Natural Hazard Research

SOCIAL SCIENCE PERSPECTIVES ON THE COMING SAN FRANCISCO EARTHQUAKE
ECONOMIC IMPACT, PREDICTION, AND RECONSTRUCTION

by
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Predicting the Economic Impact of Earthquakes
by
Harold C. Cochrane

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by
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by
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PREFACE

This paper is one in a series on research in progress in the field of human adjustments to natural hazards. It is intended that these papers will be used as working documents by the group of scholars directly involved in hazard research as well as inform a larger circle of interested persons. The series is now being supported from funds granted by the U. S. National Science Foundation to the University of Colorado and Clark University. Authorship of papers is not necessarily confined to those working at these institutions.

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PREDICTING THE ECONOMIC IMPACT OF EARTHQUAKES

Harold C. Cochrane

Abstract

A reoccurrence of the 1906 San Francisco Earthquake in 1974 would likely cost the Bay area in excess of $13 billion, approximately one half of which would take the form of lost income due to a regional economic recession. The unemployment rolls would be swelled by as many as one quarter million. The probability of such large scale social disruption following an extreme geophysical event signals the need for a broadened perspective in planning for such potentialities, and the need to review the choice of adjustments to mitigate these effects. Concentration on mean annual damages or direct damage ensuing from disaster may not take into consideration the social benefits of measures pursued to affect damage reduction. The importance of these findings lies in the implications for public policy which may need some rethinking if the potential for large scale economic chaos is to be avoided.

Introduction

The purpose of this paper is to assess the likely economic consequences following an earthquake of comparable magnitude to that which struck San Francisco Bay region in 1906. As many professional economists will currently attest, making economic predictions--particularly predictions about events as hypothetical as a large earthquake--is inviting the future to make a shambles of the projections. The results of shifts and dislocations in the national economy resulting from strategic shortages of energy have only served to underscore our limited ability to understand the painful process of economic adjustment in the wake of a severe change in the production system. Not all such adjustments came as complete surprises, however; plastics are made from petroleum, fertilizers with natural gas, and shortages in both petroleum and natural gas mean shortages in plastics and fertilizers. The reductions in outputs of plastics and food mean rises in prices, a decrease in real income, and, for some in society, going a bit more hungry than they did one year ago. In a much over-simplified way this is the type of analysis to which this paper is addressed: how damages to a region's productive capacity lead to further rounds of deterioration in economic conditions and, hence, to a potential for prolonged suffering on the part of the disaster victims.

By any stretch of the imagination, an earthquake of Richter magnitude 8.3 centered around San Francisco would be considered a catastrophe, but the word catastrophe by itself invites numerous interpretations. One commonly agreed upon meaning is any event which inflicts large losses of life. The "large", however, often remains undefined. To many who have lost their jobs in the current economic downturn, or have been repeatedly frustrated in their ability to freely move about because of gasoline shortages, these too may be forms of catastrophe or at least elements of it. To bring more precision to the use of the term, a simple geometrical device, Figure 1, is suggested.

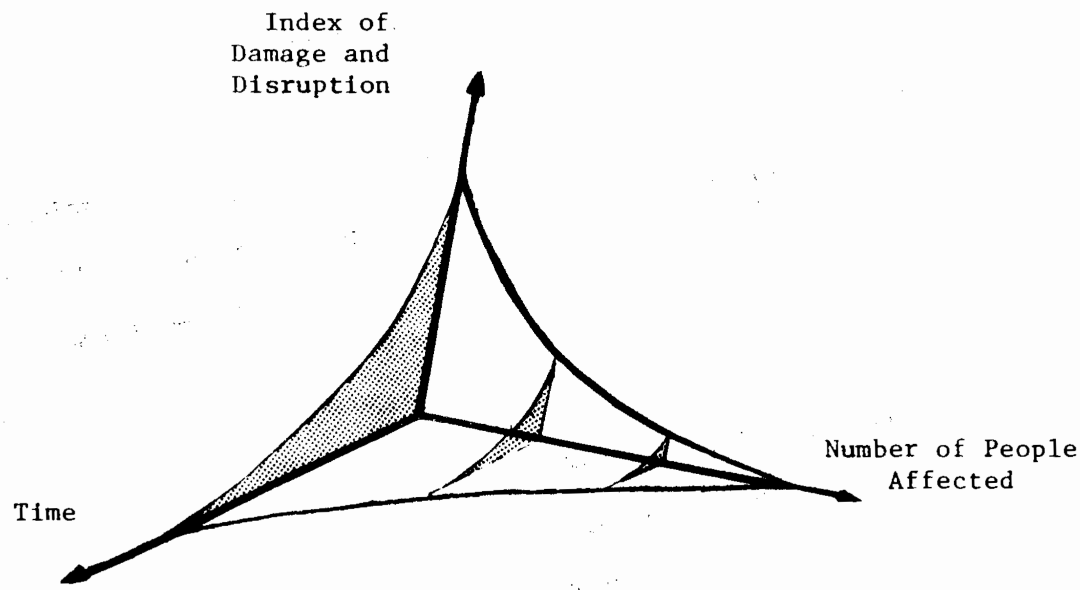

Figure 1

The figure points out that any event which inflicts damage and disruption at a specific time and place is likely to spread disruption to regions via economic and social linkages. Individuals residing in these regions will be affected to a declining degree for varying lengths of time, depending upon the magnitude of effects.[1] The importance of this observation

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[1]The shape of the surface depicted here reflects a negative exponential relationship, but one could postulate other shapes which may suggest little direct impact and increasing secondary effects over time--the energy shortage providing a prime example.

is that catastrophe is measured in terms of the volume rather than simply direct damage, a single dimension.

Conceptualizing the effects of catastrophic events in the manner suggested by Figure 1 brings to light three observations around which this paper is organized. First, the private assessment of benefits accruing from various damage-mitigating adjustments will not capture the social benefits from reduced disruption to undamaged economic activities. Second, concentration on growth in direct damage drastically understates the growth in the level of potential catastrophe by almost one order of magnitude.[2] Third, the importance of social disruption in the stream of damages depends much upon the social and economic linkages prevalent in a region, and how increasing reliance upon technology is likely to forge even stronger, yet less stable, relationships among industries and geographic areas. The grim potentialities of unemployment and severe economic dislocation deserve special attention since little analysis has yet been done to suggest how existing institutional arrangements will fare under the stress of any large scale emergency.

To provide a crude estimate of the direct as well as indirect damages, accompanying disaster, the following analysis based upon a postulated earthquake is provided.

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[2]This assumes that the basic structure of the economy remains fairly constant over time. The estimate of an order of magnitude comes from the simple relation between a volume and any of its dimensions.

Forecast Impact of a 1974 San Francisco Earthquake[1]

Aside from the grief, the horrors, and the psychological traumas inflicted on the Bay area residents from a large magnitude earthquake, a dynamic set of social adjustments would be set in motion, driven and governed by the economic and social linkages of the region. One direct result of the earthquake which will compound problems for the disaster victims is the severe unemployment which may reach a quarter of a million persons above the current jobless level. Unemployment can be translated into reduced demand for goods and services still produced in the region. Property and sales tax revenues would fall at a point in time when the need for expenditure is the greatest--when reconstruction of public facilities, roads, and utilities is vital to the recovery of the economic structure. Direct damage of productive capacity would retard the production of intermediate goods in the region. To the extent that serious shortages of critical goods develop, and inventory levels are insufficient to absorb the effects of supply disruption before alternate supplies can be found, a further decline in regional output would be expected. It is this complex interaction of supply, demand, and damage which forms the basis of the analysis to follow.

Before the indirect effects just sketched can be estimated, the direct reduction to the region's productive capacity must first be determined. This was done by simply overlaying the isoseismal pattern shown in Appendix I, Figure I-1, on a map of planning districts[2] showing the relative concentrations of residences, the number of persons employed in basic industry, and the number employed in local service industry. These districts were of sufficient

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[1] A more rigorous explanation of the methods employed in deriving the results shown here is provided in Appendix I and Appendix II.

[2] The planning districts used in this study were formulated by the Association of Bay Area Governments (1973).

scale to allow an allocation of earthquake intensity or intensities, and thereby approximate the degree to which various sectors of the Bay area population were affected. Table 1 summarizes these findings.

Table 1

Population Affected by Intensity Level

Type of Activity or Structure	Intensity -- Modified Mercalli					Total Structures or Employment Affected	Total Structures or Employment in Region
	X	IX	VIII	VII	VI		
1. Residential Units	124,000	296,000	713,000	120,000	106,000	1,358,000	1,552,000
2. Basic Industry Employment	83,000	253,000	421,000	78,000	44,000	879,000	965,000
3. Local Service Industry Employment	84,000	220,000	479,000	72,000	54,000	909,000	1,011,000

To supplement this crude breakdown of economic activity, data on county business patterns were incorporated into the analysis. By weighting the region's reduction in economic output according to the degree different counties were affected, a final assessment of a change in economic structure in the region was attained.[1]

The findings in Table 1 were converted to dollar estimates of damage by application of two intensity damage relationships, one for residences

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[1]The economic sectors used in this study correspond to the classifications developed by Bargur, et al. in their study of wastewater management of the San Francisco Bay Region.

and another for commercial industrial structures.[1] The results are shown in Table 2.

Table 2

Summary of Direct Losses

Class of Building or Structure	Losses ($ billion)
Residence	2
Commercial/Industrial	1.5
Public Sector	3.5
Total	7.0

The method of treating the indirect effects of damage to plant and equipment is treated in detail in Appendix II. In a simplified way the method is one of measuring the dynamics of economic adjustment. In terms of a circular flow, we want to know how the disaster disturbs productive capacity; how this disturbance filters through other industries and affects their output; how these combined effects influence employment and profitability and, hence, demand; how these in turn affect taxes collected; and how each of these effects then influences production.

[1]The relationships used were developed by Friedman and Whitman, et al., respectively. To be conservative in the estimation of damage it was assumed that all industrial structures conformed to what Whitman, et al., identify as the "S" building code, that is, one which incorporates the latest earthquake resistant technology. This approach of being conservative was followed throughout the study whenever uncertainty as to choice of relationships or estimates was encountered.

Considerable effort has been expended in recent years on a similar problem, that of assessing the economic impact of a nuclear attack.[1] The models thus far developed, although complex, could readily be converted and applied to the problem of natural hazards.

Because of the exploratory nature of this study, a simpler approach was undertaken--the omission of prices and capital formation from the analysis. This allowed the problem to be formulated within a linear programming framework, one in which the regional product is maximized subject to the constraints of the remaining resources and the pre-earthquake technical coefficients of production. There are certain advantages to what at first may appear to be an overly abstract and normative mode of analysis. First, production patterns are not likely to shift quickly and since the period of investigation is limited here to one year after the impact, the assumption of fixed coefficients may not be all that unrealistic. Second, the results obtained through linear programming are likely to be conservative, the losses actually materializing tending to be higher. Lastly, the analysis is conducted in real terms so price changes due to local bottlenecks--or for that matter any other institutional considerations such as bankruptcy--are ignored. Again this would tend to underestimate what the Bay area may actually experience.

The results obtained are shown in Table 3.

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[1] As an example, see Pitcher (1972) for a discussion of the General Economic Model used by the Office of Civil Defense. The Army Corps of Engineers has also considered the use of the input-output technique to estimate development benefits of water resource investments. The corps has restricted their assessment to the economic stimulation of a region as a direct result of the project, and have omitted reference to the secondary impact due to disaster (see Leven for a report describing these efforts).

Table 3

Interindustry Effects of Damage

to the Productive Sector

Economic Indicator	Levels of Economic Activity		
	Pre-Earthquake ($ Billion)	Post-Earthquake Direct Damage Only ($ Billion)	Post-Earthquake Direct plus Indirect Damage ($ Billion)
Gross Regional Product	53	43	39
Value Added	22	19	16

There are two indicators shown in Table 3, Gross Regional Product which shows a decline of $14 billion, and Value Added which is reduced by $6 billion. Although the term gross product is the most familiar in discussing economic performance, it is a misleading indicator to employ in deriving the implications of a regional economic downturn. It includes not only the value of economic activity of the region, but also the value of goods and intermediate products made elsewhere. Therefore, the Value Added category reflecting incomes to labor, capital, and other factors of production solely within the region is used to indicate the degree of economic collapse the earthquake would induce--estimated here to be about $6 billion in the first year.

One factor purposefully excluded from the inter-industry analysis, the effect of price changes, needs special attention both because of its potential for prolonging the period of recovery of the area, amd because of the implications for equity. The evidence on local inflation following a large disaster is inconclusive. Dacy and Kunreuther found that price changes following the Alaskan earthquake were rather insignificant. However, this could be explained on two grounds. First, the disaster was relatively minor in terms of total damage, around $300 million. Second, Federal government employment in the state totaled, in 1963, 58% of the work force. (Rogers, 1970). This large exogenous source of funds, as well as goods, would be sufficient to stabilize the economy given the magnitude of shock it experienced. It appears for these and other reasons that the problems of Alaska and San Francisco may not be comparable. New evidence available from Rapid City appears to indicate that a considerable rise in building costs and housing values ensued after the flood in 1972. Verification of this possibility deserves careful attention, since the prevailing belief is that acts of benevolence following a disaster serve to keep the price of essentials such as housing from escalating. A restrained set of prices may not be the case for a large concentrated disaster, like that addressed in this paper.

The implications of rapid price changes for the stricken community are twofold. First, it would tend to retard recovery since it would introduce another element of uncertainty which would only serve to compound the problems of reestablishing economic stabilization in employment and output. It may also put the regional industry in an unfavorable cost position at a point when its productive position is already weak. Second, rapid price changes would lead to a transfer of resources from the disaster victim to real estate and construction interests, many of which may be based outside the region or even the state.

Aside from price changes, disruption to the San Franciso Bay area economy is likely to result in a broader but less significant disruption to the state of California and the Western Region in General.[1] There is some evidence to suggest that southern California is fairly well insulated economically from the North. Martin and Carter (1962) found, in an inter-industry analysis of the state, that the effects of final demand for northern products are concentrated within northern California, rather than being distributed over the entire state (p. 63). In other words, the Los Angeles area is likely to be affected by the disruption in the North, but not to any significant extent.

The approach taken to develop estimates of the economic consequences of earthquakes is subject to some criticism because of its highly aggregated nature. At the outset of the study, we were faced with a decision whether a narrow approach should be undertaken which would concentrate on specific types of activities and attempt to trace the impact of their disruption, hopefully to identify a few critical activities which could suggest appropriate but isolated changes in policy. The other option was a broader based method which would sacrifice investigation of the interesting and the unusual, but might have the advantages of posing the underlying economic dynamic accompanying a large disaster. It was decided to pursue the latter course.

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[1]Although this study did not specifically address the problem of multiregional input-output effects, this would be a logical extension from the basic approach applied here.

