the extent of the government's emergency powers? It is this anticipatory nature of government action in response to earthquake predictions that may raise some of the most difficult legal and policy questions.

Tort Liability The principal concern of most government officials involved in earthquake prediction is government liability for various types of harm that might result from an official prediction. Because the

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having either characteristic may be constitutional, but the state must meet a heavy standard of proof.

[28]Although the Fourteenth Amendment applies only to the states, the U.S. Supreme Court has frequently held that the equal protection limitation also applies to the federal government by virtue of the Fifth Amendment due process clause. See, for example, *Bolling* v. *Sharpe, U.S. Reports,* vol. 347 (1954), p. 497.

[29]To date, the taking clause has been an insignificant restraint on government imposed land-use planning and zoning. For a general discussion see F. Bosselman, D. Callies, and J. Banta, *The Taking Issue,* 1973.

[30]Long a dead letter, the contracts clause of Article I, section 10, clause 1, appears to have been dramatically revived in *United States Trust Company* v. *New Jersey, U.S. Law Week,* vol. 45 (1977), p. 4418, decided by the U.S. Supreme Court. The case may be a prelude to a similar revival of the taking clause, in which case governments will have increased difficulty taking action that infringes upon private contract and property rights.

doctrine of sovereign immunity forecloses suits against the federal or state governments except when the government voluntarily waives its immunity, the legal issue is whether under existing legislation there has been a waiver of sovereign immunity with respect to injuries resulting from government involvement in earthquake prediction. The principal relevant federal legislation is the Federal Tort Claims Act,[31] and most states have similar laws about state government liability.[32]

There are several types of government action in the issuance or regulation of predictions which might be the proximate cause of injury: (1) malfunction of broadcast or other prediction and warning communication equipment; (2) incomplete or inaccurate broadcast or communication of known earthquake hazard information; (3) inadequate or negligent interpretation or collection of data; (4) failure to provide data collection, prediction, and response capacity where there is a duty to do so; (5) licensing or certification of incompetent private predictors; and (6) failure to regulate private prediction where there is a duty to do so. All of these matters must be considered under the Federal Tort Claims Act and relevant state and local legislation.

Although issues raised under the Federal Tort Claims Act do not have clear answers, analysis of them is straightforward. The purpose of the act's waiver of governmental immunity was to make the government liable for ordinary torts—those actions by government which, if performed by an individual, would lead to a finding of individual liability for harm. There are several exceptions to the waiver of governmental immunity. The government is not liable where the proximate cause of the harm is misrepresentation, an exclusion that relates to some cases involving negligence. However, the analogy of government warnings to ships by means of lighthouses is instructive.[33] The Supreme Court has held that government failure to assure continued operation of a lighthouse was negligence, not a misrepresentation of no danger, and that the government was therefore liable for damage to a barge that had relied on the lighthouse for navigation. Whether government issuance of an inaccurate prediction or failure to make a prediction would be found to fall under the misrepresentation exclusion or to constitute negligent behavior for which the government would be liable must remain an unanswered question until the courts or Congress have occasion to address the specific issue. However, the legal questions are clear.

Also excluded from government liability are cases involving the execution of a regulation or statute and the exercise of discretionary govern-

[31] *United States Code,* 28, section 2674 and following.

[32] See, for example, *Annotated California Code,* "Government," section 815 and following.

[33] *Indian Towing Co., Inc.* v. *United States, U.S. Reports,* vol. 350 (1955), p. 61.

mental functions. The government is immune from liability for harm resulting from discretionary acts even if such an act is negligently performed or an abuse of discretion. Legal analysis has distinguished discretionary functions from ministerial powers, the theory being that discretionary government activities are voluntary, not mandatory, and would be discouraged if the government were held liable for any resultant harm. The question in the context of earthquake prediction is whether the prediction process is a discretionary one for the government to pursue. If it is, the government would not be liable for any harm resulting from the issuance of a prediction. Although many lawyers have argued for a narrow reading of the discretionary function exception, it is possible that, properly formulated, an earthquake prediction program could not be the basis for government liability. Some states adopt a distinction between government and proprietary functions, which holds the state liable only in cases of injury resulting from proprietary functions, but that distinction has been expressly rejected under federal legislation.

A related question is whether the legal authorization for implementation of an earthquake prediction program imposes a duty to warn upon the federal or state governments. This is obviously a question in part of the language of the legislation and regulations. However, a duty to warn might arise from the applicable common law or from some voluntary course of government action that invites reliance. Duty to warn questions have generally been analyzed in private law terms, the courts finding that where a private individual would have a duty to warn, so would a government.

Another possible source of government liability might be the existence of government-sponsored structures which could collapse or cause damage in an earthquake. For example, a government-financed dam might be located upstream from a community for which an earthquake prediction has been issued. With the issuance of the prediction, property values might decline drastically, and the town might have to be evacuated because of the dam. Without the dam the prediction would have fewer significant costs, since the earthquake hazards would then be limited to those associated with the structures in the town itself. Numerous other government-aided or government-sponsored projects, like highways and nuclear power plants, would raise similar threats in the event of an earthquake prediction. The relevance of apparently unrelated government activities like dam construction and maintenance is a factor that should influence government decisions about the scope and form of a prediction program.

Although a cursory examination of legal principles suggests that government liability is unlikely in any of the several circumstances hypothe-

sized about earthquake prediction, cases involving seemingly analogous government warning programs (e.g., lighthouses, air traffic) would suggest that there may indeed be a chance of liability.[34] The earthquake prediction situation is quite different in that the technology is less reliable than the technology involved in weather forecasting, air traffic control, or coastal hazard warning. The effect of this technological difference is an issue to be considered in the context of government tort case law.

A final point about government liability is recognition of the possibility that an express waiver of sovereign immunity might facilitate the effectiveness of a government prediction program. Private organizations and individuals might be more inclined to respond to government earthquake predictions and warnings if the government voluntarily assumes responsibility for any harm that might result from an erroneous or otherwise damaging prediction. This poses a policy question that would have to be analyzed in terms of the expected benefits to be derived from earthquake prediction over the long term, but it is an alternative that will probably be considered. Of course, the government might also assert its sovereign immunity by expressly exempting earthquake prediction activities from those covered by the pertinent waiver of immunity from tort liability.[35] The importance of an understanding of the role of law in human decisions is particularly apparent in cases such as these where policy seeks to affect human behavior by altering legal rules.

There are some possible issues of private liability for harm associated with earthquake predictions. The prospect of suits against private predictors is evidenced by the consideration in the Los Angeles City Council of a suit against Dr. James Whitcomb and the California Institute of Technology.[36] The issue may be formulated differently. Does an individual with the technical skills to predict earthquakes have a duty to do so? Or does such an individual have a duty not to do so without first having the prediction reviewed by a government agency? General tort principles would at least suggest that once a private individual undertakes to predict and thereby warn of an earthquake, he must take due care in issuing the warning. From the individual scientist's point of view, the problem is a difficult one; many scientists feel a moral obligation to warn of possible disaster.

[34]See, for example, *Ingham* v. *Eastern Airlines, Inc., Federal Reports,* 2d Series, vol. 373 (1967), p. 227; and *Indian Towing Co., Inc.* v. *United States,* referenced in footnote 35.

[35]For a general statement of the principle of sovereign immunity see *United States* v. *Show, U.S. Reports,* vol. 309 (1940), p. 495.

[36]A resolution was introduced in the Los Angeles City Council proposing to sue Dr. Whitcomb for injuries to the city resulting from what many considered to be a prediction. The resolution was not adopted. See Los Angeles City Council resolution (Council File #76-1719), January 22, 1976, introduced by Councilman Louis Nowell.

Other questions of possible private liability include the following:

1. What is the liability of engineering firms involved in building inspection and certification for earthquake resistance? For example, a building owner may rely on the assurances of an engineer and not take other precautions in response to an earthquake prediction. If the building subsequently collapses in the earthquake, is the engineer in any way liable?
2. What is the liability of private individuals whose failure to respond to an earthquake prediction results in injury to their employees or others with whom they associate? For example, is an employer who fails to evacuate his employees liable for harm that any of them suffers in the event of an earthquake?
3. What about the reverse situation to that suggested in question 2 above? If a private individual closes his business for a period in anticipation of a predicted earthquake that fails to occur, is he liable for his employees' lost earnings?
4. What about the problem of liability relating to privately owned hazardous structures that are used for nonresidential purposes? Is the owner of a dangerous private structure liable if adjacent property values fall in the event of an earthquake prediction?

One can pose numerous other liability cases. For the purposes of this report, however, the important point is that although many of these issues may eventually be raised in the courts and are therefore relevant to earthquake prediction policy, they are not issues on which extensive research can currently be justified. The adversary nature of the American legal process makes prediction about outcomes an uncertain task. Policy makers are generally best advised to recognize potential legal problems and try to anticipate their effects. When specific government and private programs such as a plan for earthquake prediction review and issuance are anticipated, legal research on issues of liability may well be important in deciding what modifications the policy may require before it is enacted. Abstract research on these liability questions, however, is unlikely to yield significant benefits.

When the recommended research focus is applied to problems of tort liability, it yields the following conclusion: The policy objective should be to optimize the net benefits from earthquake prediction, which may require accommodating or altering tort rules. Neither can be achieved without first understanding how the tort rule in question influences human conduct. Research yielding this understanding will allow policy makers to act intelligently in relation to questions of public and private liability.

Direct Regulation of Earthquake Prediction and Its Effects The specifics of direct regulation are discussed elsewhere in this report. However, some general discussion is relevant to the theme of this chapter. The legal system has been described as a means for controlling some of the uncertainties that arise from human social existence. Earthquake prediction is an attempt to lessen the uncertainties people suffer in relation to natural processes. But the human activity of earthquake prediction will require legal definition of human relationships just as did the raising of cows or the growing of corn.

Viewed from this perspective, it is imperative that the source of government authority to issue earthquake predictions be clearly defined. This definition will allow government to identify legitimate means of involvement in earthquake prediction and also will allow private parties to know where they stand in relation to governments involved in earthquake prediction. There is little if any doubt that government may be legitimately involved in earthquake prediction, but the legal objectives of certainty and justice will be facilitated if the scope of the power is clearly defined.

Similar considerations relate to government activity designed to reduce the costs associated with earthquake prediction. The source and extent of government power to enact building codes and land-use plans, for example, ought to be well defined, so that people know what to expect. The policy decisions of whether to adopt these forms of regulation, and if so in what manner, are of course preliminary. These decisions will be made more intelligently if decision makers have the benefit of information about individual and institutional responses to legal variables. Policy decisions based on untested hypotheses are experiments at best. At worst they are random and likely to achieve little. An overriding issue is always whether government action is desirable at all. Many situations may be best handled by private actions taken within a well-defined set of legal relationships.

