1 Introduction

It is clear that damage assessment is a key ingredient in the formulation of environmental policy. Without it, it would be virtually impossible to derive rational strategies for coping with environmental impacts. Although it is dangerous to generalize, I will begin my remarks on a critical and somewhat provocative note. In my opinion, loss estimation is imprecise, based on an incomplete and erroneous conceptual foundation, and relies on hastily collected and inaccurate data. With few exceptions, the purpose of loss studies is all too often politically motivated. Fewer the ten percent of those who profess to use loss data are trained in economics, and even fewer are familiar with the principles of loss measurement. The motivations behind the use of damage assessments is clearly beyond the scope of my talk. I am convinced, however, that something can be done to improve and simplify the framework for assessing damages.

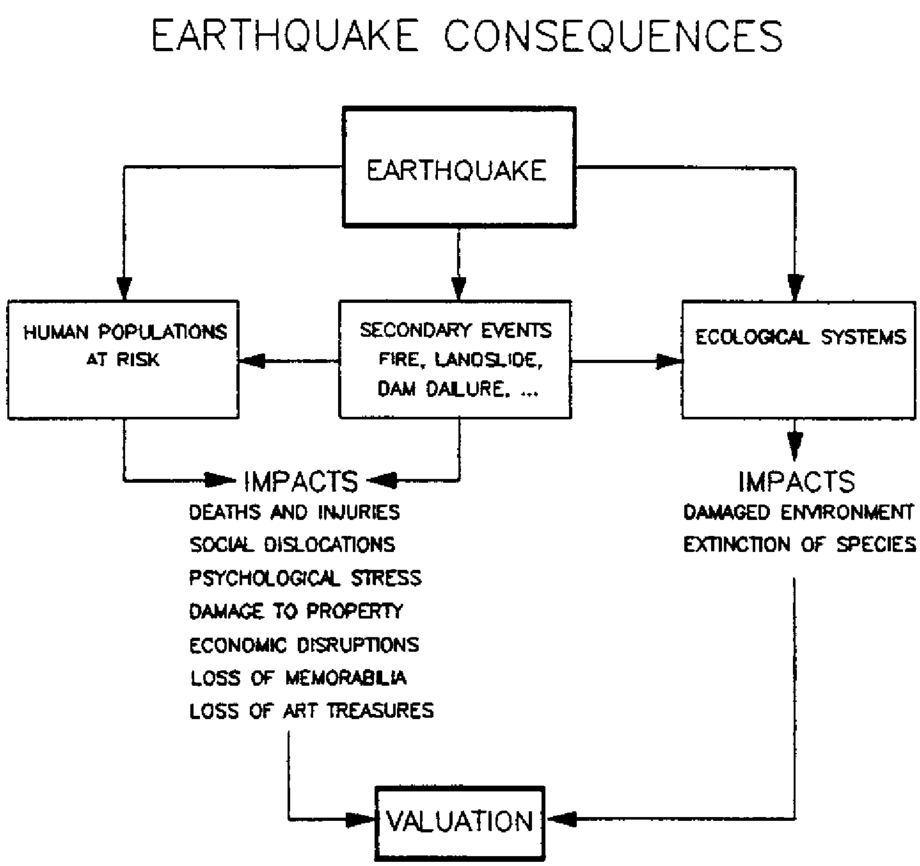
The purpose of the paper is to set down an internally consistent set of principles to assist in the presentation of losses from natural and man-made hazards. Since I will be covering a wide range of topics, not all can be treated in detail, nor can full set of examples be provided. Illustrations drawn from two recent disasters in the United States, the Loma-Prieta Earthquake (San Francisco, 1989) and Hurricane Hugo (Charleston, 1989) are furnished to illustrate several important points.

The issues presented is this paper are the product of several National Science Foundation sponsored projects to develop a guidebook for practitioners conducting damage assessments. The book is entitled "DAMAGE HANDBOOK: A Uniform Framework and Measurement Guidelines for Damages from Natural and Related Man-made Hazards." The need for such a handbook was identified by Eleonora Sabadell. Its application to the Loma Prieta Earthquake was made possible by William Anderson at the Foundation.

2 The Scope of the Problem

Tens of thousands of people may be affected by geophysical or man-produced events, either directly or indirectly. Secondary impacts such as fire, landslides and dam failures may widen the scope of damage, possibly including injury to fragile ecosystems. However, from the economist's viewpoint, the mere description of physical consequences is just beginning of a damage assessment. As the following figure suggests, these initial impacts must be valued.

Figure 1



The existence of markets makes the valuation of direct damage to mand-made structures relatively simple. Barring the pitfalls associated with depreciation and economic obsolescence discussed below, this damage category has proven to be the least challenging. But, as the following figure points out, such damage represents a small part of valuation problem. Impacts for which there are no direct market signals, such as loss of life, health, historic assets, and natural environments, are particularly difficult to evaluate. These require nonmarket techniques, or indirect tests.

Figure 2

MARKET AND NON-MARKET IMPACTS

MARKET DAMAGES		NON-MARKET DAMAGES			
DIRECT DAMAGE	SECONDARY DAMAGE	HUMAN CAPITAL	SOCIAL CAPITAL	CULTURAL ASSETS MEMORABILIA	ENVIRONMENTAL CAPITAL
COMMERCIAL PROPERTY RESIDENTIAL PROPERTY PUBLIC FACILITIES	VALUE ADDED	LIFE HEALTH MENTAL HEALTH	DISRUPTED SENSE OF PLACE	LOST HERITAGE OPTIONS BEQUESTS	WATER CLIMATE GENETIC POOLS LANDSCAPE HABITAT

This paper will address the full range of damages depicted, albeit some in lesser detail than others. But before doing so, the meaning of the terms natural hazard impact and policy relevant damages deserve attention.