Historical evidence against which these results may be compared is meager and somewhat suspect because of the peculiar situations from which data have been drawn. The inappropriateness of the Alaskan situation has already been mentioned. The alternative is the Second World War to provide the last series of major urban catastrophes, of which records have been kept. For example, a bombing survey conducted in Germany by Galbraith, et al. in 1946 concluded that bomb damage to the civilian economy was not a proximate cause of Germany's military collapse. "There was no evidence that shortages of civilian goods reached the point where German authorities were forced to transfer resources from war production in order to prevent a disintegration at the home front" (p. 136). The effects of bomb damage on the civilian economy were of a relatively long-term nature and the war against Germany was concluded before their maximum impact was felt (p. 137). Apparently, at least in wartime, the partial destruction of cities, as it occurred in WWII, does not lead to a loss in war production commensurate with the loss in property (Iklé, 1958, p. 225).

These observations confirm our suspicions about the resiliency and abilities of populations to endure and recuperate from massive disruption, but these observations about the German war economy may not apply to a peace time, technologically based economy of the San Franciso Bay region. It is not likely that the Bay area could muster the fervor in peace time necessary to duplicate the German experience. Nor is such a duplication necessarily desirable. It is not likely that local authorities would be willing to expose the local citizenry to hazardous and undesirable working conditions for the sake of a speedy recovery of industrial output.

Implications for Adjustment Choice

The magnitude and form of damage that the postulated earthquake inflicts upon the Bay area invites speculation about the mitigating effects of alternative adjustments--giving particular emphasis to how these adjustments may have an expanded role in preventing extensive social disruption.

Land Use Management -- In much of the natural hazards literature, the justification for practicing various forms of land use management lies in the reduction of direct damages associated with extreme events. The above analysis suggests that it is equally important to screen encroachment into hazardous areas so as to reduce the possibility of a crippling loss of sensitive economic activities.

Building Codes -- Combined with the selection process under Land Use, one could conceive of building codes that would be variable depending upon hazardousness of the location, as well as "importance" of the industry. Since the main point emerging from analysis of interindustry effects is the considerable divergence between private and social costs, one could recommend subsidization of earthquake reinforced construction as a desirable investment for the Federal government to undertake. This is particularly germane if one considers the price effects resulting from a large instantaneous demand on the construction industry and the associated distribution of resources that may entail.

Insurance -- If construction price increases are substantial, as they are likely to be, earthquake insurance will have a diminished value to the homeowner and the industrial concern. First, premiums are paid, apparently, with the expectation that the structure is restored. A local construction inflation could divert resources away from physical reconstruction toward increased profits for building supplies and other related activity, or toward the increased cost necessary to induce out of state construction firms to move into the area. These effects have implications for government action considered below. Second, although a firm may be insured for direct damage to plant and property, its productive activity may be interrupted for such an extended period that bankruptcy may ensue.[1]

Relief and Rehabilitation -- A situation similar to that of insurance applies to relief and rehabilitation (SBA loans). The benefits will be spread between victims and the construction industry. However, the problem of relief and rehabilitation payments offers some interesting additional considerations. The Federal government could attempt to stimulate different sectors of the local economy differentially so as to attaining any one of a number of given objectives--maximize gross output, maximize employment, or maximize revenue collected at the local level of government.

These objectives could be assessed with the aid of an input-output planning device similar to that used here. For example, if the objective was to maximize employment during the immediate impact period, sectors that have high employment multipliers would be stimulated. These usually consist of industries that buy from and sell to the region, and are usually labor-intensive; capital-intensive, export-oriented industries would be relatively unproductive in meeting the objective.

A similar approach can be applied to the equity problem. Since we

[1]During interruption of operation it must still pay interest on debt even though its variable costs, labor, and material are nonexistent. Without revenues this expense could force numerous bankruptcies.

know that certain industries employ differing gradations of labor--some highly skilled and highly paid, such as aerospace, and some not so--activities can be differentially stimulated so as to equitably distribute the benefit of employment. Naturally, these considerations must be coordinated with the long-run redevelopment plan for the community.

Warnings and Earthquake Prediction -- The techniques discussed above for post-disaster evaluation of systemic effects can also be applied to a preparedness program which needs to evaluate the benefits and cost of evacuating certain sectors of the economy in response to an earthquake prediction. One certainly would not recommend wholesale evacuation of a city, particularly under conditions of current forecast accuracy (error in time, location and magnitude). One would prefer a more orderly evacuation of the more sensitive industries combined with a program of strengthening buildings on selective basis, depending upon the industry's potential for creating disruptive effects on the economy. It should also be recognized that the collapsing of the local economy through selective evacuation poses a unique problem for local government. Traditionally the problem facing the municipality is to determine how economic development will broaden the tax base. The situation depicted for earthquake prediction is just the obverse of this.

Other adjustments -- Consideration of interindustry effects invites speculation on other forms of adjustment. For example, increased levels of inventories may insulate undamaged industries at least temporarily, from strategic shortages and bottlenecks. The normal function of inventories is to provide a form of insurance against an uncertain future (labor strikes, energy shortages, etc.); natural disasters also belong in this category.

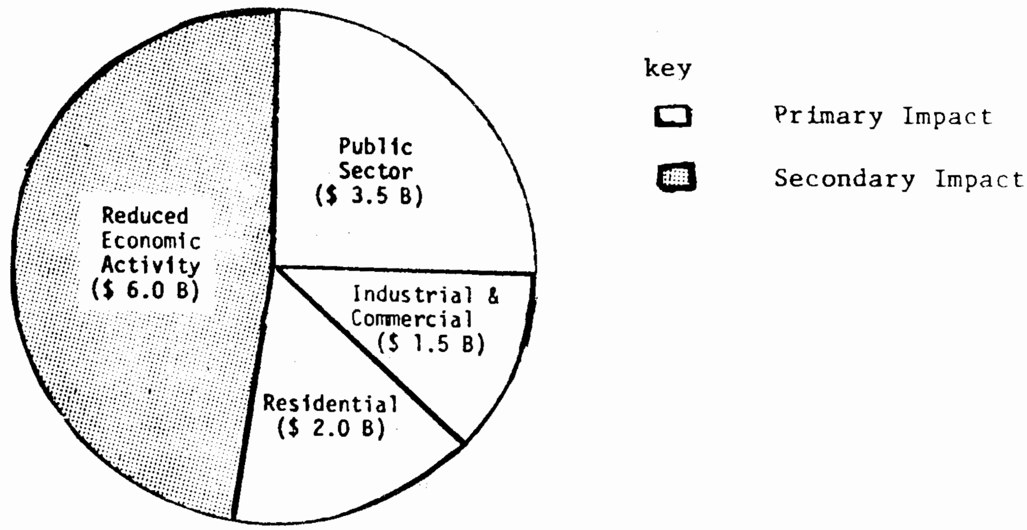
The financial community has been neglected in the interindustry analysis presented in this paper. But it may turn out to be one of the more significant elements of the problem. If left unchecked, the direct damages associated with disrupted production could lead to extensive loan default. If Federal Reserve requirements are maintained, this could lead to the closing of smaller independent banks, which in turn could exacerbate the recovery process. This suggests that the Central Bank make contingency plans which are consistent with the redevelopment effort. This same reasoning applies to the trading of stocks of affected companies; a trading panic may well result from the uncertainties surrounding stricken local based corporation The Securities and Exchange Commission may find it necessary to suspend trading on a selective basis. Each of these are highly speculative but invite further analysis on various methods of forestalling regional economic chaos.

Conclusions

A repetition of the 1906 San Francisco earthquake would cost the Bay area a minimum of $13 billion, but the employment of more pessimistic assumptions than those used in this study may escalate the cost by a factor of three or four. These losses would be divided almost evenly between direct damage to personal, business, and public property (primary impact), and indirect damages in the form of a decline in regional economic activity (secondary impact). Figure 2 shows a breakdown of these effects.

Figure 2

Breakdown of Losses



TOTAL COST
$ 13.0 Billion

The most important conclusion one may draw from these findings is that the effects of a large earthquake extend far beyond the damage which is visual. The magnitude of the secondary impacts suggests additional questions to those which research on the catastrophic event has traditionally addressed. Several pressing questions that grow out of the paper are:

1. How can the local government best deal with regional economic contraction in the wake of disaster?

2. What plans should be made by institutions to avoid the perpetuation of economic recession?

3. How will changes in industrial organization and specialization (both horizontal and vertical) affect the magnitude of secondary impact? What are the trends?

4. What strategy can the Federal government employ to quickly, efficiently and equitably stimulate a crippled regional economy?

5. What can the local or Federal governments do to blunt the expected inflation following a large earthquake?

6. What are the implications of the above for choice of adjustments to the hazard?

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Appendix I

Assessment of Direct Damages

To derive an estimate of direct damages to residential housing and commercial plant and equipment the isoseismal pattern shown in Figure I-1. was superimposed on a planning map of the nine county bay area[1] (See Figure I-2 for the map used in this study). Each area in Figure I-2 corresponds to a planning district. These districts are aggregations of census tracts and provide estimates of the number of residences, the number of persons employed in basic industry[2] and the number employed in local service industry.[3]

By assigning these intensities to the planning districts, the distribution of damages among industry types and residences was approximated. Figures I-3 through I-5 show the result of applying these procedures. The shaded districts encompass 90% of all damaged residences (Figure I-3), basic industry (Figure I-4), and local service industry (Figure I-5). The reason for displaying the damages in such a manner is to determine the counties most severely affected. With this information the vector of regional outputs, used in the interindustry analysis discussed in Appendix II, could be more accurately assessed.

To proceed from the estimates of populations affected to a calculation of direct damages, it was necessary to apply an intensity damage relationship to the value of structures affected. Because of the differences

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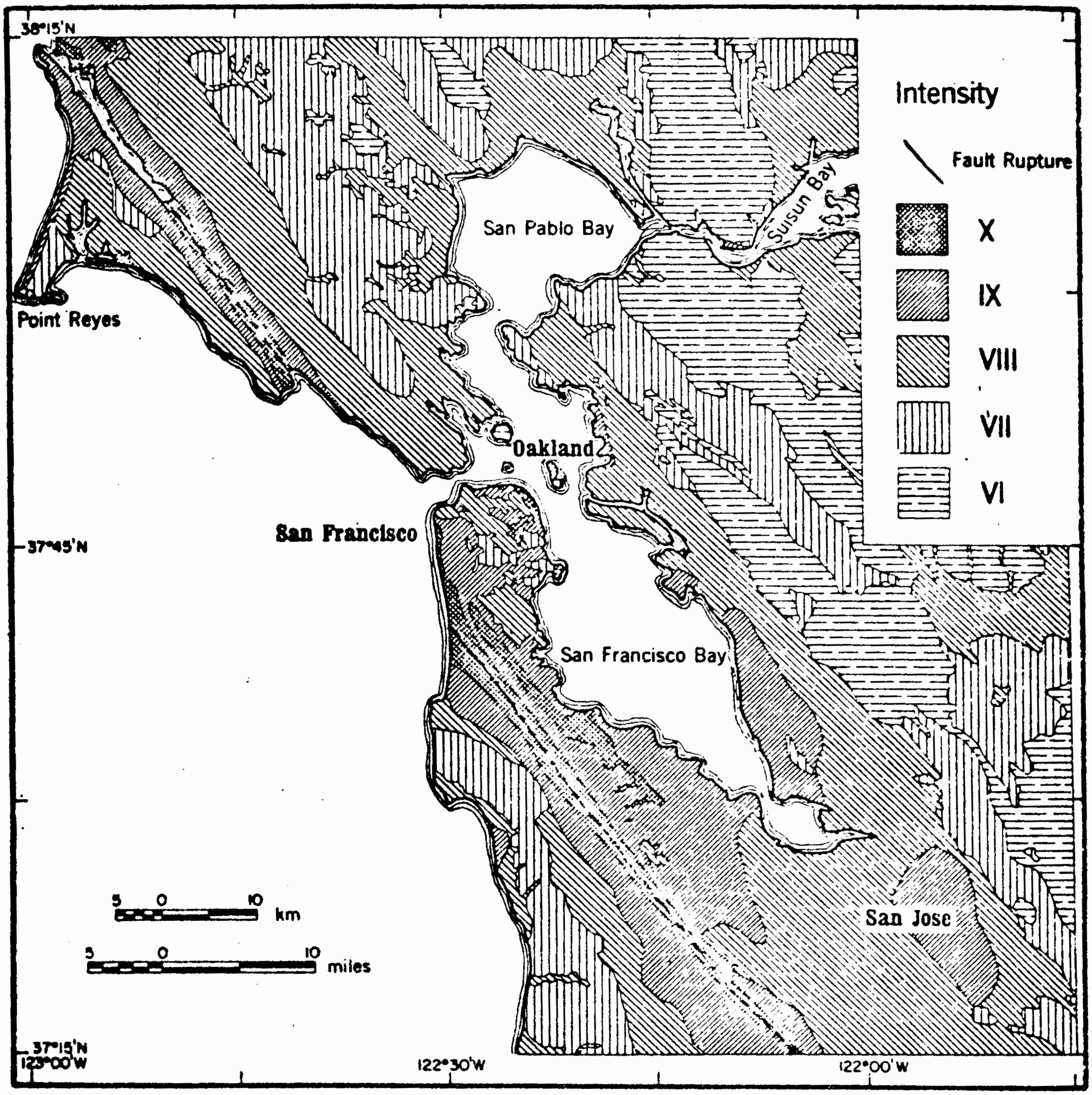
[1]The planning map used was developed by the Association of Bay Area Government's Metropolitan Transportation Commission.

[2]Basic industry is defined as those activities that produce goods and services mainly for export out of the region or for intermediate use by other firms in the region.

[3]Local service industry is composed of those activities which are dependent upon the location of the nighttime residential population from which most of the demand for consumer goods and services originates. Industry categories as retail trade, business services, finance, insurance and real estate are representative of this classification.