SUMMARY

Legal research should be designed to develop an improved understanding of the role of law in affecting human responses to earthquake prediction. Because law is probably the most useful and most used tool of social policy implementation, it is imperative that its role be understood. Moreover, because law is an important social variable, it must be considered in almost any sociological, economic, or political study. Lawyers are necessary participants in this research, but few are adequately trained in

methodology to perform the research independently. Traditional legal research—that is, the determination of legal doctrine—will seldom be justifiable except in the context of specific policy implementation. Finally, government regulation is an integral part of the system of legally defined relationships and must therefore be studied in the context of the entire legal system.

7 Studies of the Generation and Dissemination of Earthquake Predictions

Earthquake predictions will originate primarily from the activities of earth scientists engaged in scientific inquiry and application of science-based technology. The geophysical data will be evaluated by an individual scientist, a group of scientists, or a government agency, who may decide to issue publicly a prediction or a warning. The public at large will typically receive its initial information from mass media reports, but information from other sources will play a role later. Moreover, if the lead time between the prediction and the earthquake is as long as several weeks or months, there will be ample time to revise the prediction in response to new geophysical information and public reaction.

This chapter identifies a series of research topics dealing with the processes by which earthquake predictions are generated, updated, and disseminated. In terms of our conceptual framework, these discussions elaborate the contents of box 1 in Figure 1 and its connections to other components in the model. It focuses on the two groups most prominently involved—earth scientists and news organizations—although other predictors and information channels will also be noted.

GENERAL PERSPECTIVE AND MOTIVATION FOR RESEARCH ON THE PREDICTION PROCESS

Public interest in earth scientists and news media follows from our characterization of the prediction problem in chapter 1. If predictions were

precise as to time, magnitude, location, and probability, if their theoretical bases were firmly established and widely accepted, if lead times between prediction and event were short, and if patterns of response to predictions were firmly embedded in tradition, then the dynamics of generating and disseminating predictions would be of little interest here. The only problems would be to see that earth scientists got the resources they need and that accurate information reached the public. But as we have noted, these conditions are not likely to be met for some time. On the contrary, the technology will probably require the predictor to make quite complex judgments that will be open to challenge within the scientific community itself, and the proper actions (predictions, news releases, and warnings) will not follow in a simple manner from the data alone. Accordingly, it is important to study how these judgments will be made.

The proposition that a prediction or warning will involve making a complex judgment rather than an automatic response is fundamental to our approach and, in our view, justifies careful study of the seismological community and the news media. We know that even in the simplest judgmental process, like the detection of a weak signal in a background of noise,[1] anticipated consequences of the judgment, expectations about the frequency of the signal, and other motivations determine the response in addition to the signal itself. Such factors are isolated and controlled experimentally, rather than ignored, by psychophysicists. Moreover, when individuals must make judgments in ambiguous situations, they are particularly open to outside influence; and even when the situation is clear to a particular individual, controversy among his peers often leads him to modify his response.[2]

Of course, we are not implying that social and psychological processes will be the major determinants of whether a prediction is issued. We believe, however, that because of the complexity of judgment and the lack of firm theoretical grounding of predictions, such factors cannot and should not be passed by. The major motivation of predictors will be to meet their intellectual responsibilities to the public at large. But to the extent that these responsibilities are not clearly defined in a particular (complex and ambiguous) situation and to the extent that these responsibilities are open to controversy and varying interpretations, it is impor-

[1]See R. D. Luce, R. R. Bush, and E. Galantes, "Detection and Recognition," *Handbook of Mathematical Psychology,* vol. 1, 1963, pp. 103–189 and references cited within.

[2]See the experiments by M. Sherif and S. Asch, which are fundamental in social psychology, and the large body of literature on them. The original experiments are M. Sherif, "A Study of Some Social Factors in Perception," *Archives of Psychology,* no. 187 (1935); and S. Asch, "Effects of Group Pressure on Modification and Distortion of Judgments," *Group Dynamics,* 1953.

tant for scientists and policy makers alike to take account of any possible impact the factors noted above may have.

Judgmental and external factors will be important at three points in the prediction process: (1) whether to issue a prediction (and what kind it should be) given the geophysical data; (2) whether to issue a warning given a prediction; and (3) whether (or how) to revise predictions given new geophysical information and feedback. As we have noted in chapter 3, the consensus among predictors and the degree of confidence they express in their predictions will probably be important determinants of public response. How such consensus might be achieved and whether it is desirable to achieve consensus in the face of legitimate disagreements are problems we shall want addressed. Similarly, the question of how warnings should be issued (and by whom) is closely related to the question of the effectiveness of alternative ways of making these decisions. Given the controversial nature of prediction technology assumed here, the answers to such questions will not turn on logical deduction alone.

In studies of the processes by which predictions are generated, evaluated, and revised, the psychology of the predictors will be of less concern than will their relationships and the organizational and professional affiliations that shape their actions. This point is particularly pertinent, since many of the policy questions that must be addressed—the kind of prediction-evaluation mechanisms to be set up, the phrasing of warnings—are basically organizational.

Before we suggest specific research topics on the prediction process, it might be well to illustrate further the kinds of problems we have in mind. We have indicated that if the prediction technology requires complex and probabilistic judgments on the part of predictors, then peer pressure and public response to the initial statement, media pressure, and a host of other factors will probably be important. We know little about which such factors will affect the prediction or its updates, or how they will do so. Will initial media pressure force the predictors to make their predictions more specific than originally intended, as was the case in the Kawasaki, Japan, prediction in 1975? Will the attitude of other scientists who disagree with the interpretation of the predictors' data compel the predictors to retract their predictions or issue a "backing off" update? Will scientists be reluctant to issue predictions in the first place, for fear of the disruptive socioeconomic consequences that might befall the target community or for fear of personal or institutional liability? In order to understand the consequences that predictions may have on society, it is necessary to understand the effect that society may have on predictions.

To illustrate the effects of the scientific organizational structure on earthquake predictions, we might hypothesize that if earthquake predic-

tion as a field of study has a "community of scholars" with common interests, a sense of identity, and a strong peer network, then an individual predictor may have strong group support in the face of critical reactions from outsiders. Conversely, if earthquake prediction research is carried out by individual scientists from several competing and unaffiliated disciplines with minimal contact and without a sense of communal identification, then an earthquake predictor may face the consequences of the release of his information with less social armor than would be the case in the previous illustration.

STUDIES OF SEISMOLOGISTS AND OTHER EARTH SCIENTISTS INVOLVED IN EARTHQUAKE PREDICTIONS

One line of research should address the nature of the earth sciences and pursue questions related to their structure. One set of issues relates to the question of the extent to which scientists engaged in research related to earthquake predictions represent a "community" that influences the behavior of its members. How do predictors see their role in the prediction process? What is their role relative to the government?

GROUP CHARACTERISTICS

There are a number of questions that need to be addressed on the collective aspects of this scientific endeavor. What is the nature of the interaction among seismologists and other earth scientists involved in earthquake prediction? To what extent do those working in this area exhibit group characteristics? How do the different disciplines involved in earthquake prediction research relate to one another? More specifically, what is the frequency of contact among those involved in earthquake prediction and the density of the network of relationships?

The collective expectations and sentiments that exist among earth scientists involved in earthquake prediction should be identified, particularly the degree of consensus with respect to professional ethics, public responsibilities, and relations with the public, with the government, with journalists, and so forth.

Additional data should simultaneously be gathered on the behavior of earth scientists with respect to other groups. For example, scientists might be asked for their beliefs about popular understanding (or misunderstanding) of science as a whole, of the nature and dynamics of earthquake prediction technology, and of the meaning of prediction

statements—especially those portions dealing with the probability of occurrence. Included here would be questions on assumptions about the way people are likely to react to predictions, about social and economic consequences of predictions, and about how predictions should be handled.

STUDIES OF THE RELATIONSHIP BETWEEN THE SCIENTIFIC COMMUNITY AND OTHER COMPONENTS OF THE SYSTEM

Another important set of issues surrounds the relationship between the earth scientists and engineers and the other participants in the framework described in chapter 2. Three of these are discussed here—other predictors, the public at large, and the government.

RELATIONSHIP WITH OTHERS INVOLVED IN EARTHQUAKE PREDICTIONS

The probable relationship between the extent of consensus among scientists regarding the validity of a prediction and the response of recipients of prediction information has been noted. Of similar importance would seem to be the extent of agreement between earth scientists and other claimants to earthquake prediction capability. Included here would be nonscientists and pseudoscientists who attract widespread popular attention with provocative forecasts.[3] But also included would be amateur groups using simple scientific instruments, and researchers from disciplines other than the earth sciences, such as zoologists using unusual animal behavior to forecast possible quakes or reputed astronomers forecasting on the basis of orbital configurations and gravitational stress.

Whatever the contesting group, the extent of competition or conflict with earth scientists, especially when it is reported by the news media, is of both theoretical and practical interest. Until the reliability of one or another prediction technique is firmly established, competition between scientific and nonscientific groups and between different scientific disciplines appears likely. An important research variable is the relative ability of each contestant to control scarce resources, such as research funds, as well as the formal mechanisms of prediction evaluation, popular pres-

[3]For a description of several such situations, see J. E. Haas and D. S. Mileti, *A Report to the National Science Foundation on Socioeconomic and Political Consequences of Earthquake Prediction,* 1977; and R. A. Stallings, "Collective Behavior and the Prediction of an Earthquake: Preliminary Considerations," 1977.

tige, and the like. Analogues for developing hypotheses may be found in social science literature on the professions and on professionalization. The early history of relations between doctors and midwives and the recent interplay between medicine and osteopathy are illustrations.

RELATIONSHIP WITH GOVERNMENT

Previous discussions in disaster literature use the term "warning" to encompass both measurement and evaluation of environmental changes, as well as dissemination of information about actions to take to prepare for the event. With the relatively short period of time typically involved between detection of the first signs of threat and the first possibility of impact, this all-encompassing approach seems appropriate for most instances of hazard warning, since the same people are involved in both forecasting and at least initial warning. But perhaps because of uncertainties and the extended lead times, a division of responsibility has evolved whereby scientists formulate and assess a prediction, while state and local government officials decide about issuing warnings. This distinction has two important implications for framing research: It underscores the fact that different groups engage in these distinct processes, and it renders problematic rather than certain the relationships between the two and, hence, between acts of prediction and acts of warning.

An important research topic therefore concerns the views of each group on the responsibilities and expectations of the other. For example, after initial issuance of a prediction by scientists, local officials may await further instructions from them as to precisely when to issue a warning, and failing to receive this, they may issue none at all. Should there be public displays of conflict between scientists and officials, the effects of such controversy on the public should be assessed in the course of related research on a sample of households (see chapter 3).