Figure I-1

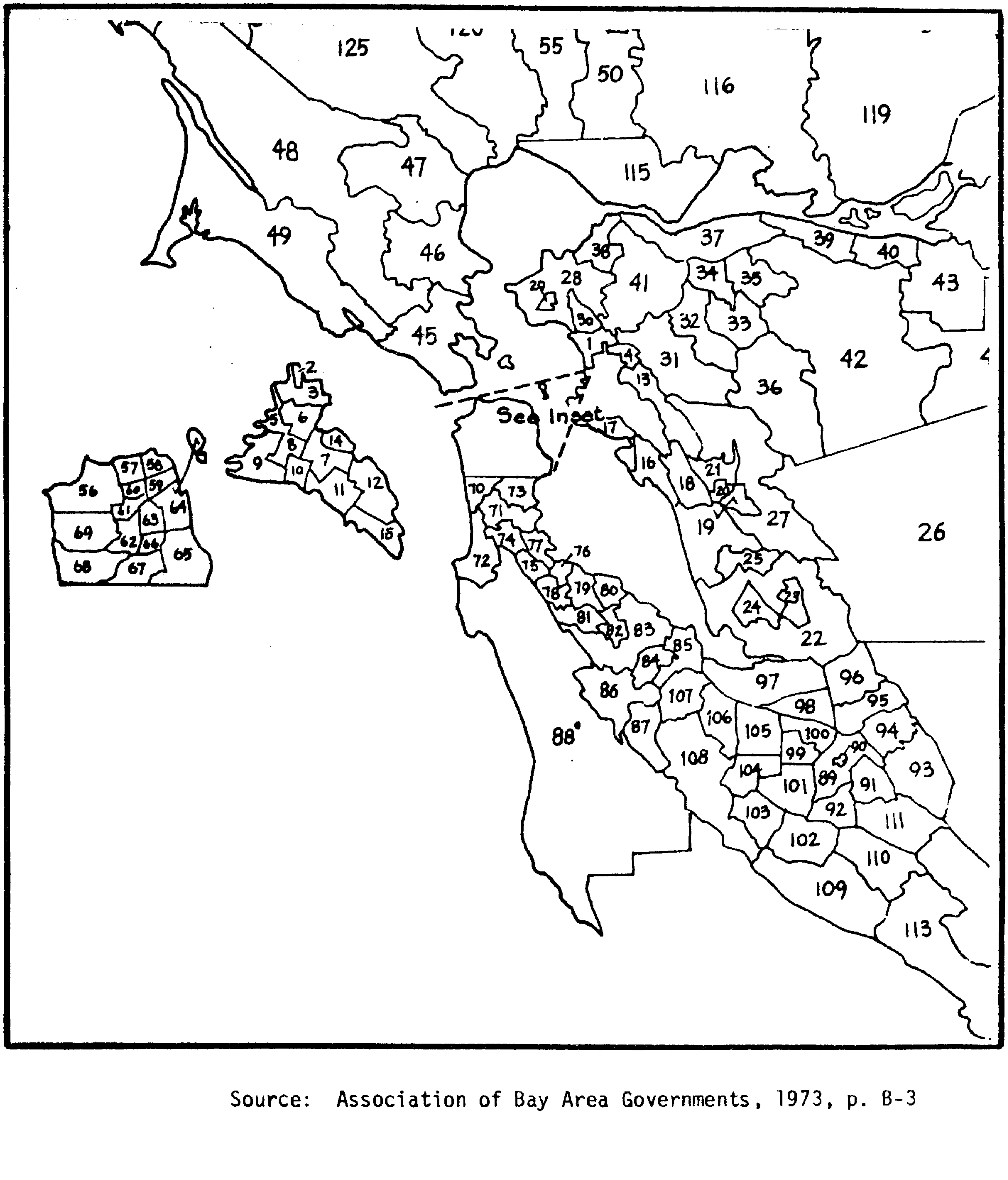
Intensity Distribution from a Magnitude 8.3 Earthquake on the San Andreas Fault



Source: NOAA, 1972, p. 14

Figure I-2

Planning Districts



Source: Association of Bay Area Governments, 1973, p. B-3

FIGURE I-3

RESIDENTIAL

UNITS

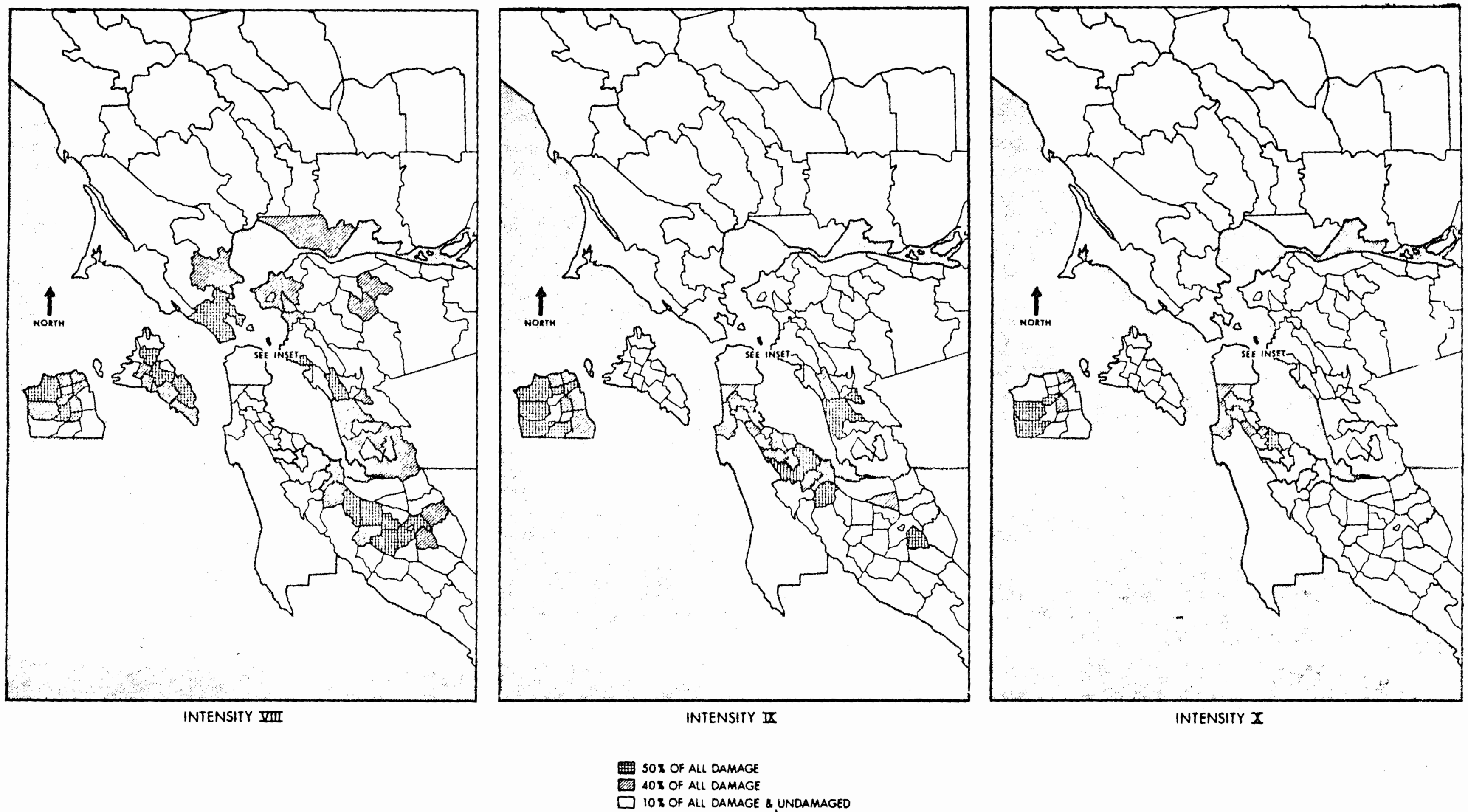
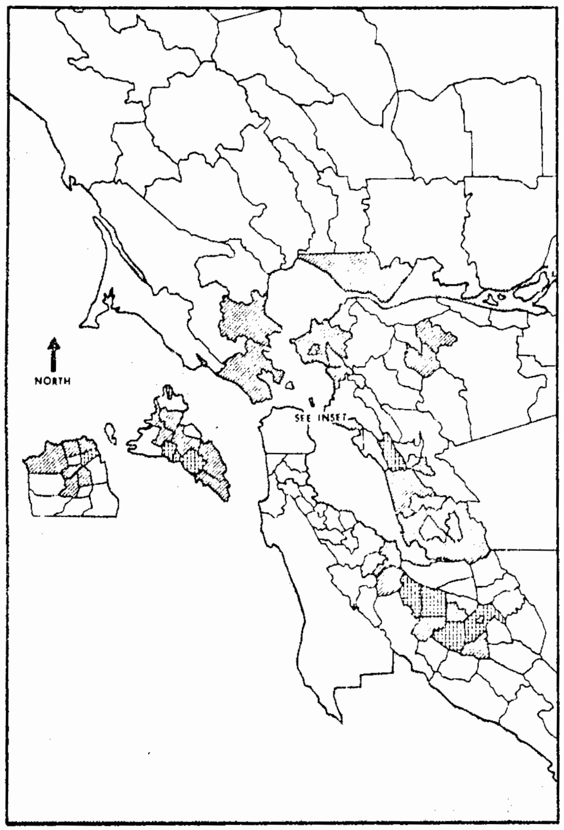
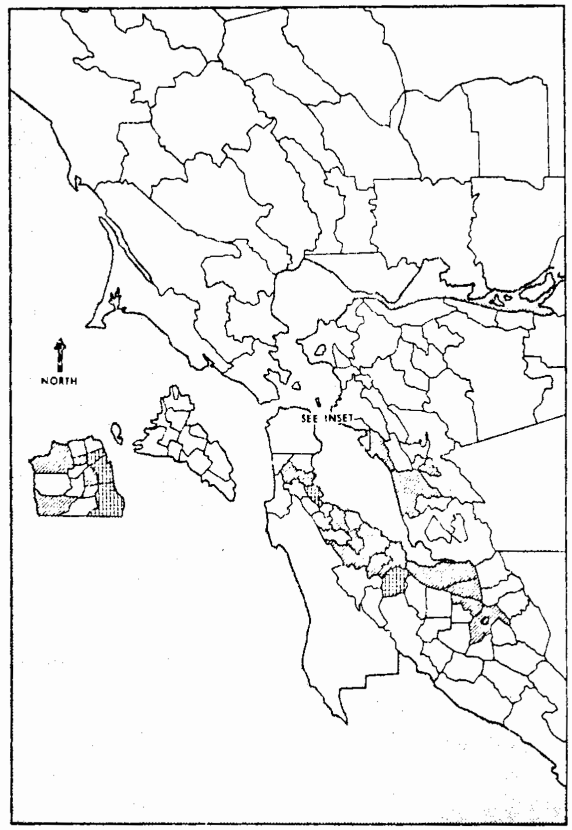


FIGURE I-4

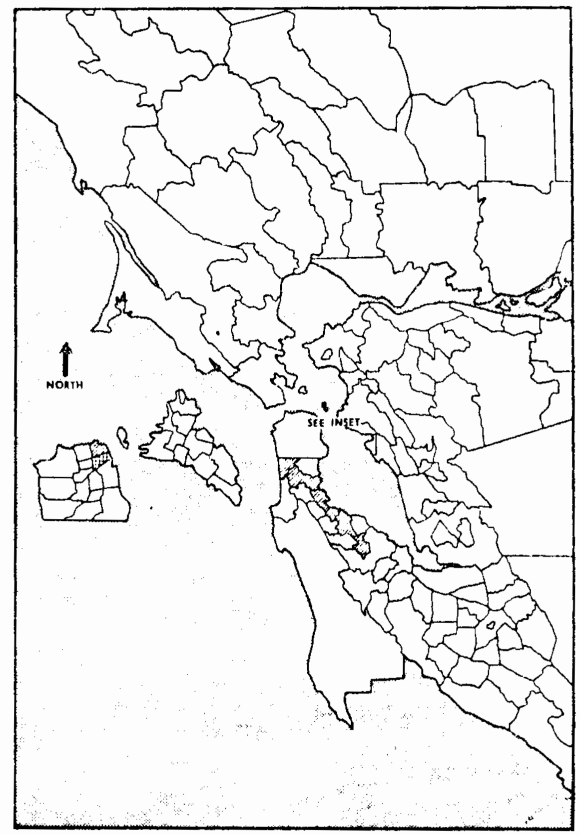
BASIC EMPLOYMENT



INTENSITY VIII



INTENSITY IX

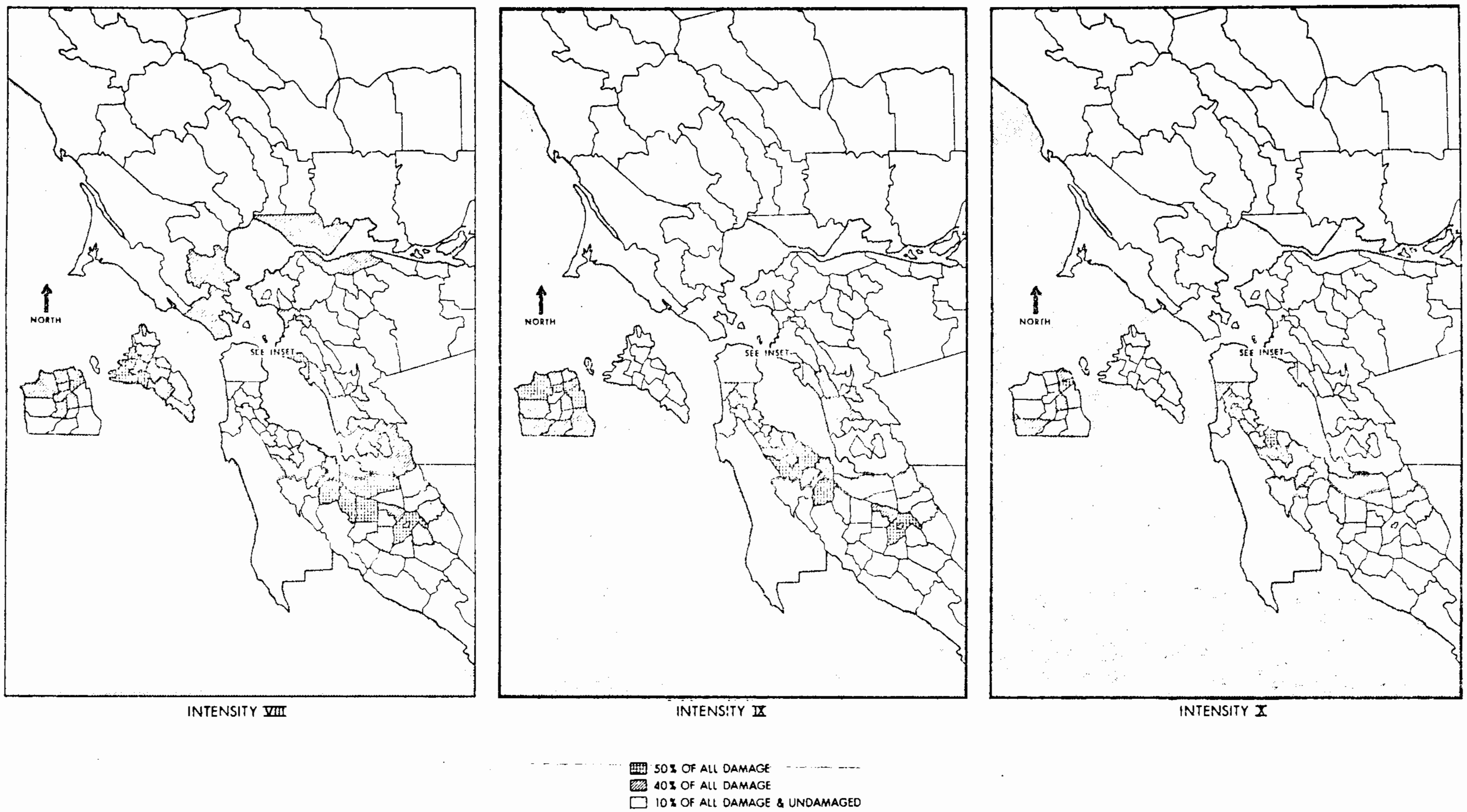


INTENSITY X

50% OF ALL DAMAGE
40% OF ALL DAMAGE
10% OF ALL DAMAGE & UNDAMAGED

FIGURE I-5

LOCAL SERVICE EMPLOYMENT



in response to ground motion of various building designs, two relationships were selected for use in this study. The first, for residences, is shown as curve 1 in Figure I-6. The curve for commercial buildings was more difficult to estimate because of the multitude of building designs in the San Francisco area. This uncertainty was resolved by applying the most optimistic relationship, that is a building response which incorporates all the latest earthquake design technology.[1] See curve 2 in Figure I-6.

Assuming a mean value of $20,000 for residential structures, the total damage to this building classification approximates $2 billion. The estimate compares favorably with one made by NOAA, 1972 on the same earthquake--$1.2 billion.

Estimating the direct damage to commercial and industrial properties is somewhat more difficult since the actual number of structures by planning district was not given. The value of these buildings had to be derived from knowledge of industrial employment. There are more complex ways of deriving this relationship,[2] but course nature of other estimates in the study does not warrant an elegant derivation of building value. Rather several rules of thumb are employed.

First, it was assumed that the ratio of current depreciation to gross depreciable assets is constant for all industries at about 9% (Williams, 1962, p. 162).

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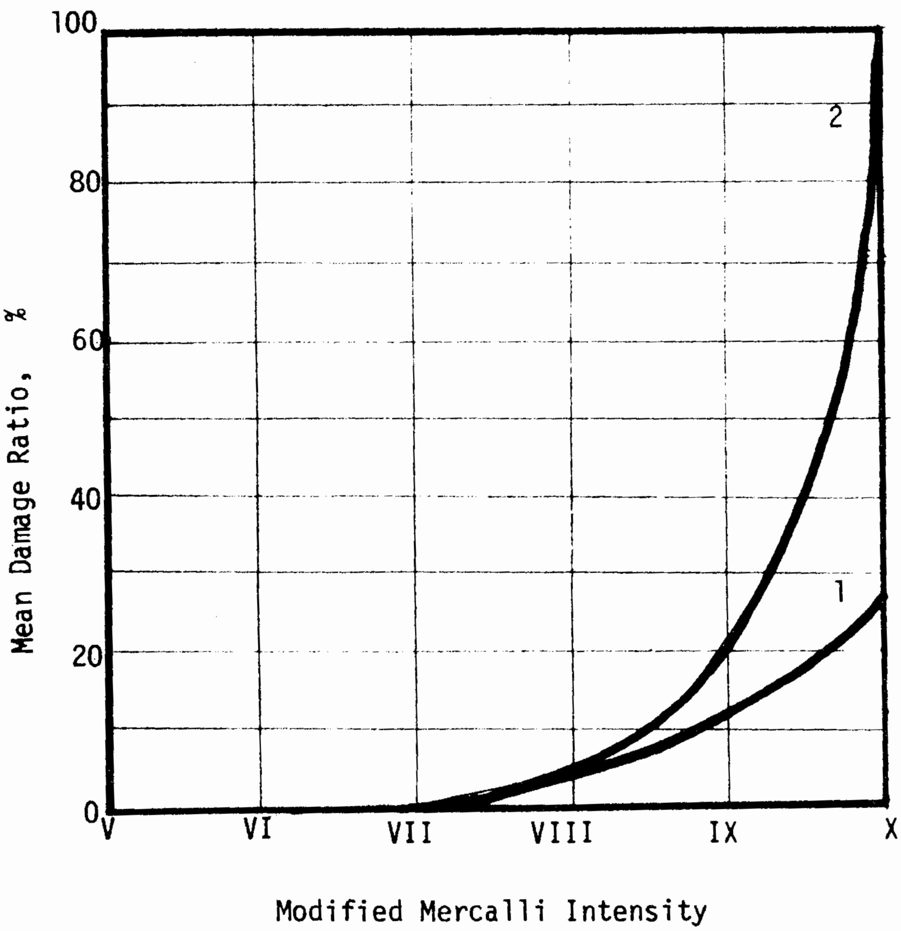
[1] This was labeled building code "S" by Whitman, et al., 1973.

[2] A more thorough analysis could be suggested, one which would postulate a production function, Cobb-Douglas, and proceed to relate labor input to its capital complement through knowledge of value of shipments and an empirically derived coefficient of substitution.

Figure I-6

Intensity Damage Relations



Source: Curve 1 -- Friedman (1969)

Curve 2 -- Whitman, et al. (1973)

Second, it is assumed that the capital cost expressed as a percentage of the value of shipments can range from a low of approximately 1% to a high of 5%. For several examples of this capital cost by industry, see Table I-1.

Table I-1

Capital Cost by Industry For

a Few Selected Industries

Industry	Capital Cost* (% of Value of Shipments)
Meat Packing	.92
Millinery	1.25
Paints	1.55
Gray Iron Foundaries	4.56
Machine Tool Accessories	4.98

*percentages are mean costs for all states.

Source: Williams, 1962 p. 121

With these assumptions and the knowledge that the gross regional product is $52 billion, the total industrial capital at risk should range between $5 billion and $25 billion, the true value probably lying closer to the latter estimate. Although the value of capital for the region may approximate $20 billion, much of this is in the form of equipment and inventories which would be salvageable, providing that widespread fires do not erupt. Hence, the structure value, in which we are interested, is estimated to be one half of capital value, or $10 billion.

Damage was calculated from the distribution of employment in intensity zones (Table 1 in text), and the intensity damage relationship provided in Figure II-6. These data along with resultant damages are provided in Table II-2.

Table II-2

Industrial and Commercial

Damages by Intensity Zone

	Modified Mercalli					
	X	IX	VIII	VII	VI	Less Than VI
Employment Affected (% of total employment)	8.3	26.6	45.0	7.5	5.0	10.6
Value of Commercial and Industrial Structures Affected ($ million)	830	2,360	4,500	750	500	1,006
Mean Damage Ratio* (% of structure value)	100	20	5	2	1	--
Damage by Intensity Zone	830	472	225	15	5	--

TOTAL DAMAGE $1.5 billion

*From Figure I-6

The estimation of public sector damages puts us on even less solid ground than that of the preceding two categories. The best we could do within the limits of data currently available is to forecast damages to be a proportion of private sector losses.

A rough breakdown from previous earthquakes in the United States shows that public losses may slightly exceed the private.

Breakdown of Private and Public Damage

(%)

	San Fernando Earthquake (1971)[1]	Alaskan Earthquake (1964)[2]
Public	52	75
Private	48	25

1. Source, NOAA, 1972, p. 17

2. Source, Dacy and Kunreuther, p. 51

Based upon this experience, the public sector damages are estimated to be equal to that of private damage, or about $3.5 billion.

The sum total of direct damage, including both public and private is about $7 billion.

Appendix II

Regional Economic Analysis

Regional input-output analysis is used in this paper to identify those second and higher order social effects that result from the occurrence of a natural phenomenon. These social effects can take on a number of characteristics, but for practical purposes, this discussion is limited to the economic realm--estimating reduction in production, unemployment, lost tax revenues, reduced local government expenditures, etc.

Any given region of the country contains an ongoing economic process. The region imports goods and services from other regions, it carries on its own chains of production, it consumes a proportion of the final output, and it exports the remainder either as an input to a neighboring region's economic process or to satisfy the neighboring region's final demand. Naturally, the complexity of this process is highly dependent upon the industrial development of the region and the number and variety of activities carried on.

The evolution of economic interdependence has occurred at a cost--although efficient, these linkages provide for an unstable system. One need look no further than the impact of the current fuel shortage to realize the delicacy with which economic sectors are tied together. One convenient way to visualize these interdependencies is to think of them as "cooking recipes" (these are what economists refer to as production functions).

(1) coal (1 ton) + iron ore (.2 tons) + capital + labor $\rightarrow$ steel (.1 ton)

But coal in turn requires its own "recipe".

(2) capital + labor + petroleum $\rightarrow$ coal

By a similar procedure, "recipes" for each major product produced in the economy can be derived. These functional relationships are the subject of input-output analysis.

An input-output (I-0) table consists of a set of technical coefficients which are similar to the "recipes" depicted in (1) and (2) above.

(3) Purchasing Sector (j); Output Sector (i)

$$\begin{bmatrix} a_{ij} & \cdots & a_{in} \\ \vdots & \ddots & \\ a_{nj} & & a_{nn} \end{bmatrix}$$

Where: a_{ij} is the technical coefficient. They represent the direct requirements of the output of any sector i per unit of any other purchasing sector j.

The matrix shows the structural interdependence for the region's production. The total amount produced of any particular commodity depends upon two factors: 1) the final demand for that commodity; and 2) the intermediate demand for that commodity in the production of other commodities. Therefore, by knowing the I-0 matrix, the amount of products available for final demand can be determined by subtracting the intermediate demands from the total amount of commodities produced.

(4) $X - AX = D$ where: D is final demand AX is interindustry requirements and X is industrial and commercial output by sector.

By rearranging these matrices, a solution for the amount produced by the region can be obtained.

(5) $X = (I-A)^{-1} D$ where: I is the identity matrix and $(I-A)^{-1}$ is commonly referred to as the Leontief inverse.[1]

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[1] Each element in the Leontief inverse is called an interdependency coefficient. These coefficients represent direct and indirect requirements of one sector, per unit of final demand of another sector.

The derivation of (5) is not as important as the recognition that the gross product of a region is dependent upon final demand for goods and services, and the interdependence of intermediate production in the region. Not all goods produced are directly consumed. Rather, they may be transformed into other goods which are then sold to final demand.

(5) is the equation traditionally used to determine the regional economic impact of any change in the final demand for that economy's goods and services. In other words it is useful for estimating how the output vector X responds to changes in D. However, the problem of predicting the indirect economic impacts of a large earthquake requires knowledge of how the economy will respond to a drastic reduction in supply of various factors or production, as well as goods available for final consumption.

By rearranging (5) into

(6) $(I-A)\ X = D$

we see that final demand for goods and services is isolated on the right side of the equation, and supply of these items on the left. The earthquake will have the effect of reducing output in one or more industries in the area. For example, assume that the assessment of damage in the area suggests only minor damage to all industries except the special machine and equipment industry in a particularly vulnerable location in the Bay area. In this situation, the post-impact array of goods and services available to the region's consumer must be adjusted for the partial loss of this one intermediate good.

$$(7) \qquad \overset{t_o}{\begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ \cdot \\ \cdot \\ \cdot \\ x_{86} \end{bmatrix}} \qquad \overset{t_1}{\begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ \cdot \\ \cdot \\ \cdot \\ x_{86} \end{bmatrix}}$$

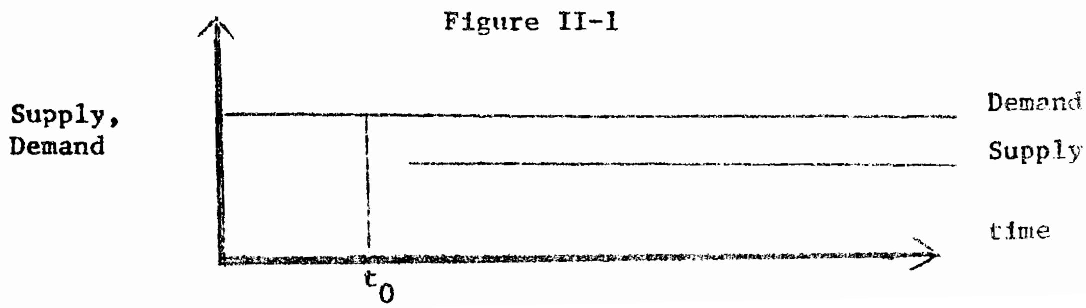
where: t_o is a pre-impact vector of industry outputs

t_1 is a post-impact vector before secondary effects are assessed

To assess losses to the region as the sum of damages and lost production in the special machine and equipment industry is to underestimate the economic impact by the magnitude of all the secondary effects. Since this industry may be an important ingredient in the output of other industries, the effects on their production must also be determined. Unfortunately, the usefulness, of input-output analysis is somewhat diminished under these circumstances, since there are a number of options that these industries have to mitigate the effects of this temporary shortage. They may substitute other factors in their production processes or they may import if possible. However, if the disaster is severe enough and affects industries vital enough to the production process, then even these options are closed.

At this point we know that the capability of supplying the final demands shown in (6) have diminished (see Figure II-1) through a combination of direct and indirect effects.

Figure II-1



Before t_o in Figure II-1, the levels of output demanded and supplied were approximately the same--in other words, there existed an equilibrium set of prices for each of the major products produced and consumed in the region. After impact (t_o), supply and demand diverged because of the disruption in economic activity. Given this situation, two forces will be set in motion to restore equilibrium: 1) prices will change for products that are in short supply; and 2) supply of the affected sector's product will increase due to increased imports into the region and eventual recuperation of affected industries. The input-output model by itself cannot forecast either of these changes; they must be evaluated by the model builder. Ideally the price increases would signal both supply sources outside the region as well as possible sources inside the region to increase production and thereby reduce bottlenecks.[1]

All this neglects the demand side of the equation--as shown in Figure II-1, it is assumed that demand remains invariant throughout the adjustment process. This is clearly unrealistic since the decrease in output in affected sectors will reduce employment and hence final demand, at least to the extent that unemployment compensation fails to meet the level of wages previously attained. Unemployment coupled with reduced output and sales in the region would lead to a decline in revenues collected at all levels of government. The local level which relies heavily on property and sales taxes would be directly and immediately affected as would be the state[2] and Federal governments whose revenues are derived from the income tax. To the extent

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[1]For a more sophisticated analysis which attempts to incorporate prices and production functions in assessment of indirect effects of disaster, see H. Pitcher and R. Collins.

[2]If withholding is practiced.

that these governments (particularly the local) provide services to industry, and particularly in light of the necessity of the local government to balance its budget, the supply of products by industry will be further curtailed.

These effects can readily be incorporated into the above analysis by making the household and government demands, which have been treated exogenously in (5) and (6) above, endogenous. That is, we must close the model by creating an A matrix which include both government and households (call it A*).

$$(8)\ X' - A^{*}X'' = 0$$

where: X' is the output capabilities just after the earthquake

X^1 represents the direct effects of the earthquake-reduced levels of interindustry inputs and incomes (wages, rents, profits, taxes) because of damages to plant and equipment. The object is to determine how this distortion in sector activites can lead to further declines in output and final demand (X''). For reasons cited above, this is not directly attainable from the relation shown in (*). There has been little work done to assess the possible substitutions that can be made under crisis conditions, or how such substitutions may affect regional productivity. Nor has much evidence been accumulated to suggest the magnitude of price changes that may be triggered from the first round reduction in output. Because of these limitations in our knowledge, a simplified approach to the problem was taken. First, it is assumed that the earthquake did not significantly damage the ability of the government or other social organizations to function. Second, it is assumed that bankruptcies will not ensue because of reduction or reorientations in output strategy. Third, loss of life does not affect the remaining capital productivity. Fourth, labor and capital are mobile. In short, these assumptions are made to provide an optimistic estimate of reduction in regional output. In all probability the violation of any or all of these assumptions would lead to a much greater decline in economic activity than is projected on the basis of this analysis.