Questions of the relationship between science and government are of course neither new nor limited to the topic of earthquake prediction. The role of government in science and the attitude of scientists toward government are larger in scope than are questions about earthquake predicting. Hence development of analogues such as the relationship between scientists and government in many arenas—consumer protection and product safety, communicable disease control and epidemics, television violence, genetics, biological and chemical weapons—should suggest hypotheses. Issues of the proper role of scientists in the warning process—and of the proper role of government in the prediction process—are clearly important policy questions.

RELATIONSHIP WITH THE PUBLIC

Several issues on public relations have already been discussed; only two further points need to be added. One has to do with the subjective qualities of a prediction and how these might differ between scientists and the public. The term "credible prediction" has been used to signify a prediction that people accept as plausible, but scientists and the public apply different criteria in assessing plausibility. Thus there is a distinction between the validity of a prediction and its credibility. Validity constitutes the technical merits of a prediction as perceived by scientists; credibility is a characteristic of the public's subjective perception of the prediction. Several implications follow from this distinction. For one thing, it is easy to characterize a prediction having little validity but wide credibility. Earthquake predictions for California as well as other parts of the world in late 1976 and an earlier prediction by a seer in North Carolina are two examples.[4] But the opposite case, a prediction with great technical merit but relatively little credibility, is also possible.

By separating the technical merit of a prediction from the credence it is given by the public, the researcher is able to ask questions about the correlation between validity and credibility. The correlation between them is likely to be low, especially early in the development of the technology. Second, this distinction clearly suggests that credibility is a function of social forces encompassing more than purely technical considerations. Its determinants should be sought in the public milieu, not from the makers of earthquake predictions.

There is a second somewhat different issue involving links between scientists and the public at large. A statement forecasting some future earthquake too vague to be considered a prediction by scientists (who require that a prediction include statements of time, magnitude, location, and probability) may well be considered a prediction by the public, even though the term "prediction" is not used. This possibility seems likely, given the problems that officials and media representatives have in understanding the state of the art of prediction and prediction evaluation, and the belief that—especially in the first few instances—scientists will be conservative in their use of the label "prediction."

One conclusion is that it is difficult to say just when an earthquake prediction exists. In fact, an earthquake prediction may be in effect for some (e.g., residents of a community at risk) but not for others (e.g., scientists, local officials). In other words, some people may be behaving as if a quake had been forecast while others act in the belief that no such

[4]Haas and Mileti, *Socioeconomic and Political Consequences of Earthquake Prediction.*

prediction exists. Researchers should guard against a "technological fallacy," that is, assuming that people will take predictions into account only after technologically sound predictions are possible. It is incorrect to assume that people will wait to act until scientists signal the right moment. There is much to be learned from early near predictions, first, because they are likely to trigger behavior from which inferences may carefully be drawn to anticipate the consequences of later, more definitive predictions and, second, because the effects of near predictions are likely to be felt throughout the entire warning and response system.

SCIENCE AND TECHNOLOGY OF EARTHQUAKE PREDICTIONS

We have treated the field of earthquake prediction as if it were a science in the traditional sense. That is, we have assumed that the field consists of individuals engaged in deriving hypotheses from developing theory, collecting data on the variables found in those theories, and making decisions regarding their merits. Furthermore, we have assumed that one of the prime objectives of this activity is to contribute to knowledge of geophysical phenomena.

At the present time these assumptions seem correct. That is, the behavior of scientists most visibly involved in activity labeled "earthquake prediction research" is consistent with this concept of the scientific enterprise. However, whether the bulk of earthquake prediction work in the future will remain of this type is a question researchers should bear in mind. One possibility is that the field will evolve into a "technology" rather than a science. That is, reliable techniques may emerge for predicting earthquakes based on low-level, nontheoretical propositions of an "if x, then y" type. Organizationally, the development of such technology would surely mean that different sets of individuals and organizations would be involved. The bulk of funding would be expended as operating costs of an earthquake prediction system rather than as basic research, which might have to "ride piggyback" on top of development activity. The result might well be described as the evolution of a "technological community." A useful analogue of this form of development might be the United States Weather Service.

ORGANIZATION OF THE PREDICTION PROCESS

There are many ways of organizing the production, evaluation, and promulgation of predictions and warnings. Moreover, we have yet to take into account the organizational settings in which scientists work. An important policy question, then, is this: What are alternative ways of

organizing the prediction activities, and which will best serve the public interest? Comparative organization studies should address this question: What are the alternative organizational arrangements, and how should they be compared?

One system would be to let the scientific community develop the predictions, peers evaluate them, individual scientists and laymen decide whether a warning is indicated, and the public at large do the best it can. Perhaps this method might be supplemented by adopting an explicit code of ethics, as is the case for meteorological predictions and warnings. Most observers agree that the scientific community is ill equipped to fulfill this role, especially if it has to act expeditiously. Nevertheless, this form of organization works well in other areas, is not particularly subject to special interests, and seems well suited to attract talented and imaginative practitioners. It thus cannot be dismissed out of hand.

Another procedure might be to keep the process of prediction and warning as much as possible within a specific government agency. This agency would then gather the data and make predictions, review them for validity, and decide with the public's good in mind what information should be released and what warning is warranted. (The U.S. Geological Survey's current procedures resemble this arrangement.) Such a procedure would, however, be subject to all of the failings of public bureaucracies. Recruitment patterns would differ from those of a university-based prediction system. Career scientists might be hesitant to act if they had to face review by their own agency, and the review panel itself might be subject to defensiveness. Internal decisions about the public good might not substitute adequately for the political process, and the interests of significant groups might be ignored. Then, too, there is a question of whether prediction and warning can be successfully kept to the designated group and other would-be participants excluded from the field. If a warning is not made, there is some legal question as to whether the prediction must be released under the Freedom of Information Act. If this is the case, can standards be written and monitored to prevent opportunistic use of the information? It is not obvious that the use of public bureaucracy—despite its dependability, objectivity, and professionalism—is better than an unregulated system.

A third option is that earthquake prediction could be a profitable form of private enterprise and therefore best handled by market mechanisms. As prediction technology becomes more routine and less tentative, the market would provide a realistic alternative to the first two arrangements. Private business engages in weather and economic forecasting activities similar to an advanced science of earthquake predictions. In terms of their effect on land values, for example, there is little to distinguish the work of geologists who search for oil, which might increase the

value of land, from the work of geologists who search for earthquake danger, which might diminish the land's value. Indeed, market incentives might speed up the development of the technology, and competition between companies might produce a better product. On the other hand, one can argue that the inability of the public to judge the quality of the product it is "buying" might lead to market failure and rampant opportunism and that some form of regulation might be required. Along these lines, one would then consider the relative performance of such regulatory alternatives as licensing and certifying predictors and warners, establishing a set of standards on how predictions must be made and promulgated, and franchising prediction authority to qualified firms who agree to abide by contractual terms and supply a prediction of high scientific merit.

These three arrangements are simply illustrative, and further work is needed to provide additional specifications. They should, however, give an indication of the importance of organizational considerations in the development of earthquake prediction policies.

THE ROLE OF THE MASS MEDIA IN DISSEMINATING EARTHQUAKE PREDICTION INFORMATION

GENERAL RATIONALE

The general rationale for focusing attention on the mass media of communication and their role in disseminating information on earthquake predictions is based on several theoretical and practical considerations. First, studies of how the mass media collect, process, and disseminate news about disaster predictions, warnings, and actual impacts are obviously important for understanding the behavior of people and organizations in the predisaster and postdisaster periods. Disaster research studies conducted during the past 25 years have repeatedly documented the key role of the mass media in influencing people's interpretations of and responses to disaster-related events.

Second, the disaster prediction, warning, and impact contexts provide unique opportunities for examining the more general problem of the nexus between the mass media's handling of news events and the behavior of their audiences. Because disaster-related reporting carries with it the aura of potential or real danger to people, property, and the social order, it is more likely to be attended to and acted upon by people and organizations in the affected area. Thus the linkages between the mass

media handling of information and the subsequent behavior of members of the audience are probably more easily identifiable in the disaster context than in the context of reporting on more routine, nonthreatening news.

Finally, many of the usual difficulties of securing the cooperation of news media representatives in studies of their organization and mode of operations are likely to be lessened because disaster-related news is so obviously and clearly related to the public's safety and welfare. It is therefore possible to develop a greater sense of importance and legitimacy for studies of disaster predictions, warnings, and impacts than for studies of other types of newsworthy information.

THE MASS MEDIA ROLE IN DISSEMINATING EARTHQUAKE PREDICTIONS AND WARNINGS

An understanding of the socioeconomic consequences of earthquake predictions requires an understanding of how the mass media handle information on predictions and warnings. Predictions and warnings of earthquakes do not pass directly to members of the threatened community; rather, dissemination of earthquake prediction information falls within the domain of the news media. The information received by such organizations, the way it is prepared for dissemination, and the content ultimately transmitted to the public all influence the actions of people in the danger zone.

The following three hypothetical examples may serve to highlight how the mass media handling of earthquake prediction information may influence the behavior of people and organizations in the threatened area. First, assume that an earthquake prediction has been issued and that 90 percent of the members of the scientific community interviewed by researchers believe the prediction to be valid. However, local television stations, which have a policy of giving equal time to dissenting views on controversial issues, give equal weight to those who hold the prediction to be valid and those who do not. The public thus receives a different image of the extent of consensus in the scientific community than actually exists. Second, an in-depth report of a family's selling its home in order to move away from the danger area is presented as representative of local response to the prediction when, in fact, no other families are taking such action. Finally, and more fundamentally, general editorial policies make it likely that a disproportionate amount of attention will be devoted to reporting the negative impacts of predictions. The decline of property values in the target community, for example, would be more likely to be

seen as newsworthy and reported than would the fact that property values remained unchanged as a result of the prediction.

In analyzing the role of the mass media, the Committee suggests the need for three types of studies of predictions, near predictions, and quasi predictions: (1) content analyses of news reports, (2) the analysis of the structure and policies of news organizations, and (3) the links between the news media and other organizations.

Analyses of News Reports The content of both written and broadcast reports should be described for the entire cycle of the prediction (i.e., from first public announcement through the postearthquake period). Such descriptions should not only include the substance of news stories but also information on how prominently the stories are displayed (e.g., front page above the fold in the case of newspapers, lead story versus short statement as a lead-in to the weather report in the case of radio and television), whether they rely on wire service reports exclusively or use follow-up interviews by local reporters as well, whether the tone is alarmist or skeptical, and so on.