With these assumptions the problem can be placed in a linear programming framework in which the objective is to maximize the regional output plus final demands[1], subject to the constraints imposed by (8). In equation form

$$(9) \quad \text{Max} \sum_{i=1}^{n} X''_i$$

$$\text{Subject to:} \quad AX'' \geq X'$$

$$X'' \geq X'$$

X" is the regional outputs and final demands and they are subject to the interindustry and capacity constraints. Again, the capacity (or income and input) constraints are derived from the direct damages.

One may rightfully argue that reformulating the problem into one of optimization does not, or would not capture the actual behavior of the regional economy in the wake of a large scale disaster. But again, we are following an optimistic track by suggesting that the economy may in fact perform worse than an optimum; any results obtained in this analysis may understate the magnitude of the indirect effects. And this at least provides a benchmark, against which more pessimistic assumptions could be compared.

Application of this technique to the Bay area economy required an estimate of change in productive capacity, developed in Appendix I, and an input-output table of the region (Table II-1).

The results of applying the linear program to the regional productive capacities are shown in Table II-2.

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[1] One could also establish the objective of maximizing value added or employment.

Table II-1

Technical Coefficient of the Bay Area Economy*

	1. Agriculture, Forestry and Fisheries	2. Mining	3. Construction	4. Food and Kindred Products	5. Paper and Allied Products	6. Chemicals and Chemical Products	7. Petroleum Refining and Related Industries	8. Stone and Clay Products	9. Fabricated Metal Products	10. All Other Manufacturing	11. Transportation, Communication, Electric, Gas and Sanitary Services	12. Wholesale and Retail Trade	13. Finance, Insurance and Real Estate	14. Services and Government Enterprises	15. Total Final Demand
1. Agriculture, Forestry and Fisheries	.1021	--	.0009	.1033	--	.0005	--	.0001	.0000	.0050	.0001	.0005	.0083	.0002	.0038
2. Mining	.0001	.0049	.0007	.0000	.0006	.0019	.0387	.0042	.0000	.0009	.0020	.0000	.0001	.0001	.0000
3. Construction	.0123	.0006	.0001	.0034	.0038	.0015	.0014	.0004	.0006	.0017	.0315	.0081	.0653	.0226	.1352
4. Food and Kindred Products	.0669	--	.0001	.1718	.0048	.0175	.0006	.0007	.0000	.0005	.0014	.0062	.0006	.0253	.1076
5. Paper and Allied Products	.0006	.0013	.0040	.0145	.2177	.0232	.0040	.0321	.0071	.0146	.0007	.0064	.0013	.0063	.0011
6. Chemicals and Chemical Products	.0185	.0088	.0177	.0052	.0277	.2126	.0283	.0314	.0084	.0192	.0012	.0021	.0012	.0086	.0061
7. Petroleum Refining and Related Industries	.0174	.0079	.0181	.0038	.0094	.0321	.0721	.0090	.0048	.0028	.0257	.0077	.0052	.0042	.0567
8. Stone and Clay Products	.0004	.0050	.0526	.0063	.0032	.0074	.0016	.0801	.0058	.0061	.0003	.0018	.0002	.0016	.0004
9. Fabricated Metal Products	.0019	.0044	.0832	.0218	.0088	.0147	.0147	.0101	.0557	.0242	.0025	.0018	.0002	.0017	.0037
10. All Other Manufacturing	.0113	.0386	.1324	.0075	.0685	.0300	.0017	.0276	.3084	.2788	.0255	.0142	.0084	.1080	.1035
11. Transportation, Communication, Electric, Gas and Sanitary Services	.0239	.0440	.0356	.0461	.0537	.0488	.0709	.0839	.0266	.0300	.1051	.0343	.0188	.0865	.0585
12. Wholesale and Retail Trade	.0337	.0212	.0878	.0350	.0374	.0297	.0107	.0328	.0351	.0355	.0193	.0162	.0147	.0269	.1169
13. Finance, Insurance and Real Estate	.0497	.0953	.0118	.0092	.0114	.0179	.0146	.0170	.0131	.0137	.0323	.0693	.126	.0529	.1287
14. Services and Government Enterprises	.0238	.0287	.0006	.0605	.0217	.0722	.0272	.0311	.0255	.0323	.0925	.0962	.0543	.0869	.1382
15. Value Added	.6365	.6990	.0172	.5400	.5306	.4910	.7120	.4965	.5081	.5404	.6591	.7357	.6944	.5652	.1389

* Derived from Bargur, Davis and Lofting, 1971.

Table II-2

Direct and Indirect Effects of the Earthquake on the San Francisco Bay Region Economy

Sector	Pre Earthquake[1] Structure of Outputs (million $)	Post Earthquake Structure of Outputs (million $)	Direct % Reduction in Output from Pre Earthquake Levels (%)	"Optimum" Structure of Outputs (million $)	Indirect % Reduction From Direct Effects (%)
1 Agriculture, Forestry & Fisheries	533	533	0[2]	533	0
2 Mining	81	81	0[2]	81	0
3 Construction	3,470	3,407	0[2]	2,871	16
4 Food & Kindred Products	3,071	2,149	30	1,408	34
5 Paper & Allied Products	327	277	15	277	0
6 Chemicals & Chemical Products	569	438	23	436	.5
7 Petroleum Refining & Related Industries	1,617	1,584	2	1,584	0
8 Stone & Clay Products	295	268	9	268	0
9 Fabricated Metal Products	661	482	27	150	69
10 All other Manufacturing	5,108	3,728	27	3,728	0
11 Transportation, Communication, Electric, Gas & Sanitary Services	2,831	2,378	16	2,378	0
12 Wholesale & Retail Trade	3,537	2,653	24	2,653	0
13 Finance, Insurance & Real Estate	4,142	3,106	25	3,106	0
14 Services & Government Enterprise	4,914	3,685	25	3,685	0
15 Value Added	21,717	18,516	15	16,210	9

1. Source: Bargur, Davis and Lofting

2. It was assumed that because of the nature of these activities, agriculture, mining and construction would be unaffected, at least directly, by the earthquake.

FORECASTING THE CONSEQUENCES OF EARTHQUAKE FORECASTING

J. Eugene Haas

Scientific research on earthquake prediction is underway. In only a matter of a few years, earthquake forecasts with high reliability will be available. Some of the forecasts will deal with damaging earthquakes. Even if carefully planned, such forecasts can not be suppressed for long. These forecasts seem likely to reduce potential deaths and injuries (Kisslinger and Algermissen 1973). It is very much an open question, however, whether all things considered, these forecasts will turn out to be more of a blessing than a curse.

This paper treats three related questions. What could be done with an earthquake forecast where the lead time was at least one year? What are some of the likely outcomes of early earthquake forecasts? In anticipation of earthquake forecasting in the near future, what type of research is needed?

I. What could be done if there was a credible forecast of a damaging earthquake with 12 months or more lead time?

Since there is so much that could be done (Final Report, 1974), at least ideally, I will simply discuss the highlights in outline form.

A. Local Government Actions at the Local Level:

Develop community-wide emergency response plans

1. General Planning --

Review and/or update earthquake hazard mapping for area

Update community master plan

Develop and/or update urban renewal or similar program planning and application

Develop and/or update community emergency response plan

2. Altering Budgets and Taxation --

   Revise estimates on expenditures

   Reduce planned expenditures for "less essential" programs

   Alter tax structure to meet anticipated expenditures

   Prepare and adopt tax relief measures for property owners who may suffer significant loss.

3. Action to Reduce Loss to Public Facilities --

   Remove "damagable" property and inventory from unsafe and marginal structures

   Improve building inspection process

   Strengthen structures and systems as feasible

   More rigid inspection and enforcement to reduce fire hazard and hazard from toxic and combustible materials

   Improving response capability, especially as regards fire fighting

4. Actions Designed to Reduce Loss to Private Property --

   More rigid inspection and enforcement to reduce fire hazard and hazard from toxic and combustible materials (applies principally to industrial and commercial establishments)

   Revision and strengthening of ordinances relating to fire and similar hazards

   Improving response capability, especially as regards fire fighting

   Require that all "questionable" private structures be examined for seismic resistance by competent specialists

   Require strengthening or alteration of private structures as needed and feasible

Revision and strengthening of local version of the Uniform Building Code

Intensive educational efforts aimed at producing increased action to reduce private loss

5. Actions Designed to Reduce Casualties and Social Disruption

(Many of the actions listed under "3" and "4" above apply here also.) Additional actions: --

Detailed examination by competent specialists of emergency response plans for all facilities serving the public and/or accommodating large numbers of persons.

Revision and strengthening of relevant ordinances dealing with emergency response actions.

Intensive educational efforts aimed at establishing and improving emergency response plans. (Includes focus on organizations and similar collectivities such as an apartment building as well as individual families.)

Develop plans for evacuation combined with plans for the emergency feeding and housing of local residents outside of area of the anticipated earthquake.

Develop any special plans deemed necessary to maintain public order and protect property in evacuated areas.

In coordination with local employers develop arrangements for a safe "journey to work" for places of employment located in high and moderate risk areas.

Develop an inventory of all significant local sources of food-stuffs, water, vacant housing, medical supplies and equipment, structures that would be readily adapted to classroom use, clothing and bedding and any type of specialized equipment thought to be especially useful following an earthquake.

Develop an inventory of local specialists whose skills are likely to be especially needed in pre-earthquake planning and/or in response to the earthquake.

B. Local Government in Relation to Non-local Agencies and Organizations

1. Federal Governmental Agencies (Office of Emergency Preparedness 1972) --

Inquiries, negotiations and applications regarding:

Earthquake hazard mapping

Earthquake prevention

Validity and specificity of the earthquake forecasts

Technical advice, assistance and funding relating to inspection and alteration of structures and systems

Technical advice, assistance and funding relating to governmental responsibility for the needs of a displaced population (food, housing, medical care, schooling, recreation, unemployment benefits, etc.)

The character and funding possibilities for any Federal Program that might be relevant to any aspect of the restoration and reconstruction effort

2. State Agencies and Other Political Units Within the State (California Emergency Plan, 1970) --

Contacts with state agencies could be principally aimed at securing technical advice and funding. For other political entities it could be principally to secure information. In a few instances the development/enlargement of mutual aid agreements may be involved.

3. Professional Associations, Labor Unions, etc., at State, Regional, and National Level --

   Secure information on pre- and post-earthquake availability of specialists and skilled laborers.

C. Private Organizations with Local Involvement

1. Actions to Reduce Direct Property Loss
2. Actions to Minimize Indirect Economic Loss
3. Actions to Protect Health and Welfare of Members

D. Individuals and Families

1. Actions to Reduce Household Loss
2. Actions to Minimize Investment and Related Loss
3. Actions to Protect Health and Well Being of Individuals

II. Based on the current literature, what are some of the likely outcomes of early earthquake forecasts?

Theoretical Overview

Organizations are self serving. The observer will seldom go wrong if he assumes that the principal driving force in any organization is for the maintenance or enlargement of its autonomy, security and prestige (Haas and Drabek, 1973). Thus, if one wishes to anticipate how an organization will respond to changed internal or external circumstances, he should examine how the new circimstances are likely to relate to this basic driving force.

Every organization has a domain. The domain is composed of normative notions about the types of activity that the organization ought to or may legitimately be engaged in and the location of such activity. It also includes normative ideas about the authority which the organization may wield in relation to other organizations, groups, and individuals.

The organization's prestige is also a domain dimension (Haas and Drabek, 1973).

If we ask then, which organizations should be noted in any examination of the probable consequences of earthquake prediction, the concept of organizational domain has immediate relevancy. Earthquakes damage and destroy structures and physical systems which means the disruption of individual lives and social systems (Haas and Norton, 1970; Haas and Ayre, 1970; Kates, et al., 1973). Any organization that is likely, according to a specific earthquake forecast, to recieve physical damage will thereby be subject to some social disrupion (Haas and Drabek, 1970). Its property is now known to be at risk to a much greater extent than before. Thus, any organization having physical resources in the projected earthquake area will _ipso facto_ have its domain potentially altered. But even organizations whose physical resources are all located outside of the forecast area may offer services (e.g., insurance, legal advice, directing the actions of local organizations) or be conducting activity of some type (e.g., lobbying, sales activity for a foreign firm) within the forecast area. Such organizations also face the possibility of domain alteration. For example, following an earthquake forecast the demand for some of their service may increase or decrease dramatically (Drabek and Haas, 1969). New activities may be demanded of them. Failure to perform well under the new circumstances may significantly undermine the organization's prestige. Local organizations may become more likely to defy the authority of "higher" external organizations. Thus, for many organizations the earthquake forecast _per se_ will alter their domains even if the earthquake doesn't materialize at the time forecast.

But any change in the environment of an organization need not represent a threat to its domain. The change may indeed offer a whole series of opportunities for organizational aggrandizement. Just as a flood produces numerous opportunities for organizations with equipment to pump out basements and high winds produce opportunities for those who build signs and repair roofs, just so is it probable that certain organizations will find the city which is the focus of a credible earthquake forecast a gold mine of opportunities. However, which specific type of organization will be interested and what the character will be of the opportunities that develop is difficult to pin point as of now. Nevertheless, it seems safe to forecast that a credible earthquake forecast will produce numerous opportunities and that the opportunity vacuum will be quickly filled.

Organizations monitor their environments more or less. Some do so through a whole range of procedures and specialized personnel at considerable cost while at the other extreme some organizations garner information regarding relevant parts of their environments in a most casual and sporadic manner (Haas and Drabek, 1973). Those whose current monitoring processes are effective and comprehensive will be among the first to take official cognizance of the likelihood that successful earthquake forecasting is on the horizon. Such recognition will lead to a reconsideration of current organizational policies and activities and even to quick change when a credible and relevant earthquake forecast comes along. It would be surprising if certain large commercial firms weren't already well along in the monitoring and reconsideration of policies process right now. A few public organizations have, in fact, already made some initial policy decisions about their response to the early credible earthquake forecasts.

Most organizations, however, are not as alert and responsive as suggested above. The majority of organizations for which a particular early earthquake forecast is relevant are likely to be caught by surprise. As a result their immediate response is likely to be slow and somewhat less predictable in character.

Some Relevant Hypotheses

What is presented next are hypotheses and extrapolations from the current hopefully relevant literature. Given what appears to be the unique character of earthquake forecasting due to the possible very long lead time, there are few close parallels in the field of hazard warnings. Some few findings from the literature do appear to have possible relevance, however.

1. Persons receiving messages which portray a threat from the physical environment tend, initially, to interpret the message content so as to make it seem less threatening (Mileti and Krane, 1973).

   Implication: At least for the first few days for the first few earthquake forecasts, most citizens will play down the potential seriousness of the events depicted in the warning messages.

2. Few warning messages are accepted at face value when first received. Recipients usually engage in what is called the confirmation process (Mileti and Krane, 1973). They ask of a convenient source (including the next-door neightbor), "Is it true?" "What have you heard?"

   Implication: For the average citizen the credibility of early earthquake forecast will be shaped more by the casually collected views of non-specialists than by information and opinion emanating from experts.

3. Panic behavior in the face of a geophysical hazard is rare (Quarantelli and Dynes, 1972; Haas and Ayre, 1970; Kates, et al., 1973).

   Implication: Following an earthquake forecast irrational flight or stunned inactivity will not be a significant problem.

4. Public officials hestiate to issue disaster warnings until they become convinced that the projected events will actually take place (Anderson, 1970; Miletei and Krane, 1973).

   Implication: Public officials in the areas to which the earthquake forecast applies will try to avoid taking a position publically on the probable validity of the forecast. To the extent that that is impossible, their comments and actions will tend to undermine the credibility of the forecast.

5. Organizations existing in turbulent environments reveal a greater adaptability in performance structure (Emery and Trist, 1965; Haas and Drabek, 1973).

   Implication: Those classes of organizations which normally have more stable environments (e.g., banks, most departments of municipal government) will evidence the longest periods of indecisiveness following a credible earthquake forecast.

6. Within any organization, the greater the division of labor and the higher the level of skills required of employees, the more location dependent the organization is (Thompson, 1967; Blau and Schoenherr, 1971).

   Implication: Following a credible forecast of a major earthquake the first organizations to move out of the "threatened" area will be firms with limited division of labor and unskilled to semi-skilled workers.

7. As the relative level of security of an organization declines the trend to opportunistic action increased (Thompson, 1967; Haas and Drabek, 1973).

Implication: Within the threatened community those organizations whose profitability is closely tied to land development and property values will be among the first to use new and questionable business practices.

III. Research in Anticipation of Earthquake Forecasting

Because earthquake forecasts appear to be qualitatively different from other established hazard warnings, the first few credible forecasts may bring with them some surprising consequences. It is, therefore, critically important to look in a comprehensive and painstaking manner at the socioeconomic, political and legal context in which the early forecasts will exist. Whether earthquake forecasts eventually produce a net social benefit or not may be determined in large measure by the response to the first few credible forecasts. If in <u>advance</u> of those forecasts responsible public agencies and private interest groups develop plans and policies which are based on realistic assumptions about the actions of other organizations and the behavior of citizens at large, the whole situation will be less volatile and less likely to produce an economic downturn, unnecessary social disruption and political upheaval.

An earthquake forecast involves the specification of the time, place and severity of an individual event (Kisslinger and Algermissen, 1973). When the first scientifically credible earthquake forecasts come along there will be a variety of responses from the responsible Federal, state and local agencies, from the mass media and other interested organizations in the private sector, and from citizens who reside in or near the area to which the forecasts apply. Indeed, some semi-credible forecasts may produce considerable social disruption.

The best sources of information concerning the most likely outcomes or early earthquake forecasts appear to be those persons who are most likely to be involved in the process of initiating a forecast, implementing actions relating to the forecast, and responding to the forecast. In other words, we need to inquire of the actors how they think the "play" is likely to turn out.

Let us consider California for example. In a few instances the organizational response processes to earthquake forecasts have already been set in motion. Some policies regarding how earthquake forecasts will be handled at the state level have been established recently. A special panel of eminent scientists may soon be set up to examine the evidence when a forecast appears to possibly have a scientific basis.

Overall we believe we can specify seven classes or types of organizations which will be involved in the response to the first credible forecasts. Within those organizations we can select those officials who will be setting policy and/or acting for the organization in responding to the forecasts. These are the organizations and individuals who are most likely to be the principal actors on the scene when the first credible forecasts come.

The classes of relevant organizations for California are:

(1) Organizations employing seismologists who are engaged in and/or responsible for research and development in earthquake prediction.

(2) The California Office of Emergency Services and the state, Federal and other organizations which are represented on the Governor's Earthquake Council.

(3) Organizations of the news media.

(4) Other non-local public and private organizations which would automatically be notified of an earthquake forecast by one or more of the agencies in classes one or two above. These are organizations recognized as having responsibility for public health, safety and welfare.

(5) Non-local organizations representing private sector interests who may see the forecasts as producing adverse conditions or special opportunities; e.g., insurance, banking, industrial, commercial and investment organizations.

(6) Local organizations recognized as having responsibility for public health, safety and welfare matters.

(7) Local organizations representing private sector interests; e.g., Chamber of Commerce, Board of Realtors, builder's association, labor unions.

In addition, it would be important to contact a sample of citizens residing in the "threatened" area. Beliefs about their probable behavior whether correct of inaccurate may be a crucial factor in what policies and planned actions the seven classes of organizations may carry out.

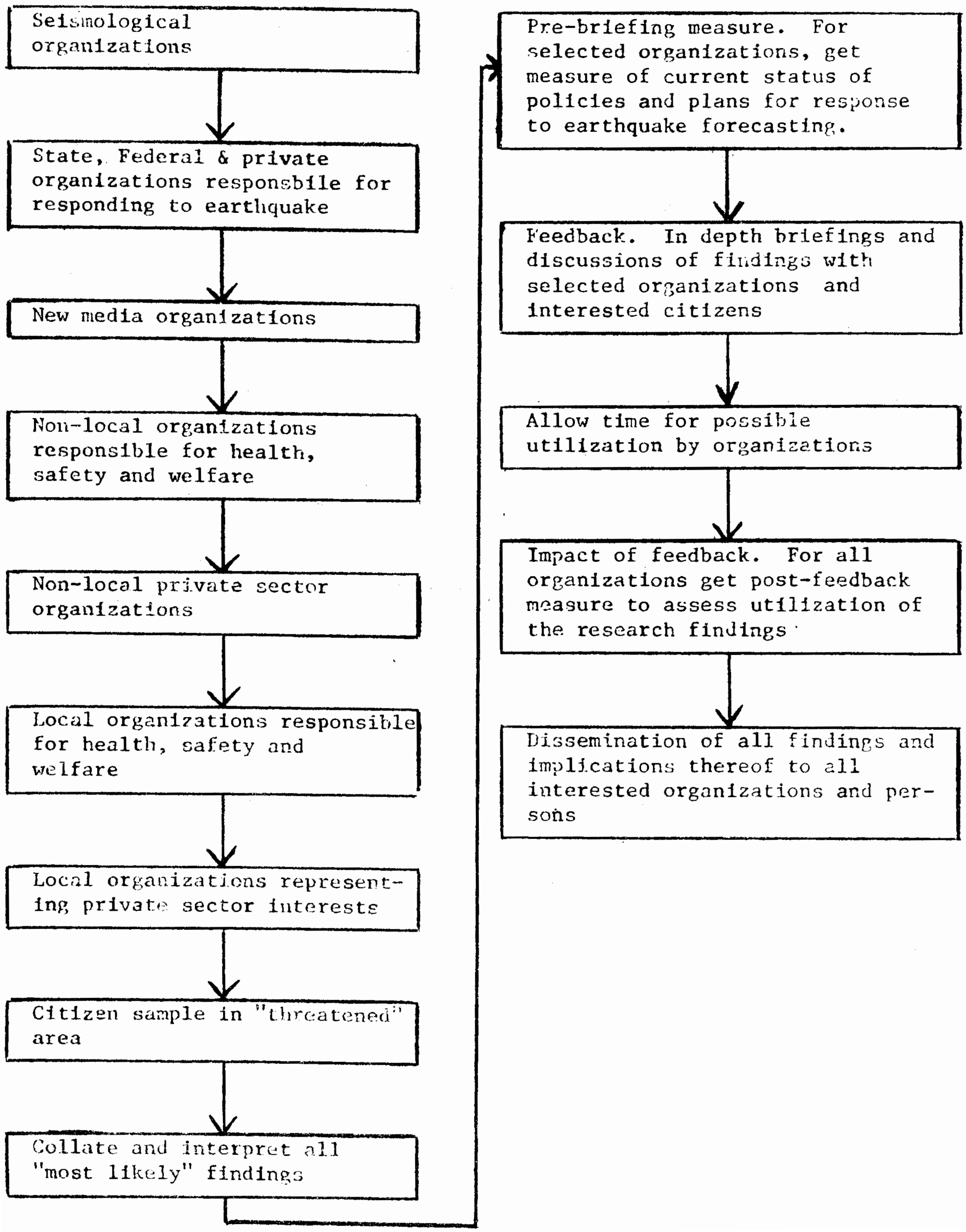
The initial data collection effort should be a sequential one and a modified Delphi process could be used. Thus, for example, individuals in seismological organizations would be contacted first. Individual informal discussions would be held to ascertain each person's perspective on earthquake forecasts, to discuss issues relating to the potential actions of their organizations and to get estimates of what seems to be the most likely involvement of each organization in the first credible forecasts. For seismologists, questions to be discussed might be: What are likely to be the characteristics of the first credible forecasts? What is likely to be the amount of lead time for the first forecasted damaging earthquake? Which agencies are most likely to release that type of information first? Which areas of California are most likely to be the first candidates for a credible forecast?

After all respondents within a specific class of organizations had been contacted in that manner, their ideas would be summarized and translated into some limited number of "most likely" mini-scenarios (Assessment of Natural Hazards, 1973) depicting what an organization of that type will probably do in regards to the first few forecasts. In a second contact with each of the original respondents, using a more structured interview format, the mini-scenarios would be presented to each respondent and he would be asked for his considered, final judgment as to which of them is most likely and next most likely to actually occur. There would then be a consensus of judgment to use as a basis for bounding the discussions with the next set of respondents, those persons next in line class of organizations. This two-round data collection process would be completed with each class of organizations before moving on to another class and so on through the seven classes. In each case the first round contacts would open with a brief discussion of the findings growing out of the modified Delphi process, e.g., "We have had discussions with persons in organizations such as X, Y and Z. The consensus regarding the character of the early earthquake forecasts is as follows. The consensus as regards the release of such forecasts seems to be as follows. And so on. Now let us assume that events will in fact, develop pretty much as the consensus suggests. If that were to be the case what is most likely to be the response of your organization to the forecast per se and to the likely actions of other organizations and individuals?" Such an approach to each interview could separate, at least somewhat, fantasy from "realism" and thus bound the character of each discussion.

Upon completion of the data collection from the seven classes of organizations, one would be prepared to contact a sample of citizens. Again, these initial informal discussions would be based on and bounded by the earlier findings from the "most likely" mini-scenarios. In that way each citizen respondent could better envision a "realistic" socio-economic setting that is likely to exist when the early forecasts come. Questions asked might be: "What, if anything, are you likely to do differently as the predicted date approaches? Which of the probable actions of public officials are you likely to condone and cooperate with; and which, if any, are you likely to resist or undermine?" And so on.

FIGURE 1

OUTLINE OF SEQUENCE OF DATA GATHERING, FEEDBACK AND MEASUREMENT OF IMPACT



The sequential data gathering process intended to delimit "most likely" outcomes is depicted in the left column of Figure 1. Once that cycle of data gathering was completed and interpretative summaries developed a feedback for utilization process could begin. Extensive briefings for selected organizations and agencies could be conducted. These briefings would be followed by question and answer periods and where appropriate small group discussion sessions. This approach could be used so that the user representatives would have ample opportunity to go beyond the consideration of the factual component of the findings and consider at length the probable implications of the findings for the policies of their own organizations.

But what of the impact of the briefings? If those who set policy and develop plans for an organization learn to some detail from the research findings what the most likely actions are for a number of other relevant organizations (e.g., the news media, mortgage lending institutions, insurance companies), will they then reconsider their own policies and plans? Will the feedback process thus have a measurable impact?

Any serious effort to assess such an impact on public and private organizations would require a complex research design. The general approach that could be used may be seen in the right hand column of Figure 1. The specific design would have to be responsive to the social and political constraints in which the research was conducted. A modification of the Solomon Four Group Design as illustrated in Figure 2 would provide for the greatest possible generalizability of the findings when the work was concluded.

FIGURE 2

REPRESENTATION OF MODIFIED SOLOMON FOUR GROUP RESEARCH DESIGN FOR ASSESSMENT OF THE IMPACT ON ORGANIZATIONS OF THE FEEDBACK ON RESEARCH FINDINGS

Organizations Designated as:	Informal Discussions Followed by Structured Interviews re. "most likely" outcomes	Pre-briefing Measurement	Briefing	Post-briefing Measurement
Experimentals	Yes	Yes	Yes	Yes
Controls I	Yes	No	Yes	Yes
Controls II	No	Yes	No	Yes
Controls III	No	No	No	Yes

The Experimentals and Controls I would be randomly assigned from the pool of all organizations, both local and non-local, that were involved in the original cycle of contact and interviewing. Unlike the Experimentals, the Controls I would not receive the "treatment" of pre-briefing measurement. Even though that measurement would be designed as a measure of the organization's policies, plans and operating procedures regarding response to earthquake forecasts, the measurement process might in fact sensitize the organization to earthquake forecasting and thus have an impact. Measurement or testing has been shown to have that type of consequence (Campbell and Stanley, 1963). The Controls II would be local organizations from another comparable locality who were not involved with the initial cycle of discussion and interviewing. They would receive the pre-briefing and post-briefing measures only. The Controls III would have no contact with the research effort until the final post-briefing measurement.

Both Controls II and Controls III would be from the comparable locality and randomly assigned.

What has been presented here is but a brief sketch of the type of research that needs to be done in the near future. The first credible forecasts of damaging earthquakes are surely less than a decade and perhaps not more than five years away. It is therefore, critically important to look in a comprehensive and painstaking manner at the socioeconomic, political and legal context in which the early forecasts will exist. Whether earthquake forecasts eventually produce a net social benefit or not may be determined in large measure by the response to the first few credible forecasts. Attempting to estimate at this early stage the impact of those forecasts without using a solid behavioral science base seems to be folly (Mitroff and Ruroff, 1973). If, in advance of those forecasts, responsible public agencies and private interest groups develop plans and policies which are based on realistic assumptions about the actions of other organizations and the behavior of citizens at large, the whole situation will be less volatile and less likely to produce an economic downturn, unnecessary social disruption and political upheaval.