Past studies of the media in disaster have generally been of two types, neither of which is especially germane to the earthquake prediction problem. Some have examined the role of the media, especially radio, in the immediate short-term warning situation;[5] others looked at local news coverage of the aftermath of disasters.[6] More relevant here are studies of news policies of radio and television stations for broadcasting disaster news[7] (see below) and studies of audiences supposedly panicked by frightening (fictional) news stories.[8]

Purposive sampling of the news media is recommended for the larger metropolitan areas. Samples should be guided by the following parameters: size of market (radio and television stations with the largest news

[5]See W. A. Anderson, "Disaster Warning and Communication Processes in Two Communities," *Journal of Communication,* vol. 19, no. 2 (June 1969), pp. 92–104; and R. A. Stallings, *A Description and Analysis of the Warning Systems in the Topeka, Kansas Tornado of June 8, 1966,* 1967.

[6]See H. E. Moore, *Tornadoes over Texas: A Study of Waco and San Angelo in Disaster,* 1958, pp. 194–205; J. Waxman, "Local Broadcast Gatekeeping during Natural Disasters," *Journalism Quarterly,* vol. 50, no. 4 (Winter 1970), pp. 751–758; and J. Hannigan, *Newspaper Conflict and Cooperation after Disaster: An Exploratory Analysis,* 1976.

[7]See R. M. Kueneman and J. E. Wright, "News Policies of Broadcast Stations for Civil Disturbances and Disasters," *Journalism Quarterly,* vol. 52, no. 4 (Winter 1975), pp. 670–677.

[8]See K. E. Rosengren, P. Arvidson, and D. Sturesson, "The Barseback Panic: A Radio Programme as a Negative Summary Event," *Acta Sociologica,* vol. 18, no. 4 (1975), pp. 303–321.

audience should be included as well as newspapers with the largest circulation, daily and Sunday); class and ethnicity (stations and papers catering to the major population groupings in the area covered by the prediction, such as the black community, ethnic communities, and class-related audiences like listeners of country-western radio stations); region (media oriented to specific geographic areas of the metropolitan area—included here would be any urban-rural differences in programming orientation); and special interest media (underground newspapers, teen-oriented FM rock stations, etc.). Such data should reveal which elements of the threatened population are *not* reached by the media, as well as what information various audiences receive. In smaller cities, all media would be monitored.

Analyses are obviously more easily conducted with the printed media, since newspaper or library archives may be consulted. Special problems are encountered with electronic media, however. Radio news broadcasts can be recorded and transcribed; television news reports likewise can be recorded on audio tape, with field notes to describe visual characteristics of the broadcast if video tape equipment is not available. In places where the number of stations outnumbers researchers, some sampling may be employed to monitor different stations on different dates. In any case, record keeping by news organizations (of news scripts, broadcast tapes, and the like) should not be overestimated.

ANALYSIS OF THE STRUCTURE AND POLICIES OF NEWS ORGANIZATIONS

Factors affecting the content and handling of information on earthquake predictions and warnings should be sought in the structure and policies of news organizations. Here the organization itself (or perhaps that subdivision responsible for news) becomes the unit of analysis.

Structural variables possibly related to the content of news might include the presence of a specially designated science writer; the absolute number of reporters available to cover news stories (day, night, and weekend); the pattern of assignments for reporters (is one reporter designated to handle all earthquake prediction stories, or are stories assigned to whoever is available regardless of expertise?); and the amount of discretion reporters have in the preparation of earthquake stories.

Perhaps some of the points raised above could be approached as matters of organizational policy. Other policies to be identified include use of scientists or reporters with scientific expertise to supplement "head-

line" scientific news with in-depth coverage; editorial philosophy in approaching the news (e.g., sensationalistic versus conservative); specific editorial practices such as grouping several stories on the same topic (e.g., earthquake); and other policies such as giving equal time to experts or opinion leaders with opposing or dissenting views.

Particular attention needs to be paid to the relative emphasis given different earthquake and earthquake prediction news items under conditions of simultaneous predictions. There may be tendencies to group news stories on the same topic and to report stories which might otherwise have gone unreported—such as wire reports of minor earthquakes in other parts of the world—in conjunction with predictions of earthquakes in the United States. In this regard, detailed study of news items not covered or not reported is as vital as is analysis of news reports themselves. Also, similarities and differences in the handling of predictions from reputable scientific sources and from all other sources deserve special attention.

Data such as these seem best gathered through interviews conducted with editors, news directors, assignment coordinators, and reporters. Validity might be checked by asking respondents in rival news organizations about the policies of their competitors. At the time when interviews are conducted, any relevant documents, policy statements, records, or scripts should be obtained.

LINKS BETWEEN THE NEWS MEDIA AND OTHER ORGANIZATIONS

Finally, relations between news media, scientific organizations (private, government, and university), and government agencies should be identified and described, as they also bear on the nature of earthquake information released to the endangered population. Data should be obtained on such matters as the quality of rapport between particular news organizations (or particular reporters) and individual scientists or scientific organizations; whether such relationships are direct or mediated through a public information officer; extensiveness of the network as indicated by the familiarity of reporters with other related organizations; and so forth. The roles of news organization owners and of advertisers with interests in the threatened community should be assessed. As above, personal interviews with key informants seem the most appropriate method of data collection, with partial validation achieved through interviews with their opposite numbers in parallel organizations.

CONCLUSION

For research and for planning purposes, routine, scientifically valid predictions of earthquakes are by most estimates a decade or more away. This means that data for policy making can be gathered and analyzed before the new technology is ready. Research on generation and dissemination should begin as soon as possible. Both topics seem to be of equal priority, but perhaps the study of the scientific community should be approached with greater urgency, given the complexities involved and the likelihood of unexpected developments.

What we have described in this chapter are two sets of basic research studies, one in the sociology of science and the other in the social organization of news coverage and reporting. Both represent an opportunity to move beyond the *ex post facto* nature of most previous studies of natural hazards. Both help to complete the picture we have outlined of the earthquake prediction process, so that public policy may rest on the fullest possible understanding of community response processes.

8 Research Strategies and Priorities

The previous chapters have detailed complex, related research problems: the adjustments and decision processes of individuals, households, businesses, and government agencies; their social interactions; the influence of institutional forces such as markets, the law, and government regulations; and community, regional, and other large-scale geographic and social units affected by earthquake predictions.

This chapter outlines a strategy for social science research on these multifaceted problems. It contains three parts: The first section reviews three standard research frameworks required to address the substantive issues raised in the previous chapters. The second section discusses general criteria for establishing research priorities. Using these criteria, the final section establishes specific priorities among the recommended research topics.

This report has addressed both basic theoretical questions and applied policy problems. It should be clear, then, that the Committee on Socioeconomic Effects of Earthquake Predictions wants to recommend a set of research studies that is responsive to the descriptive needs of theory building and to the prescriptive needs of policy making. In developing its research recommendations, the Committee chooses not to specify funding levels for various research areas or topics, nor to estimate the total needed to complete the entire set of research projects. Certainly, the pursuit of the research recommendations discussed below will necessitate substantial effort and support. In particular, the study of decision-making processes, emphasized throughout this report, will be difficult, time

consuming, and costly. But it is needed. The attempt here has been to provide a plan of action that will contribute to both basic and applied research needs.

GENERAL FRAMEWORKS OF RESEARCH ON THE SOCIOECONOMIC EFFECTS OF EARTHQUAKE PREDICTIONS

There are three general types of research appropriate to the problems detailed in this report: (1) monitoring, (2) theory building, and (3) policy analysis. Monitoring is defined as the periodic measurement of the characteristics of major target populations.[1] Theory building is defined as the construction of explanatory or predictive statements about these characteristics. The discussion of monitoring serves to highlight the very pronounced data needs of both theory building and policy analysis in this area and to provide the foundation for the development of research priorities. It should be noted, however, that the Committee does not believe that monitoring studies should be conducted in isolation from theory. Indeed, the major purpose of this report has been to provide a theoretical basis for the monitoring studies. Because study of the socioeconomic effects of earthquake prediction will inevitably raise policy questions—questions which have been given particular attention in this report—this section ends with a discussion of policy analysis in the social and management sciences.[2]

MONITORING

The key questions to be addressed by monitoring are these: (1) What are the target populations? (2) What theoretically relevant variables are to be measured? (3) What monitoring techniques are to be employed? For purposes of this report, answers to the first two questions are provided in chapters 2–7, and in this chapter we briefly summarize the previous discussion.

[1]The term "monitoring" is used here in a broad sense to subsume the types of measurement problems identified in this report and the data collection techniques available to address these problems. Although the term is perhaps most closely associated with policy evaluation research, it conveys quite well the descriptive needs and techniques of theory building and policy analysis in the social sciences.

[2]The degree to which policy analysis actually influences government decision making is uncertain, even though government support for policy research has grown tremendously in the past 15 years. For a documentation of this trend and a discussion of problems of applying policy research, see M. Rein and S. H. White, "Policy Research: Belief and Doubt,"

As noted in earlier chapters, the major target populations are (1) individuals, including residents of communities in question, households in those areas, earth scientists, and organizational and political elites; (2) private groups and organizations, including various types of business organizations, political and parapolitical associations, earthquake-related scientific groups and organizations, and the communications media; and (3) government units, including local, state, and federal government organizations and administrative units such as towns, municipalities, special purpose districts, counties, states, etc.

The conceptual framework (chapter 2) outlines categories of theoretically relevant variables that should be monitored. The substantive chapters then detail more specific measurement needs tied to particular research problems. The conceptual framework also highlights broader system phenomena that should be monitored. These include relationships between target populations (e.g., interactions between households, businesses, and government) and larger processes evidenced by the combined behavior of various social units (e.g., consequences of household and business behavior for regional economies, community structure, etc.).

In discussing monitoring techniques, our intent is to highlight methods that are available, not to provide detailed descriptions on how to use them. It should also be noted that the preferred method depends on the specific target populations and research problems being addressed; moreover, monitoring will often require the use of multiple techniques in order to be effective. The following techniques are of direct relevance to the research problems discussed in this report: (1) field surveys of individuals and households, (2) field surveys of private and public organizations, (3) case studies of private and public organizations, and (4) use of public documents.

The primary purpose of field surveys of individuals and households will be to collect data on the respondents' personal and social characteristics and behavior as related to the earthquake prediction process. Chapter 3, for instance, suggests that the credibility that people attach to earthquake predictions is an important determinant of subsequent behavior. It also notes that both perceptions and behavior are influenced by numerous other personal variables such as stakes, socioeconomic

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Policy Analysis, vol. 3 (Spring 1977), pp. 239–273. Some recent studies of the use of social science research by governments suggests that it affects policy making less through direct problem solving and more through the gradual assimilation of the perspectives, concepts, and theories promulgated by the social sciences. For a review and commentary on these studies, see C. H. Weiss, "Research for Policy's Sake: The Enlightenment Function of Social Research," *Policy Sciences,* vol. 3 (Fall 1977), pp. 531–545.

status, cognitive skills, earthquake experience, interpersonal contacts, political views, and so on.

Both perceptions and behavioral responses are potentially affected by a variety of institutional forces as well. Chapter 4 refers to the role of market prices as a source of information on the responses of others, chapters 5 and 6 suggest the importance of political and legal constraints on individual and collective action, and chapter 7 outlines processes related to the content, sponsorship, and dissemination of earthquake predictions, all of which contribute to variations in credibility. Questioning households about the influence of these institutional forces will increase our understanding of the forces themselves and how they operate. If well executed, household surveys provide a useful way of documenting the relationships specified by the conceptual framework.

An ideal research design for monitoring households would be to undertake field surveys in a number of earthquake-prone regions and then undertake specific follow-up studies when a prediction is made.[3] The previously cited Turner study of household behavior in the Los Angeles area is designed in such a pattern of preliminary survey and follow-up research. The sampling plan must reflect the variables one is interested in measuring. For example, an oversampling of wealthy households will be necessary to measure the full range of stakes and their effects on reactions to earthquake predictions. Similarly, if the impact of past experience is deemed important, there must be an oversampling of communities that have recently experienced a damaging earthquake. A survey examining the impact of a prediction on insured or uninsured households would have to oversample the insured portion of the community or region under study, and so on.[4]

The primary advantage of these types of field surveys is that they provide an assessment of variable relationships at relatively low unit costs. They also permit the study of hypothetical questions before the issuance of actual predictions—whether such factors as the degree of consensus about a prediction, the time window, and the probability of occurrence will affect projected behavior. With theoretical guidance and longitu-

[3]Postprediction surveys will require longitudinal designs in which individuals are studied at intervals after the issuance of a prediction. However, as noted in chapter 3, given the current uncertainty about the characteristics of future predictions, it is not clear what these intervals should be. It should also be noted that repeated cross sections may be required for research on households and organizational and political elites, particularly if predictions involve long periods of time between the date the prediction is made and the time when the quake is predicted to occur. On the other hand, panel designs appear to be more feasible for surveys of earth scientists.

[4]See Kunreuther, *Disaster Insurance Protection*. See also P. H. Rossi *et al., Are There Long Term Disaster Effects?: Estimations of Effects of Floods, Hurricanes, and Tornadoes Occurring 1960 to 1970 on Counties and Census Tracts in 1970,* 1978.

dinal data (data collected at multiple intervals over an extended time period), field surveys can provide insights about causal relationships. But the data requirements are great, particularly if the intent is to trace decision-making processes. The more elaborate the data requirements, of course, the more costly the surveys will be in design, sampling, administration, and analysis.

Although households have been used for illustrative purposes here, they are not the only target population for field surveys of individuals. This report also calls for surveys of earth scientists, in order to gather specific data on their beliefs and behavior and, indirectly, to measure the social characteristics of the scientific community involved in earthquake prediction. And the report calls for surveys of organizational and political elites in the public and private sectors (leaders of businesses, mass media editors, heads of political and parapolitical associations, government agency officials, and elected representatives at federal, state, and local levels). These surveys will certainly yield important data on the perceptions and behavior of key decision makers. Of equal importance, these leaders can provide information about the organizational and political contexts in which they act.

Organizational studies receive particular attention in chapters 4 (business), 5 (government), and 7 (mass media organizations). Organizational research is generally of two broad types. One approach asks top organizational officials to describe the behavior of their organizations. By combining the techniques of field interviewing with these officials with analysis of organizational records, the performance patterns of relatively large samples of organizations can be obtained.[5] A second approach is to undertake intensive case studies of a much smaller sample of organizations in order to collect more detailed data on activity patterns and decision processes—the roles played by individuals and organizational divisions in the development of adjustments, the impact of organizational routine on information processing and decision making, and the influence of internal conflict and bargaining on the development and implementation of policy. Both types of research can use either cross-sectional or longitudinal designs. The unit costs of case studies are, of course, substantially higher than those of field surveys.

For conducting organizational research on the socioeconomic effects of earthquake predictions, we suggest a strategy that combines the

[5]Conventional sampling procedures applied to studies of the general population are inappropriate for studies of organizational elites because key people and organizations may be excluded. The problem is to construct sample frames which represent theoretically relevant categories of organizations and then randomly select organizations and leaders within these sample frames. An example of this approach in disaster research is the ongoing study by P. H. Rossi *et al., Research Program on Natural Disaster Recovery Process: Relief, Rehabilitation, and Preparedness,* 1977.

strengths of both approaches. Field surveys of firms, government agencies, and mass media organizations should have two functions: (1) to provide data on policy-making processes and the role of institutional forces (e.g., markets, the law, government regulation) in developing policy and (2) to measure patterns of adjustment behavior by large samples of these types of organizations. The study of policy-making processes assumes that top organizational officials are responsible for policy making and therefore are knowledgeable about policy processes and the institutional forces that affect these processes. The objective of studying patterns of organizational adjustment is to have primary data on the product of organizational activity, which can be used for policy analysis and for building, refining, or testing organizational and broader systems theories.

In a complementary fashion, case studies should be used for in-depth research of policy implementation. The objective of such studies is to discover the organizational dynamics that determine the extent to which the policies chosen are actually followed. Research of this type, particularly in government, is scarce in the social science literature. Studies of organizational dynamics can make an important contribution to both basic organizational theory and improved public policy.

Public documents and records provide further sources of data. Various government (e.g., the Bureau of the Census, the Bureau of Labor Statistics) and nongovernment agencies regularly collect data on the socioeconomic characteristics of households, businesses, cities, and urban regions; on local, regional, and national labor and employment conditions; and on the various primary, secondary, and tertiary sectors of the economy. In addition, data on government legislation and regulations and on written and broadcast news reports are readily accessible because they are matters of public record.

Research on the socioeconomic effects of earthquake prediction requires these generally available types of data for two principal reasons. First, because these data are amenable to aggregation and trend analysis of the conditions and behavior of various target populations, they serve as useful social, economic, and political indicators. Thus data on in- and out-migration, housing values, retail sales, deposits and withdrawals, and new construction can be used to document economic conditions. Second, because many of these types of data are collected at periodic intervals, they allow for causal interpretations of such phenomena as the socioeconomic effects of earthquake predictions.

THEORY BUILDING

As stated earlier, theory building is defined as the construction of explanatory or predictive statements about the characteristics of major target populations. We interpret theory building broadly to include such activities as outlining basic assumptions, creating conceptual frameworks and typologies, elaborating logical hypotheses in verbal or mathematical form, and using empirical data to generate or test ideas. In the broad and diffuse sense, theory building can take the form of a set of discursively expressed ideas, perhaps based on a series of exploratory observations.

Clearly, both the narrow and the broad interpretations of theory building are germane to this report. Thus chapter 4 calls for the use of econometric models to examine the economic conditions of urban regions; chapter 3 suggests a series of hypotheses that predict changes in response accompanying varying levels of stakes and calls for both field surveys and laboratory experiments to test these hypotheses; and chapter 6, in a general statement of theoretical need, calls for basic research on the role of law in human conduct in order to fill critical gaps in legal and social science knowledge. At the broadest level, the basic purpose of the conceptual framework developed in chapter 2 is to describe the nature of the phenomena being considered, to outline derivative research areas, and to exhibit how they relate to each other. The conceptual framework therefore defines a general program of studies but is not in any way definitive. However, by our interpretation, it is a necessary element of the theory-building process.

The socioeconomic impact of earthquake prediction is obviously a new research problem and therefore not well developed theoretically or empirically. Thus the Committee has identified research problems and strategies, but the predictive and explanatory potential of social science research will certainty not be realized without considerable effort and support. From a theoretical standpoint, we need basic research in which theory building and data collection efforts are closely linked. In the absence of a solid theoretical tradition the earthquake prediction and broader monitoring research suggested in the previous section is essential. The timing of earthquake prediction research depends, of course, on the actual development of the ability to predict.

There are other research areas, not specifically tied to earthquake prediction but related to the theoretical needs of the research problem. Such research may involve monitoring studies of analogous situations and basic research which relates to the conceptual framework. The suggested utility of such research has been a continuing theme throughout the substantive chapters. For example, chapter 3 calls for experimental research on decision making under uncertain conditions to assess theoretical rela-

tionships between the uncertainty of an earthquake prediction and projected behavior. Certainly, monitoring research on large-scale economic disruptions, such as production cutbacks by major employers in local communities, would be useful to the economic modeling techniques and studies of business recommended in chapter 4. Chapter 5 suggests the need to conduct research on mitigation and preparedness programs resulting from recent federal earthquake legislation and on other government hazard reduction programs in order to document the institutional and organizational constraints that influence their development and implementation. The recently cited study by Rossi deals specifically with these problems.[6] Chapter 5 also calls for continuing studies of community responses to major disaster events.[7] The basic research recommended in chapter 6 has already been alluded to and could be applied in the natural hazard context and in other situations where legal variables can influence decision making. Chapter 7 suggests the usefulness of comparative research on meteorological warning systems to learn about the scientific development and public uses of hazard prediction technologies. Such research would, of course, be of general theoretical interest, but it is specifically germane to studies of earthquake prediction because it is possible that meteorological and earthquake prediction and warning systems may turn out to have much in common.

In summary, monitoring research is of fundamental importance for theory building. However, other research areas and topics can contribute to knowledge about the processes surrounding earthquake prediction. They warrant investigation on both theoretical and policy grounds. The Committee therefore suggests that earthquake prediction research should be coordinated with other types of hazards research and with more basic research in the social sciences. It should not be developed as a separate, isolated field.

POLICY ANALYSIS

A public policy can be roughly defined as a deliberate act by a government decision maker or decision-making body that is designed to produce a specific set of effects on a targeted population. Policies are based on particular conceptions about human behavior. These conceptions may or may not be sensitive to empirical evidence and logically developed ideas. History suggests that the probability of success in implementing public policies is most uncertain. This uncertainty supports the need for careful

[6] *Ibid.*

[7] An example of research on disaster warning systems is the study by R. K. Leik, J. P. Clark, and T. M. Carter, *Dissemination and Response to Natural Hazard Warnings,* 1977.

policy evaluation research and for basic social science research on policy processes.