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THE COMING SAN FRANCISCO EARTHQUAKE: AFTER THE DISASTER

Lessons from Experience, Considerations for the Future

M. J. Bowden and R. W. Kates

> ...The will to rebuild was strong and much that was done to restore and improve the City was accomplished with efficiency and ingenuity...As long as human labor, communication, institutions, and some capital were intact, the tremendous physical loss was not crucial.
>
> The drive to restore the environment as it was before, to re-create an image of the past, is quite evident. It had roots both practical and psychological. A major reorganization of the City was never seriously considered (despite the fantasies of later historians on this subject). Rebuilding was rapid and vigorous because each man could start again on his own familiar land. Street widenings were strongly contested not only because of the resultant loss of land but in fear of increased traffic or of change itself. New public open space was constantly in danger of encroachment by buildings...churches were rebuilt on their previous...plans...scarce time and cash were expended on symbolic actions...The ruins themselves were depressing and thought dangerous. Construction became a good in itself... How the new building might be used and occupied was a question that followed later.
>
> ...The disaster left a better physical city, clearly. Traffic was eased, though not for long...a major fire never recurs in the burned-out districts...houses were much safer ...streets clean and firm. On the other hand, the resultant strain on declining...institutions probably hastened their collapse, and the historic shift in the spatial structure of economy and population was further stimulated. Just as with redevelopment today the poor were driven out of the city center...capital was poured into the rebuilding, and a slowdown of trade briefly showed the effect. But the long-term result was more likely a stimulus...[1]

These words are from the opening case study of Kevin Lynch's provacatively-entitled recent volume What Time Is This Place? What time is this city whose aftermath following disaster he described? The reconstruction process that he evaluates is of a real historic event, but it need not be. It could appear in the National Academy Report that will be written ten years after the coming San Francisco earthquake. It may yet be part of the history of Managua, and it was certainly part of the history of San Francisco after 1906. What time is this place? It is the reconstruction of London after the great fire of 1666.

Three hundred years, slightly more or less, will elapse between the great fire of London and the coming San Francisco earthquake. Will nothing have changed? No, of course not. Even though there are striking, haunting similarities between the London of 1666, the San Francisco of 1906, and the Managua of 1972. The San Francisco of the coming earthquake will be a city of 700,000 rather than 400,000. The earthquake will do between $3 and $6 billion in damage rather than the several nundred million (in current prices) that marked historic parallels we draw upon. London and 1906 San Francisco drew on their own capital, Managua and the future San Francisco will not. But these and many other significant differences may turn out to be primarily differences of scale and not substance. The essentials will be the same. What are the essentials of reconstruction?

In this paper we pose some of these essentials in the form of questions, and answer them by a combination of historical analysis, projections of current trends, and considered speculation. We ask questions of survival: will the city rebuild and how long will it take?; questions of value: will it be familiar, safer, better?; and questions of equity: who will suffer, who will pay, who will lead? For the historical analysis, we draw upon Reddaway's history of the Rebuilding of London after the great fire, Bowden's and Douty's studies of San Francisco Reconstruction, the National Academy of Science's massive study of the great Alaska earthquake of 1964 and our current observations in Managua.[2] For the trend projection, we use recent Metropolitan Transportation Commission projections to the year 2000, combined with Algermissen et al. simulation of an 8.3 event on the San Andreas fault.[3] And for our considered speculation, we combine those of a historical geographer and a geographer of the future, who share their studies of the hazard (of many places), and their aftermath with warm affection for this special city. Thus in the end we offer not heroic prophecy but a modest vision, a deep concern, and a challenge — if the new San Francisco is not to your liking, there is still time.

The Scenario in Mind

The scenario in mind is based on the cited Study of Earthquake Losses in the San Francisco Bay Area. The physical event that we take as our scenario for the coming San Francisco earthquake is a recurrence of a Richter 8.3 magnitude earthquake on the San Andreas fault with the approximate isoseismal distribution of intensity of the 1906 San Francisco earthquake. With such an event, there would be maximum intensities IX and X (on the Modified Mercelli Intensity scale of XII) in some areas of San Francisco.

Depending upon the time of day such an event would occur, deaths might range from 2,000 to 10,000 in the entire Bay area, with a majority of these occurring in San Francisco proper. There may be as many as 40,000 injured, again depending upon the time of day, and 20,000 additional uninjured but homeless, depending upon the season of the year and the possibility of limited fire. Direct damage to property might be as much as $6 to $7 billion as evaluated by Cochrane (see page 7) in this further analysis of the economic effects mainly related to the cessation and disruption of economic activity. Of this $13 billion of both direct and indirect damages of such an earthquake, approximately 40% could be expected to occur in San Francisco proper.

Will San Francisco Recover?

The forces of inertia come cloaked in the myriad vested interests of the survivors--this will ensure San Francisco's recovery whatever the scale of the earthquake. There will be some spectacular building collapses and fire may cause far greater damage than the published scenarios estimate.[4] The majority of the city's buildings (including most of the tallest ones) and the vast residential sectors of the city representing billions of dollars in land values and building investment will hardly be affected. Building sites where collapses occurred will regain pre-earthquake values more quickly than in 1906 (four months), perhaps overnight, and will be sought after for restoration for a more intense land utilization.

If recovery means the complete rebuilding of the destroyed area, San Francisco's previous experience suggests that it will be eight years a-building, but with the greater part of the physical reconstruction completed in four years.[5] Alternatively, the rebuilding of Anchorage, a task but one-tenth of the one imagined by the scenario, took only two and one-half years. The less concentrated pattern of anticipated direct earthquake destruction, the probable pattern of localized (contained) fires, together with advances in capability of debris-clearing should ensure that physical recovery will be completed in six years and the bulk of it completed in three years. This will be done despite the more exacting standards, planning and ratification procedures demanded by the government agencies who will control the critical pursestrings, and despite the fact that buildings will be three to five times higher than those constructed on the same sites 1906-1908. In dollar valuation, physical space, and economic base, recovery will be over in four years. And if recovery means a return of San Francisco to its relative pre-earthquake position in the California and national economies, there is some suggestion that it never did do this after 1906 and that it will not do so after the coming earthquake.

If recovery means the return of pre-earthquake population numbers, this will also be affected in three years. By eight years, the city's population will be at least ten percent higher than in the pre-earthquake years due to the increased density of housing and the changed occupational structure of the city reflected primarily in the marked increase in office floor space. But this is a return of numbers, a recovery of the majority and of new entrants. There will be many non-returners, perhaps up to one-fifth of the pre-earthquake population: the large numbers who lose jobs as a result of San Francisco's increasing specialization of functions and the decreasing employment in the manufacturing and wholesaling sectors etc., the families who lose bread-winners or have less effective ones due to disablement, the families too proud to take aid and those too poorly informed to know what aid is available, those demoralized and psychologically disturbed by the earthquake. For them, San Francisco will never recover. Will the resurrected city be a better place to live in?

For most cities, most places and most times, the balance of historical evidence suggests--yes, reconstructed cities are better places to live for most people. But all cities, in all places, at all times, lose some of the familiar and with it the meaningful; injure more the poor, the weak and the small among its citizenry and commerce; and fail to take full advantage of the opportunity that crisis represents. In our judgment, and a value judgment it is, these problems that reconstruction pose may be greater for San Francisco than for any other American city, because San Francisco is today unique, regarded by many as the most beautiful, exciting, and liveable city in North America.

This uniqueness and character are firmly founded on the laissez-faire reconstruction following the 1906 earthquake and fire which gave the city's districts the chance to concentrate beneath a relatively low skyline. Downtown became both compact[6] and legible (even to the outsider) and the broken grid of narrow streets on a hilly terrain made San Francisco an adventure in visual experience. Surprises, closed and open views, ever changing perspectives and angles were the norm in a city that has only recently begun to lose its human scale.[7]

For its citizens San Francisco was a remarkably pleasant and efficient place to shop, to eat and be entertained, to work and to visit, for the central area was given the chance to renovate and rehabilitate and centralize just as decentralization processes brought on by the automobile were getting underway in most American cities. In the 1920s, the old downtowns of cities competed poorly with non-central alternative shopping, service and entertainments, but not with the new downtown of San Francisco--the newest in American by virture of the last earthquake.

But will the new San Francisco be a better place to live (and work) in than the one we know now? Much depends on whether the earthquake comes in 1977 or 2000, and by 2000 many of the processes now under way that will contribute to San Francisco's loss of character and uniqueness will have gone their full course. If the earthquake comes soon it will increase by three or four times the speed of the change that will make San Francisco a less attractive place to live for the San Francisco citizen that prizes its special flavor. San Francisco with or without an earthquake will become more like other American cities--the earthquake will simply accelerate that day. We see four major processes that will be accelerated, and we have named them after their archetypal urban examples.

Washingtonizing San Francisco--The number of San Franciscans employed downtown by the Federal, state, and city government has risen steadily in the last decade,[8] and construction by the Federal government has been substantial. Much of this construction is recent, conservative in height, and set back from some of San Francisco's wider streets. Its recency suggests that these buildings are earthquake-resistant. They will provide a strong focus for reconstruction. The government center--the one area where Daniel Burnham's "monumental" plan of 1905 was conceptually implemented--will be easily cleared will contain many 'safe' buildings, and might well serve as a symbol of reconstruction. As the state and Federal governments will provide the major funds for reconstruction, there are distinct possibilities that further centralization of government buildings will receive high priorities in the rebuilding, acting as a spur to reconstruction in general. The 1905 plans for esplanades and street widening will be resurrected or reinvented by government agencies desirous of learning lessons from past planning suggestions which the dear city "foolhardily" rejected in 1906. The Government Center will expand, streets will perhaps be widened to esplanade proportions in the lower Market Street area. The City Beautiful will grow, and L'Enfant, Haussmann and Burnham would find satisfaction in what will be wrought.[9]

Miamicizing San Francisco--The tourist and conventioneer have done much to mold the recent San Francisco which caters ever increasingly to the outsider. The Panama-Pacific Exposition of 1915 showed the world San Francisco's resurrection. It was the immediate cause of San Francisco's phenomenal increase in hotel space (compared to that of the pre-fire years) and the proximate cause of its rise as a tourist-convention capital.[10] The trends begun sixty years ago will accelerate and find their expression in more ten to fifteen story "American bland-Holiday Inn"-style hotels stretching from the Mark to Van Ness Avenue. The central retail shopping and service center and the entertainment centers will cater to this free-spending transient population, prices will rise, and many San Franciscans will be priced out of their downtown. This whole northwestern face of downtown will be Miamicized: to become an archipelago of sterilized hotel islands whence tourists take in local atmosphere and view the alien, exotic, mystical "culture"; the commercialized, de-Sinicized "chinatown"; the sanitized "pseudo" Beat of North Beach; and a Broadway made secure for the tourist.

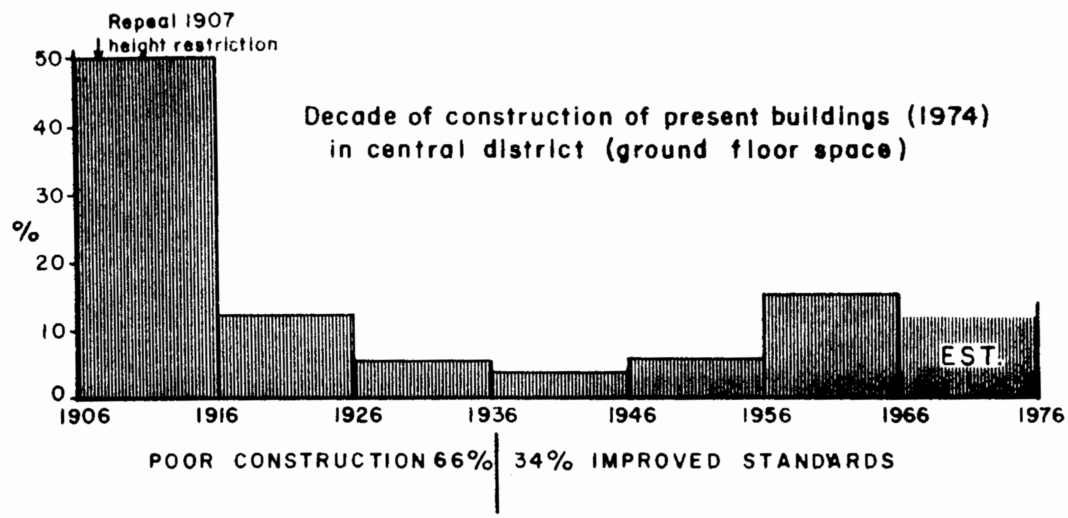
Manhattanizing San Francisco--Despite a spectacular failure of one or two new skyscrapers including an unexpected fire, the Montgomery canyon will survive. The failures will be concentrated on the "fill borders" and will be more numerous among ten to fifteen story buildings built pre World War I and in the Coolidge prosperity. The main lesson will again be that of 1906: that well-constructed skyscrapers can survive, and survive well. The skyline will be filled up with new buildings that will replace those constructed before World War II. The long-period sorting out process of service activities and business functions will continue, with decentralization of low-yielding economic activities to the suburbs, and the centralization of headquarters, offices and financial institutions in and around the Montgomery canyon. Companies new to San Francisco will seize the opportunity to build new offices in an area where land value will spiral. Spectacular failures on the fill lands will ensure that the financial district of Montgomery, Kearny and lower California streets will become what it aspires to be - "the Wall Street of the West".

Los Angelesizing San Francisco--As the central shopping area turns its back on the city's middle-class, exaggerates its high-class luxury functions and gears itself to the "outside-conventioneer" trade, San Francisco's stunted shopping centers will finally thrive. Shopping and service functions for the Bay Area's middle class will decentralize to new and existing suburban "nodes";[1] office without need for high-rent downtown locations will move to new or existing nodes in San Francisco and the Bay Area; those wholesaling, printing and manufacturing establishments surrounding the downtown area will also leave (for lower rents in other downtowns or new industrial "parks").[13] Beyond the San Francisco island core with its three major nuclei will rise new commercial service islands.[14] Like Los Angeles, San Francisco will become a middle-class city with high density enclaves of poverty.

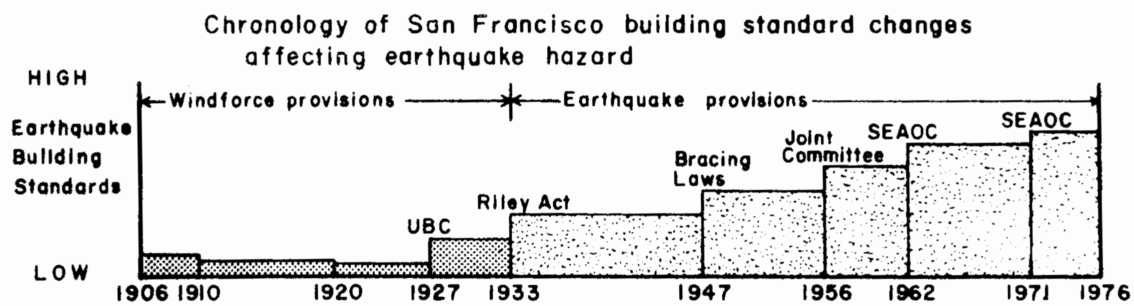
Will the city be a safe place to live (and work) in?