Two approaches to policy analysis apply to this report. The first approach defines policy analysis as a basic research problem on the processes by which policy issues emerge, options are considered, choices are made, and policies are implemented. The second approach defines policy analysis as an applied research problem in which the methods and perspectives of the sciences are used for the following kinds of activities: defining problems and objectives, evaluating policy options in light of these objectives, selecting policies, and evaluating the effects of policies chosen.[8] Although these two approaches to policy cannot be easily separated in practice, their research interests (policy processes versus policy issues) are different, and, perhaps more important, they clearly require alternative roles for the policy analyst. The basic science role is that of a neutral observer of policy processes; the "policy science" role is that of participant in these processes.[9]

Regardless of the approach pursued, it is clear that scientific methods should be used in policy analysis. Thus on the applied side, if policies have failed, it may be because they were based on erroneous conceptions about how the population would behave.[10] Isolating these misconceptions is both a theoretical and an empirical problem. Why have theoretical models failed to predict behavior correctly? What model revisions are suggested by past failures? What research design and data analysis frameworks are required for testing new policies? From a scientific standpoint, developing and testing policy should be a precise theoretical exercise that is, by definition, sensitive to empirical evidence.

[8]Although the social sciences have shown a general interest in the subject of policy making, they have not been noticeably active in developing models of policy making. The most sophisticated models have come from economics and such management sciences as decision theory, systems analysis, and operations research. Although they differ in many ways, most of these models assume that rational processes are basic to policy making; most define policy making as a logical sequence of problem-solving activities; most rely on variables that can be quantified; and most address narrowly defined problems.

[9]Harold Lasswell originally outlined a conception of the policy sciences about 25 years ago, and he and others have subsequently gradually elaborated upon it. See, for example, H. D. Lasswell, "The Policy Orientation," *The Policy Sciences: Recent Developments in Scope and Methods,* 1951; A. Etzioni, *The Active Society,* 1968; H. A. Simon, *The Sciences of the Artificial,* 1969; H. D. Lasswell, *A Pre-View of Policy Sciences,* 1971; Y. Dror, *Ventures in Policy Analysis,* 1971; and M. Rein, *Social Science and Public Policy,* 1976.

[10]Obviously, many factors other than erroneous conceptions about how the population would behave may be involved in the failure of policies. As noted in chapter 5, there are numerous individual and organizational variables that must be considered in governmental policy formulation and implementation. The findings from over 25 years of disaster research clearly indicate, however, that various stereotypes and erroneous conceptions held by policy makers on how people will behave in relation to disaster predictions, warnings, and actual impacts are a major cause of policy failures.

Earthquake predictions will inevitably raise policy questions, thus providing the opportunity for both basic and applied policy research. However, it should be noted that there is little systematized knowledge in either area. With regard to applied research on policy issues, it should be noted that the social and management sciences do not use a consistent approach to the problems of policy formulation and evaluation. Applied "policy science" draws its theories and methodologies in an eclectic fashion from other sciences. Its theoretical approaches, research designs, and data analysis frameworks are therefore as varied as the disciplines that engage in policy analysis. It is arguable whether this diversity is an inherent strength or weakness.

How then can either form of policy analysis be fruitfully pursued in the study of earthquake prediction? The role of applied research on policy formulation must necessarily be limited, at least initially.[11] This will be the case particularly if scientifically credible earthquake predictions are forthcoming in the short run (within 3–5 years). However, carefully designed policy evaluation efforts—essentially research that involves monitoring the effects of policies on target populations and documents the policies government agencies are enacting—can make a genuine contribution. In effect, it is easier to build upon successes and learn from mistakes if what actually happened has been precisely documented. Thus we believe that well-conceived policy evaluation research can contribute to both the theory and the practice of policy analysis.

Policy evaluation research addresses these three related questions: First, given that an official act was undertaken (legislation, administrative ruling, program action, etc.), how was it carried out? Was implementation consonant with the purpose? Assessment of policy implementation must necessarily be based on careful studies of the responsible government agencies. The implementation question is an important one because policies can become transformed by the agencies that are mandated to carry them out. Second, was the population targeted by the policy actually exposed to it? The policy can be enacted but fail to reach the right people. Finally, was the policy effective? This, of course, is the ultimate test. Does the policy achieve what it is supposed to achieve?

[11]There may be some areas where social science knowledge can be of early assistance in policy formulation. For example, estimating the cost of reinforcing vulnerable public buildings, given earthquakes of varying magnitudes, might involve the services of social scientists. However, we do not believe that the best we can do is apply cost-benefit analysis to disaster preparedness and disaster mitigation policies. At a different level, it is hoped that decision makers will be enlightened by the analytical perspectives of social science that relate to human responses to natural hazards.

Assessment of exposure and effectiveness can be researched by longitudinal monitoring to obtain before and after estimates of the states of target populations. When there are several target populations involved, policies can be expected to vary from one to another. Comparative study of responses by these target populations can shed light on both exposure and relative effectiveness.[12]

Precise documentation of policy effectiveness is inevitably difficult because there are likely to be several competing explanations of why a policy did or did not work. One method is field experimentation, in which there is planned variation in policy (this method has been used with income maintenance experiments). Policy experiments must necessarily be appropriate for earthquake predictions. It is obvious that withholding a prediction from a control group while giving it to an experimental group would be unethical and impractical. Conversely, arguments over the best way to convey information about earthquake hazard mitigation programs to targeted populations are likely to emerge, and it would be possible to assign different communication methods at random to various parts of the population and then evaluate the relative effectiveness of these methods.

CRITERIA FOR ESTABLISHING RESEARCH PRIORITIES

Three criteria for establishing research priorities are briefly outlined in this section: (1) the timing of monitoring research, (2) the theoretical and methodological significance of other hazards research and of basic social sciences research to the earthquake prediction problem, and (3) the contribution of research identified by criteria (1) and (2) to policy analysis. These criteria derive from the monitoring, theory building, and policy analysis frameworks discussed earlier.[13] Basic to the first and second criteria is a distinction between theoretically relevant topics that are directly linked to earthquake prediction and those that are not. The policy analysis criterion will be used derivatively to further distinguish

[12]See P. H. Rossi and S. R. Wright, "Evaluation Research: An Assessment of Theory, Practices, and Politics," *Evaluation Quarterly*, vol. 1, no. 1 (February 1977), pp. 5–52.

[13]The ultimate goals of earthquake prediction studies are to save lives and money, protect property, and minimize social disruption. Achievement of these goals, however, cannot be accomplished adequately on the basis of current knowledge. The criteria discussed in this section are focused on discovering the knowledge needed by policy makers in efforts to achieve these ultimate goals.

among earthquake prediction monitoring and broader theory-building research topics in terms of their possible relevance to policy making.

TIMING OF MONITORING RESEARCH

As suggested earlier, in the absence of a solid empirical foundation on which to predict human responses to earthquake prediction, longitudinal monitoring (preprediction, postprediction, and postearthquake) of key target populations is essential for both theory building and policy analysis. It is difficult to anticipate what will happen, but much can be learned from the careful study of responses to the first several scientifically credible predictions.

A basic problem is the timing of such research, since we do not know when scientifically reliable predictions will be forthcoming. If an accurate predictive capability takes several decades rather than several years to develop, the early establishment of comparative base line monitoring surveys would be methodologically impractical. The population characteristics change substantially over time, and base line profiles can become quickly dated. The content and circumstances surrounding future predictions are equally uncertain; thus hypothesized conditions and behaviors are likely to be increasingly realistic as time passes and the science of earthquake prediction improves.[14]

The Committee concludes that monitoring research should have high priority but that support for particular studies should be based on timing. Ideally, many of the previously discussed monitoring surveys should not be started until earthquake predictions are imminent. We recognize that precise projections of scientific advances are most difficult; however, well-reasoned judgments of timing must be made from a continuing assessment of scientific developments in this field. Thus state of the art studies like the one conducted by the National Academy of Sciences–National Research Council Panel on Earthquake Prediction should be regularly updated and their conclusions widely disseminated.[15] We will later distinguish between monitoring research that should be delayed until there is a reasonable expectation that scientific earthquake predictions are imminent and monitoring research that should be started now.

[14]One could argue that even though the social circumstances of future earthquake predictions are unclear, some dimensions of uncertainty are quite specific—namely the location, magnitude, and time of occurrence of predicted earthquakes. As suggested in chapter 3, these dimensions of uncertainty can be experimentally manipulated.

[15]Panel on Earthquake Prediction of the Committee on Seismology, *Predicting Earthquakes*.

OTHER HAZARDS RESEARCH AND BASIC SOCIAL SCIENCE RESEARCH

The Committee believes that processes related to disaster mitigation, preparedness, and response provide excellent empirical settings for developing, refining, and testing general theories in the social sciences.[16] Unfortunately, disaster research has evolved as a somewhat isolated specialty in such fields as psychology, sociology, economics, political science, and geography, although it should be noted that the majority of federal support for academic social science research in this field has gone to sociology. We believe that this separation is detrimental to both the specialty and the broader disciplines involved. Certainly, many interesting and useful studies have been done. Findings from these studies can be found in several reviews of the literature.[17] But, in the main, there have been no startling theoretical breakthroughs generated by empirical studies of disasters in the last 10–14 years, even though a voluminous body of data has been collected and disaster research has become institutionalized in various universities.[18]

The Committee obviously cannot guarantee that theoretical breakthroughs will inevitably follow if its recommendations are implemented. However, we do believe that such breakthroughs will depend on better theoretical groundwork than has heretofore been evidenced. The conceptual framework outlined in this report—one clearly shaped by past research—is viewed as a first step in the development of a general theoretical orientation to which the various social sciences can relate.

The monitoring research recommended in the substantive chapters will play a major role in developing and refining that framework. But the measurement and data analysis problems of monitoring will not be easy to solve. Monitoring research must logically derive from the best theoretical and methodological insights at our disposal. Basic research on

[16]For illustrations of the use of hazards and emergencies for studying more general social science problems, see R. H. Turner, "Types of Solidarity in the Reconstruction of Groups," *Pacific Sociology Review,* vol. 10 (1967), pp. 60–68; J. M. Weller and E. L. Quarantelli, "Neglected Characteristics of Collective Behavior," *American Journal of Sociology,* vol. 79 (1973), pp. 665–685; D. C. Dacy and H. Kunreuther, *The Economics of Natural Disasters,* 1969; I. Janis and L. Mann, *Decision Making: A Psychological Analysis of Choice,* 1977; Kunreuther *et al., Disaster Insurance Protection;* and Kreps, "The Organization of Disaster Response."

[17]See, for example, C. E. Fritz, "Disasters," *Contemporary Social Problems,* 1961; Barton, *Communities in Disaster;* Dynes, *Organized Behavior in Disaster;* and Mileti *et al. Human Systems.*

[18]This point is made by Quarantelli and Dynes, "Response to Social Crisis and Disaster."

hazards and emergencies and on broader topics such as information processing and decision making, market processes in the diffusion of information, economic modeling, and the development of social indicators can contribute significantly to a better understanding of the social dynamics and effects of earthquake prediction.