Cognition of the earthquake hazard in San Francisco has changed remarkably since 1906, the safety of buildings constructed and the character of the sites selected for buildings has roughly reflected this change. After every earthquake-fire disaster there is a high awareness of the earthquake disaster followed by a trend toward exaggerating the importance of the seemingly more manageable fire and a minimizing of the earthquake danger that man cannot control. We saw this process under way in Managua six months after the recent earthquake. The speed of this rationalization was quickened in San Francisco (1906) by the attempt to gain financial support for reconstruction from Eastern financiers unfamiliar with earthquake risk but thoroughly familiar with the central area fires of Chicago, Baltimore and Boston.[15]

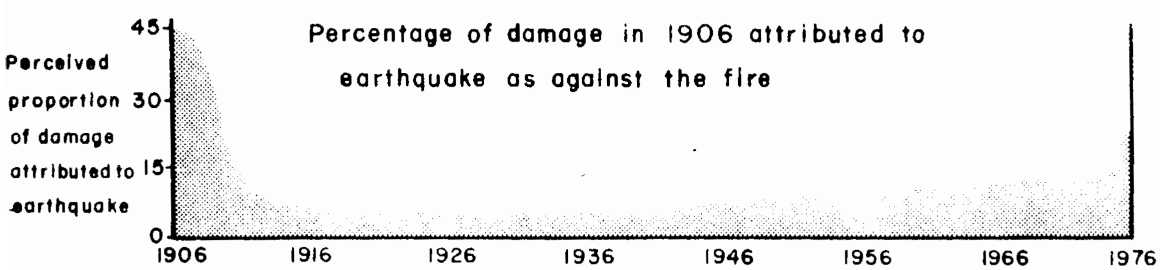
Reports by fire insurance underwriters and by self-justifying construction engineers and building materials companies stressed the low ratio of earthquake to fire damage.[16] Figures were presented in percentages widely publicized in newspaper headlines and the portion of damage attributed to the earthquake was reduced downward within a year from one-half to less than ten percent.[17] Data substantiating the high earthquake hazard in geological reports were too cumbersome, too technical, and too late to have much impact.[18] The result was that in the reconstruction period a large proportion of San Francisco's central area building stock was reconstructed without due consideration for the earthquake danger (1908-1911).[19] The danger was further minimized in the next decade (to the mid-1920s). In this period were constructed some of San Francisco's more dangerous buildings, put up in the rush to house visitors to San Francisco's resurrection and the Panama-Pacific Exposition (1915), buildings on filled land, and the increasingly tall buildings of the early 1920s.[20] Approximately two-thirds of the buildings now in San Francisco's Central District (1974) were constructed when



Repeal 1907 height restriction
Decade of construction of present buildings (1974) in central district (ground floor space)
%
0
10
20
30
40
50
EST.
1906
1916
1926
1936
1946
1956
1966
1976
POOR CONSTRUCTION 66%
34% IMPROVED STANDARDS



Chronology of San Francisco building standard changes affecting earthquake hazard
HIGH
Earthquake Building Standards
LOW
Windforce provisions
Earthquake provisions
UBC
Riley Act
Bracing Laws
Joint Committee
SEAOC
SEAOC
1906
1910
1920
1927
1933
1947
1956
1962
1971
1976



Percentage of damage in 1906 attributed to earthquake as against the fire
Perceived proportion of damage attributed to earthquake
0
15
30
45
1906
1916
1926
1936
1946
1956
1966
1976

earthquake provisions were non-existent or negligible and when the awareness of the earthquake hazard was low (Figure 1-a).

Increased awareness of dangers in the late 1920s[21] and the new building code regularly enacted since then (Figure 1-b) ensured greater safety of the few buildings constructed in the thirties and forties. The building boom of the 1950s and 1960s, however, saw the earthquake danger unmentioned at a time when construction on fill lands was at its peak.[22] The earthquake fear surfaced again as a popular concern as buildings got higher in the late sixties, as some began to think of earthquakes as cyclical and to conclude that the San Andreas fault was due (Figure 1-c). All this concern fed on a spate of books on the hitherto suppressed topic.[23] The word "earthquake" returned to the lips of San Franciscans.

The coming earthquake will remove many of the five to ten story buildings constructed before 1911; many of the poorly constructed six to twelve story hotels, boarding houses and apartments of the Exposition period, some weak buildings constructed on the fill and marsh lands between 1911 and 1918 and some adventurous buildings of the Harding "normalcy" and the Coolidge prosperity. There will be a few losses among the recent buildings that have stretched the bounds of earthquake tolerance downward on the fill lands and upward to the sky. But only the earthquake event will tell us which of these buildings will be affected.

Removal of the weak buildings and their replacement by buildings constructed according to higher standards will ensure that San Francisco is a far safer place in which to live and work after the coming earthquake. San Franciscans talked "fire" to financiers to rebuild in 1906; they must talk "earthquake" to the government agencies who will control the pursestrings for the next rebuilding. Thus, the building standards required will be higher than those in the preearthquake for all types of buildings, including those in the low density residential areas which will largely be untouched by the coming San Francisco earthquake. From a safety viewpoint, those residents most vulnerable at the moment--highrise apartment and public housing dwellers and those in hospitals and other institutional buildings--will be the major beneficiaries, if they survive the coming San Francisco earthquake.

Who will pay?

The coming San Francisco earthquake may well be the greatest disaster in the history of this country. Presently to qualify for such a dismaying distinction, the loss of life would have to exceed 6,000, that of the Galveston Hurricane of 1900, and the rate of damage that of the $3.5 billion suffered in Tropical Storm Agnes. The scenario that underlies this presentation may well eclipse these events. Where would the burden fall?

The costs of disaster, the pain of the dying and injured, the disruption of the lives of the living, the losses of real and symbolic wealth are not easily assessed, counted or scaled. The costs of disaster are clearly inequitous, falling heaviest on a few but the population affected, if only in slight measure, is large in an interdependent industrial society. We have tried to convey the orders of magnitude involved both in inequitous burden and population effect in Figure 2. The costs of disaster, the ordinate of the graph, can be read in terms of dollars or as units of social cost, the population affected for a major disaster as the coming San Francisco earthquake includes the entire United States population. While intended to be illustrative, the graph does convey the dimensions of the social burden that would ensue. And while we will not explore it, we

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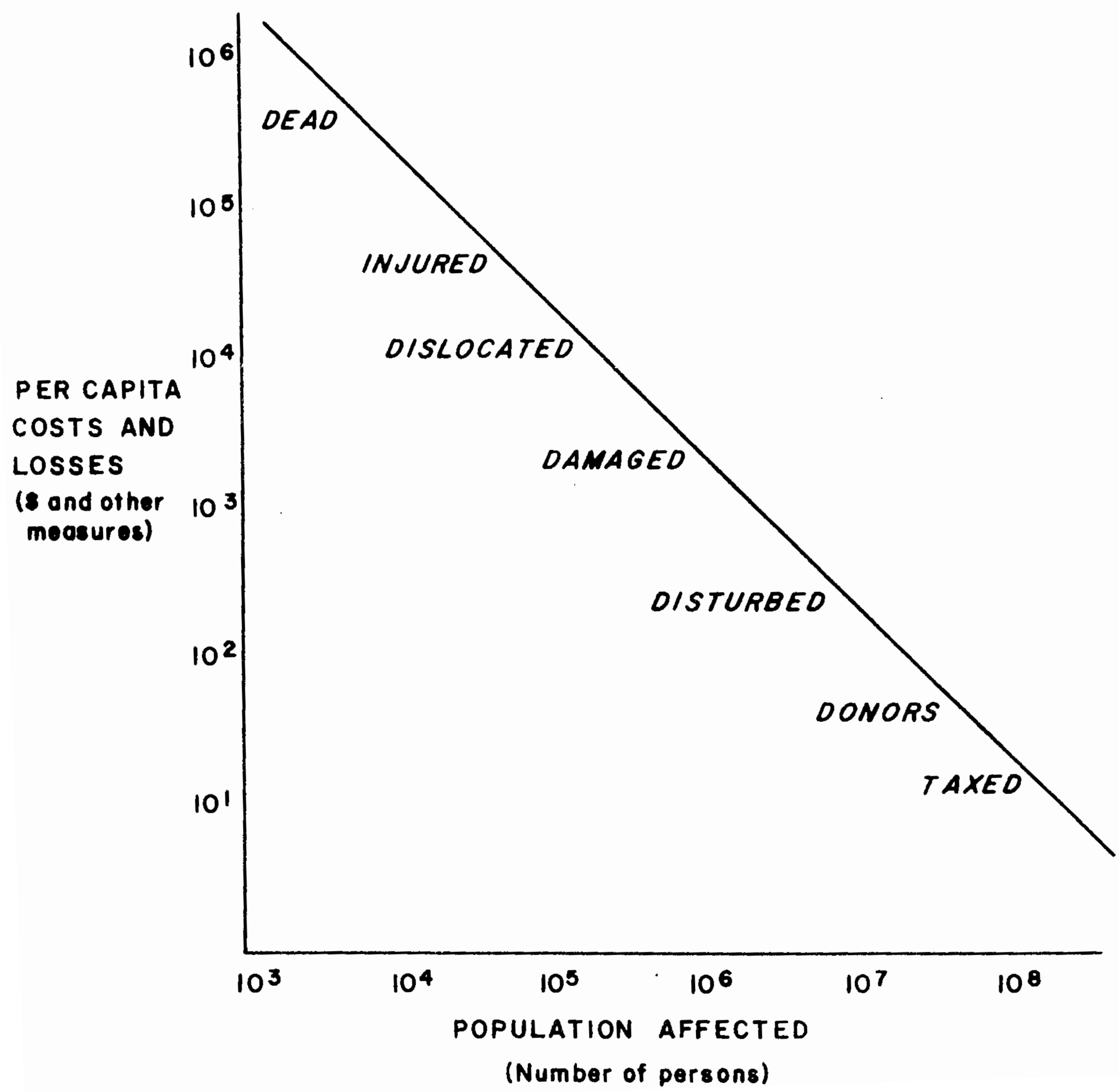

should note that there is a graph of those that gain as well.

The dead and seriously injured, their close survivors, face the greatest cost. The numbers of dead may reach into the thousands, the injured and close survivors in the tens of thousands. The economic values attributed to a life in our society runs into the hundreds of thousands the cost of hospitalization and loss of earnings in the tens of thousands.

Much further down this hypothetical social scale of suffering lie the victims of serious social dislocation that (is not) or cannot be compensated for. We know little about these types of disaster impact, but from analogous situations the costs may be high. The high cost of social dislocation includes the irreplaceable loss of employment, residence, community, treasured possessions and familiar surrounding. And it also includes the loss of replaceable property that is not replaced or compensable earnings that go uncompensated due to the pride or ignorance of the victim or the inequity and inefficency of the welfare system of disaster sharing. One only has to review the literature of urban relocation and renewal, of factory closings and declining regions, and of other disasters to appreciate that even in the situations where there is great generosity in relief and compensation, the elderly are forced to move, the older workers search futilely for another job, the ethnic community is dispersed, the fiercely independent are made wanting. All these suffer a special loss that has never been measured adequately either in monetary or mental health terms but is nevertheless real and poignant.

In the San Francisco situation, such special victims might include the low-income residents of the Mission District, the low to middle income residents of the Western addition, the low lying areas of North Beach, and the singles living in multi-story apartment dwellings constructed before 1933.

Further down the scale are the damaged who have losses of earnings, personal or real property, part of which may be compensated for by disaster relief or insurance. With per capita losses from the earthquake in the thousands their average uncompensated losses may well be in the hundreds of dollars. And finally the list of directly affected include the surrounding populace whose lives are disrupted in varying degree by the disaster including some loss of employment. To the extent that the reconstruction processes disrupt them as well, they suffer smaller but significant costs. Their number may run into the millions in the densely settled metropolitan Bay Area. Much remote, numbering in the tens of millions, are the donors who in addition to public assessments share with the victims through private and Red Cross contributions. Finally, the entire population of the United States would carry by dint of their taxes the several billion dollars of Federal aid that would flow to San Francisco to share in the relief and reconstruction effort.

At the lower end of the scale, the exact pattern of cost-spread is much in doubt. Each of the great earthquakes of this century, has had a different pattern of source money for reconstruction. In 1906, San Francisco received no significant Federal aid, rebuilt with its own funds those of its fire insurers and a small but very significant private relief effort. Alaska in 1964 received more in Federal aid than the actual damage suffered, and a minimum of insurance and private relief funds, San Fernando, a much smaller earthquake, received very heavy Federal aid, small insurance and little private relief, with a small but significant portion of private loss uncompensated. The future mix of insurance and disaster aid is before the Federal legislature now. On such deliberations, the choice will be made as to whether losses are spread over the insured time of the potential victim or spread over the social space of the taxpaying public. Whether new buildings at somewhat higher initial cost reduce future costs, whether older hazardous buildings will be phased out, are also currently being attended to in national and state legislatures. These too will shift the burden of a future loss pattern. Least likely to be examined will be the potential amenity loss--the new San Francisco may be less to our liking.

Does it have to be that way?

We have developed a model of reconstruction based on the laissez-faire reconstruction of San Francisco 1906 that assumes a scale of precedence in the return of districts in the central area that will favor: 1) the financial, office, and to a lesser extent hotel and apparel shopping districts; and 3) the high and middle income, high-density residential use of the perimeter of the central area.

The laissez-faire scale of precedence and sequence of return greatly favors the very activities that are beginning to dominate the increasingly specialized downtown and to fracture it three ways. Small establishments, activities and districts low on the scale of precedence, low-income and perhaps middle-income housing these will be the losers. This will be particularly true if fires are not common, for earthquake insurance is not commonly carried in these sectors. Indeed an important lesson from Managua (1972) and San Francisco (1906) is that fire is fortuitous to some, especially if the entire central area burns. Quick fire insurance settlements would keep many small firms in the central area, and large scale devastation will ensure that land prices are not bid up beyond the reach of all but major corporations and the government.

There are alternatives to either the firing of the central area of the acceptance of a speedy but laissez-faire return to economic normalcy. But the record of urban renewal activity, the closest analogue to the reconstruction need, is not a hopeful one. If the present and past practice of urban renewal dominates reconstruction, the outcome despite the massive governmental aid will differ little from the laissez-faire model.

However, there are four significantly different opportunities provided by the (disaster, albeit at the) high cost of death and destruction. First, massive sums become available in the humanitarian upwelling of sympathy, funds beyond the scale of conventional renewal activities. Second, either as a result of the destruction or of prior contingency legislation, extensive land areas do become available in a relatively short period of time in contrast to the slow assemblage of urban renewal sites. Third, depending on the nature of the damage pattern, the survivors, members of groups ignored by ordinary renewal processes, may find themselves more visible if only by their apparent distress. And finally today there is greater sensitivity to planning needs and more concern for equity than in previous efforts in the past. But none of these opportunities will be seized unless the construction process begins to have the care and attention heretofore focussed on disaster planning and immediate response.

The most pressing needs in our judgment for San Francisco would be: public debate and support for maintaining the post-earthquake uniqueness of the city, land assemblage and building procedures providing immediate compensation for owners while retaining public initiative for reconstruction, adapting relief and compensation schemes to the realities of urban linkages, providing relocation aid for undamaged but weak activities where linked to the damages, and including a seismic reconstruction contingency plan as part of the normal planning cycle for the city and its environs. Finally, since the new land needs for reconstruction are from two to four times greater than that used before, some relocation is inevitable outside the corporate limits of the city, and this needs to be planned as well. A tall order for any city, but unless something like it happens, the social costs may well exceed the economic ones of the coming San Francisco earthquake.

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