Because research of these types is independent of the development of earthquake prediction technology, support for it can occur any time. In some cases, this support will involve expanding existing research programs (e.g., economic modeling) funded by the National Science Foundation or other government agencies. In other cases, new research programs will probably be required (e.g., the role of the law in human conduct). The actual mechanics of program development must, of course, be worked out later. We believe that such research should be supported, at least in part, by funds allocated for social science research on earthquake prediction. Specific recommendations are offered in the final section of this chapter.

CONTRIBUTION OF RESEARCH SELECTED BY CRITERIA 1 AND 2 TO POLICY ANALYSIS

The application of social science research to policy analysis presents an interesting problem of establishing research priorities that can simultaneously contribute to (1) general theoretical interest in policy processes and (2) applied interest in specific policy issues. The former implies comparative research into the individuals and social units involved in policy making and implementation. The substantive policies, whatever they may be, are important primarily in the sense that they provide an empirical context for study. Applied research of policy issues implies using speculation and more formalized projective techniques to identify policy issues, engaging in analytical problem solving to compare policy options, and designing evaluation studies to determine if policy objectives have been met. Certainly knowledge gained from both perspectives can contribute to improved policy making. Thus the Committee believes that a program of studies on the socioeconomic effects of earthquake prediction should be responsive to both concerns.

As stated earlier, it is our view that the role of social science research in the formulation of specific earthquake hazard mitigation policies is somewhat limited in the short run. However, contributions to improved policy making can certainly derive from well-designed policy evaluation efforts, which would contribute to theoretical interest in policy processes and to applied interest in policy issues. To reiterate, policy evaluation

involves assessment of implementation, exposure, and relative effectiveness. The extent to which policies are implemented is influenced by complex organizational and institutional processes. These processes, which are of general theoretical interest, will be studied within the context of specific policy issues. It is worth noting again that the special policy issues also have an important theoretical content—that is, policies are based on conceptions about human behavior. By definition, therefore, evaluation of exposure to, and relative effectiveness of, specific policies involves a testing of these conceptions. Empirically, such research is a special form of the more general monitoring research discussed in the previous section. Specific recommendations for policy research are offered in the concluding section of this chapter.

RESEARCH RECOMMENDATIONS

The following research recommendations are based on the three criteria outlined above. For each criterion a specific set of recommendations will be listed, and this will be followed by a general discussion of the set.

MONITORING RESEARCH

1. Longitudinal surveys of individuals, households, firms, and governmental units (discussed in chapters 3, 4, and 5) that assess socioeconomic effects of earthquake prediction are highly recommended. However, they should not be undertaken until there is a high probability that scientifically credible earthquake predictions will be forthcoming within a few years.

2. Regional interindustry/econometric modeling research (discussed in chapter 4) that assesses regional economic consequences of earthquake predictions is highly recommended. However, it should not be undertaken until there is a high probability that scientifically credible earthquake predictions will be forthcoming in a few years. This research should be coordinated with the monitoring surveys listed under recommendation 1.

3. Intensive case studies of how firms and governmental units will adjust to the predictions (discussed in chapters 4 and 5) should for the most part be undertaken after the monitoring surveys listed under recommendation 1 have identified research sites for comparative analysis of

policy-making and policy implementation processes. However, given the important policy implementation role of governmental units and the unique problems of assessing governmental performance, some case studies of government agencies located in the initial prediction areas should be undertaken simultaneously with longitudinal monitoring surveys.

4. Studies of the organizational problems related to the scientific development of earthquake predictions should be initiated now.

5. Longitudinal monitoring studies of mass media policies and reporting of earthquake prediction news (discussed in chapter 7) should be initiated now.

The longitudinal monitoring surveys listed under recommendation 1 are essential for both theory building and policy analysis, but they should not be started until it is methodologically practical to do so. Present uncertainty about the future development of earthquake predictions suggests that it is premature to support base line monitoring research on individuals, households, firms, and governmental units.[19] As stated earlier, judgments of timing must derive from a continuing assessment of scientific developments in this field. The monitoring surveys should systematically compare a reasonable number of communities in scientifically instrumented earthquake hazard zones (at least 10 and preferably as many as 25 or more) and representative samples of households, businesses, and government agencies within these communities.[20] Care must also be taken in the early identification and sampling of organizational and political elites.

The monitoring surveys listed under recommendation 1 will serve these two functions: (1) to provide essential base line data for subsequent measurement of postprediction and postearthquake effects and (2) to examine hypothesized behavior in immediate preprediction periods based on different prediction scenarios. The first function is of highest priority because it provides for measurement of actual behavior in response to

[19]The previously cited study by Turner—which involves monitoring the perceptions and behaviors of residents, the media, and organizational and political elites—should provide useful data on the social dynamics of an open-ended preprediction period. As indicated in recommendation 5, the Committee is interested in research on the mass media. However, the utility of the Turner study for assessing the effects of specific earthquake predictions is dependent on the unlikely short-term development of a prediction capability.

[20]We assume that initial sampling must draw heavily on the more highly instrumented areas of the West Coast. However, ultimately it will be desirable to have more broadly based instrumentation and community samples.

earthquake predictions. We speak here of such key measures as the diffusion and public interpretation of earthquake prediction and earthquake hazard reduction information; the adjustments taken by various target populations and the combined effects of these adjustments; the influence of individual, organizational, and community characteristics on the adjustments made; and the role of institutional forces (e.g., social networks, markets, government incentives and regulations, and the law) on various response patterns. Much can be learned theoretically and practically from initial scientific predictions if we carefully document what happens through closely spaced monitoring surveys. The second function of monitoring surveys involves collecting data on the projected behavior of these target populations (e.g., spending plans of households and firms) given alternative predictions. Such research should provide insight about what determines the degree to which people believe earthquake predictions and how credibility and other variables affect behavior. The findings of research on projected behavior should be of theoretical interest and may also yield policy guidance for formulating earthquake prediction and warning messages.[21]

Individuals, households, firms, and government units are constituent elements of larger social systems. The regional interindustry/econometric modeling research suggested by recommendation 2 will be important for measuring reciprocal relationships among these elements and the effects of these relationships on the regional economy. Economic modeling provides a useful tool for monitoring or simulating the cumulative effect of public behavior in the private sector and the influence of government policies on that behavior. The monitoring surveys suggested by recommendation 1 will be important sources of primary data for economic modeling. Thus longitudinal monitoring and economic modeling should be coordinated.

The intensive case studies of firms and government units suggested by recommendation 3 should generally not be started until monitoring surveys have isolated the range of adjustment patterns that businesses exhibit. Case studies should then be targeted for those firms and agencies that display extremes of action or inaction under varying degrees of earthquake threat. However, it will be necessary to initiate some case studies of government organizations involved in responses to initial earthquake predictions. Government plays an important role in implementing policy and, compared to business, its performance is generally

[21]Predictions of moderate to major earthquakes will be relatively rare and geographically dispersed. Thus the potential value of research on hypothesized behavior is not confined to the period immediately preceding initial predictions. Indeed, the realism of scenarios will be considerably enhanced if early predictions and their effects are carefully documented.

more difficult to measure, let alone evaluate. As suggested in chapter 5, field surveys may identify the presence or absence of government hazard reduction activity (e.g., disaster planning, building codes, land-use control, and other government regulations). However, intensive case studies are needed to improve understanding of the importance of the activity for the units involved in implementation and for the target populations that are supposed to be affected by these policies.[22] Often the problem is not one of measuring performance in terms of obvious implementation yardsticks; rather it is one of determining what to look for in the measurement of performance.

In monitoring how the various levels of government respond to future developments in earthquake prediction and warning, it will be important to know the extent to which federal, state, and local governments incorporate these capabilities in their public policies, programs, and plans. Similarly, it will be necessary to examine the ways in which the three levels of government coordinate their ideas for handling earthquake predictions.

Recommendations 4 and 5 both derive from chapter 7. The same uncertainty about the development of earthquake prediction capability that dictates postponing monitoring surveys also argues for the early support of research on the earth sciences and mass media. With regard to recommendation 4, the social structure of scientific activity that gives rise to earthquake predictions should be carefully documented. In the narrow sense, such research should identify the social organization problems of developing a scientifically based earthquake prediction and warning system. In the broader sense, such research should contribute to a better understanding of the relationships between the scientific community and the public. The proper relationship between science and government in researching natural hazards will necessarily involve long-term policy questions. Much can be learned from research that documents the earthquake prediction experience.

With regard to recommendation 5, it is reasonable to assume that the mass media will play important roles in both disseminating and interpreting news about earthquake predictions and their social effects. Indeed, the media have already given considerable attention to such news items as the Chinese predictions, the Palmdale Bulge, and quasi predictions by scientists and amateurs. Because there is little systematic research on the role of the mass media in their reporting on controversial environmental hazards, research on earthquake predictions provides an excellent opportunity to fill a major gap in the hazards literature. Moreover, by docu-

[22]Intensive case studies of policy implementation should also include research on the role of emergent groups and associations (discussed in chapters 3 and 5) that may become politically involved in government policies.

menting precisely the roles that the mass media play in disseminating and interpreting information, such studies will provide practical guidance for the media as they go about developing their approaches to disaster and hazards reporting. Since the media are already reporting earthquake prediction developments, many data are readily accessible, so the monitoring research suggested by recommendation 5 should be initiated now.

OTHER RESEARCH OF THEORETICAL AND METHODOLOGICAL RELEVANCE TO THE EARTHQUAKE PREDICTION PROBLEM

6. Methodological studies on the development of socioeconomic monitoring systems should be undertaken to prepare for the data collection, management, and dissemination requirements of research on the socioeconomic effects of earthquake prediction.

7. Small-scale field surveys of individuals, households, firms, and governmental units should be undertaken to elaborate empirically the conceptual framework (discussed in chapter 2) in a comparative context. Principal attention should be given to assessing the effects of information processing, "stakes," social networks, and institutional forces (in particular, markets, governmental settings, and the law, as discussed in chapters 4, 5, and 6) on private and public sector responses to various human hazards and risks.

8. Research on the development of regional interindustry/econometric modeling techniques (discussed in chapter 4) should be supported to improve these techniques for assessing effects of earthquake predictions and of other hazard phenomena.

9. Experimental research on decision making under conditions of uncertainty (discussed in chapters 2 and 3) should be undertaken to assess theoretical relationships between the dimensions of uncertainty implied by earthquake predictions and projected behavior.

10. Basic research on the relationships between science and government in the development and implementation of scientific knowledge about human hazards (discussed in chapter 7) should be undertaken to document the institutional forces and constraints that impinge on these relationships.

11. Comparative research on government and community responses to various hazards and large-scale disasters should be continued. Particular attention should be given to documenting institutional constraints on

the development of disaster mitigation and preparedness programs and to establish empirical relationships between disaster mitigation and preparedness programs and postdisaster responses.

The research recommendations in this second set are in general order of priority. The monitoring systems implied by recommendations 1–5 will be essential for theory building and policy evaluation, but they will be difficult to develop and integrate. One approach would be to create a singular, multipurpose data management system or, at least, specific mechanisms to coordinate related systems. This approach is akin to the problems of building national, regional, and local social and economic accounting systems. In developing such systems, however, there are basic design problems which defy simple solution.[23]

The following issues relate to monitoring the socioeconomic effects of earthquake prediction. First, the Committee has necessarily given limited attention to sampling, variable selection, index construction, and other research design problems which must be considered in the study of the various topics. Solutions to these design problems must precede any major data collection effort. Second, there are multiple target populations to be monitored, and the population characteristics to be measured vary considerably from one to the next. Furthermore, the social relationships among these target populations are substantively relevant (e.g., the various relationships among the earth sciences, the private sector, and the public sector). The integration of research designs on the various target populations is therefore an important need. Third, there will be problems of aggregating and disaggregating data from various target populations. This will require coordinating various monitoring and data analysis activities. Fourth, it will be difficult to integrate primary and secondary data sources. Given the costs of collecting primary data, secondary data must be an important resource, and one that is creatively used. Since secondary data are collected for purposes other than the research discussed in this report, locating and integrating disparate data sources that can provide monitoring information will be a continuing problem. Finally, given the large volume of information to be collected and the multiple uses to which it can be put, there is a general need for organizational mechanisms to disseminate monitoring information.

We suggest that the National Science Foundation (NSF) carefully consider the problems just outlined when planning a research program for those monitoring activities listed under recommendations 1–5, partic-

[23]For an interesting history and discussion of the technical and political issues related to building broad-based monitoring systems, see E. S. Dunn, Jr., *Social Information Processing and Statistical Systems,* 1974. (Note in particular chapters 5, 6, and 7.)

ularly those listed under recommendations 1 and 2. Since many disciplines and researchers are likely to be involved, the NSF should coordinate the research effort. Indeed, should earthquake predictions be shortly forthcoming, this coordination role will be crucial.

It may be that predictions of moderate to severe earthquakes are many years away. If that is the case, there will be more time to do the theoretical, methodological, and organizational groundwork required for a well-conceived research program on earthquake predictions. Recommendations 6, 7, and 8 should be viewed as a group and be given high priority during the preprediction period because they can provide this needed groundwork. The topics listed under these recommendations involve basic research, but they relate directly to the conceptual and methodological needs of earthquake prediction. They should be jointly supported by the earthquake prediction program and other units of NSF that have related research interests.

Recommendations 9 and 10 are research topics that should receive somewhat lower priority than recommendations 6, 7, and 8 because they relate less directly to the pivotal problem of developing effective monitoring research on the socioeconomic effects of earthquake prediction. However, the theoretical relevance of recommendations 9 and 10 to the earthquake prediction problem can be stated unequivocally.

As noted in chapter 2, previous studies of decision making under conditions of uncertainty raise serious questions about models based exclusively on the assumption of rationality. Such patterns as limited search for data, reliance on informal social networks for information, and biases on processing information (e.g., uncertainty avoidance and selective perception) have been empirically documented. It is reasonable to assume that decisions are shaped in part by information and the social contexts in which it is acquired, but knowledge about the behavioral impact of presenting information in different forms is limited. Recommendation 10 calls for research within the context of experimental designs because such research is generally cheaper than field surveys and more efficient in isolating causal relationships. Moreover, one can build on a solid experimental research tradition on the subject of decision making. Such research should include both common and infrequent hazards that reflect theoretically relevant dimensions of uncertainty.

With regard to recommendation 10, we believe that basic research is needed (1) on the institutional problems of linking science and government in hazard research, (2) on the analysis of risks and benefits, and (3) on the development of hazard reduction programs. There is increasing research about the techniques of hazard analysis and risk-benefit analysis, but little study of the institutional problems of using these scien-

tific techniques. Thus there are no simple prescriptions about the proper roles for science and government in this area. Neither are there simple answers to the problems of creating organizational mechanisms to resolve scientific and public policy debates about risks and hazard reduction policies to deal with them. On both theoretical and applied grounds we believe that the need is for behavioral research on the specific roles, linkages, and institutional constraints that operate in various hazards areas. Thus, as indicated in recommendation 4, we believe that much can be learned from a careful documentation of the earthquake prediction experience. But, as suggested in chapter 7, earthquakes are only one of many empirical contexts within which to study the relationships between science and government in making public policy. Given the long-range importance of these relationships, the broad program of research outlined in recommendation 10 should be supported.

Recommendation 11 is of lower priority than recommendations 1–10. Since the comparative research of government and community response to hazards and large-scale disasters has been federally supported for a number of years, both by NSF and by other agencies, this area is not so urgent as some of the other topics. Much interesting and potentially useful knowledge has been generated by this research tradition, and we think it should be continued. Indeed, chapter 5 of this report calls for more research on government responses to disasters. But the diversity of past and current support for this research argues against its being given equal priority with recommendations 9 and 10. To the extent that funds are available for support of traditional disaster research, we believe that particular attention should be given to documenting institutional constraints on the development of earthquake hazard reduction and preparedness programs and to establishing the effectiveness of these programs for postdisaster responses.

POLICY ANALYSIS

All of the preceding recommendations contribute to policy analysis. The studies outlined in recommendations 1–3 should be initiated when earthquake predictions are judged to be imminent in order to provide essential data for policy evaluation research. In the interim, the studies outlined in recommendations 6–8 should be undertaken to provide the theoretical and methodological groundwork for subsequent research to monitor the effects of earthquake predictions. The monitoring research on the earth sciences and the mass media outlined in recommendations 4 and 5 should be undertaken to formulate policies related to the development and dis-

semination of earthquake predictions and warnings. The basic research on decision making and on science-government relationships outlined in recommendations 9 and 10 and the traditional disaster research outlined in recommendation 11, although of lower priority, should be undertaken to formulate earthquake and other hazard mitigation programs.

Also of lower priority are the specialized policy problems reviewed in chapters 4 and 6. These include the following:

12. Research on the problems of marketing earthquake insurance programs (discussed in chapter 4) should be undertaken in preprediction periods for possible use in the development of model insurance programs.

13. Surveys of the diversification of banking assets (discussed in chapter 4) should be undertaken in preprediction periods to determine bank vulnerability to mortgage default.

14. Traditional legal research (discussed in chapter 6) should be undertaken to assess the liabilities of scientists and public agencies in developing earthquake prediction and warning systems.

The research recommendations in this final set are listed in decreasing order of priority. As stated earlier, the Committee believes that the major focus of policy analysis, at least initially, should be on policy evaluation research. As defined, policy evaluation research must necessarily involve study of the government agencies involved in policy processes and the populations to be affected by them. Policy evaluation is therefore encompassed by the monitoring research outlined in recommendations 1–3. Such research should receive high priority.[24]

It is difficult to anticipate the impact of well-designed monitoring research on subsequent policy formulation. We believe that even at a descriptive level the findings of competently performed behavioral research can help make policy. But as noted in chapter 5, it is essential to disseminate the findings of monitoring research quickly. Although dissemination is an important concern of the NSF's applied research program, there is little systematic research on the comparative benefits of different ways of disseminating research findings. In developing coordinated monitoring research, we therefore suggest that the NSF give con-

[24]It is assumed that the samples of households, firms, and government units will be sufficiently broad to capture the key populations targeted for earthquake prediction and earthquake hazard reduction policies and programs. The primary function of monitoring research is, of course, to document behavior—behavior which is both theoretically interesting and relevant to the evaluation of policy.

siderable attention to the design and evaluation of systems for the dissemination of research findings.

Recommendations 6–8 outline studies that relate to the theoretical and methodological problems of undertaking broad-based monitoring research. In a longer-term preprediction period, such studies should be given high priority because they can make major contributions to more effective monitoring and dissemination systems. Support requirements for such studies will be modest compared to requirements of subsequent earthquake monitoring research, and we believe that policy evaluation research will benefit accordingly, both in this area and more broadly.

If it is started now, the monitoring research on the earth sciences and the mass media may yield policy guidance relatively soon for the formulation and dissemination of earthquake predictions and warnings. We suspect that the process by which science and government develop an earthquake prediction capability will be one of trial and error, characterized by experimentation with different organizational ways of evaluating scientific work and reporting the results. Similarly, the mass media will be trying to develop reporting policies based on their experiences in reporting and interpreting earthquake prediction news. The policy benefits of this research will not be fully realized until the research is tied to subsequent monitoring research of individuals, households, and businesses. The private sector is not likely to be significantly affected by the preprediction activities of the earth sciences, the government, and the media. However, the responses of the public to initial predictions may have substantial impact on future government and media policies. Thus, for purposes of policy analysis, the coordination of monitoring research (recommendations 1–5) is important.

Finally, recommendations 12, 13, and 14 represent a third priority level of more specialized policy research, which was discussed in the substantive chapters. Recommendations 12 and 13 both derive from chapter 4. They received relatively low priority in that chapter because the activities of the banking and insurance industries will become quickly known after the issuance of earthquake predictions and because the behavior of both industries is heavily regulated by a set of uniform rules. Although there may be a role for outside research on the development of model insurance programs and surveys of bank vulnerability, the industries themselves will be doing it. On the other hand, it is clear that the highly recommended monitoring research on the behavior of households and businesses will provide important data for policy making by these industries. NSF should therefore give high priority to disseminating research findings to the banking and insurance industries.

With regard to recommendation 14, chapter 6 argues that a large-scale independent examination of possible legal problems related to earthquake prediction is unwarranted. Rather, the role of traditional legal research should be interpreted quite narrowly—as a resource in providing legal counsel when specific policy decisions are being made. For this reason, research on the liabilities of scientists and government agencies in the development of earthquake prediction and warning systems receives relatively low priority here.[25] Of greater relevance is the examination of the law as an institution that influences to varying degrees public and government behavior. We strongly recommend that legal variables be included in the monitoring studies of the target populations and that lawyers be involved in the design of these studies. As chapter 6 notes, there is a fundamental need for basic research on the effects of law on human conduct. Research on the socioeconomic effects of earthquake prediction provides an excellent opportunity to fill significant gaps in the legal and social science literatures.

[25]We note, however, that such legal research could be accomplished at relatively low cost. Related research of considerable breadth was recently done on government liability in the development of disaster home warning systems. See J. Huffman *et al., Legal Constraints on the Planning and Development of Disaster Home Warning Systems,* 1977.

156 Intentionally Blank

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