3 Natural Hazard Impacts[1]

At a purely physical level, we speak of the impacts of a natural hazard event:

> An impact of a natural hazard event is any measurable physical change in geological, ecological, atmospheric or human systems attributable to that event.

1 Sections 3 and 4 are excerpted from Howe, et al. (1990).

Among the impacts of a flood would be changes in alluvial materials in the valley, changes in the numbers and types of the various plants and animals, permanent shifts in the direction, volume or velocity of water flows, physical destruction of crops and livestock, changes in buildings, losses of human life, deferral or abandonment of production processes, etc. What principle underlies the identification and measurement of these impacts? It is the "**with-without principle**":

> We seek to identify and measure all changes between the system as it evolves with the natural hazard event having taken place and as it would have evolved without the occurrence of the natural hazard event.

It must be noted that this principle does <u>not</u> mean identifying and measuring a set of variables at points in time <u>before</u> <u>and</u> <u>after</u> the event. One reason is that changes attributable to the event can be dynamic and continue overtime so that the "with-without" must be cumulatively measured by monitoring the system over time. The other reason is the <u>continuation</u> <u>of</u> <u>changes</u> that were occurring prior to the event. Loss studies are, of necessity, conducted over long time intervals, during which economic pressures unrelated to the disaster can mount. Because of this, it is possible to conclude that a disaster produced an economic change, which more rightly should be attributed to unrelated but correlated factors. U.S Steel's decision to shut down the Johnstown mill after a devastating flood in 1965 was linked to a chronic decline in the plant's profitability, rather than the sudden onset of damage. The event simply provided management the excuse to terminate operations, a decision which would have eventually been made with or without the disaster. Under such circumstances it would be incorrect to attribute loss of jobs and the accompanying economic downturn to the flood.

If we carefully apply the **with-without** principle to a system affected by a natural hazard event, we can identify and (in principle) measure the <u>impacts</u> of the event. Yet, even minor natural hazard events have innumerable impacts: the number of stones moved; the positions of sandbars; the number of bird nests lost; and many human impacts. How does one set reasonable limits on the number and types of impacts to be identified and measured? As always, the relevant range of impacts depends on the questions being asked. Three classes of questions are relevant here: (1) scientific questions about the functioning of physical, life, and social systems; (2) anthropocentric questions about things of concern to man, i.e. questions involving "values"; and (3) policy questions that deal with tradeoffs among and rankings of values.

A scientific question deals with the functioning of a system and, in itself, does not involve values. How does an increase in nutrient inflow to a pond affect the algal population? There are no values here, no implication that increased nutrients and algae are good or bad. How does high seas fishing for tuna affect the dolphin population? Again, this can be investigated and answered without any use of values.

4 Policy-relevant Damages

In a purely scientific investigation, all impacts may be relevant, depending on the scope of the investigation. In an ecological study of a small pond, minute energy fluxes or uptake of heavy metals may be important, while in a global water balance study, only the largest-scale variables may be relevant, e.g. continental precipitation and evaporation, run-off, changes in storage, etc. In scientific investigations, there are no values, just relationships among parts of the system. Nonetheless, a major function of scientific inquiry is to inform the policy- making process about relationships that may have policy relevance.

Some impacts have values directly associated with them. A loss of 1,000 tons of grain due to a windstorm usually will have a market value. Whether or not that market value (measured by market price) is the value measure best suited to aiding policy decisions is an issue to be addressed later, but it may be under some circumstances. When impacts have no values associated with them, the impacts generally are ignored, except by the scientific community.

Loss management should emphasize the tradeoffs involved in purchasing additional safety. All too often policy-relevant losses and total losses are confused. This tends to skew public priorities irrationally. Events which evoke images of catastrophic damage often serve to fuel political rhetoric but seldom illuminate those strategies which are economically efficient. For example, the wide spread destruction Hurricane Hugo's winds wrought on the Francis Marion National forest (Hurricane Hugo, 1989) resulted in untold recreational losses in addition to lost timber. However, from a mitigation standpoint, the value destroyed and recreation days lost is of little relevance. One must ask whether the event could have been avoided at reasonable expense. The answer is no!

5 Categories of Damage

The categories of damage highlighted in Figure 2 are briefly described below. The intent is provide a framework, and to point out pitfalls, such as double counting, which could be avoided.

5.1 Damage to Assets[2]

One of the major forms of losses from natural hazard events is damage to man-made capital assets. It will be useful to classify these assets as:

- long-lived business and government assets;
- business and government inventories;
- non-business residential real properties;
- personal property other than residential and financial;
- financial assets.

Financial assets really represent underlying real asset values, while their market or appraised values will be affected by changes in profits and damages to real assets, we must avoid double counting financial asset values and the underlying asset and profit values. The financial effects of disaster are simply a reflection of the damages. In most instances these tend to be minimal. For example, the total loss from Hurricane Hugo and Loma Prieta combined amounted to under $10 billion, nine tenths of which were sustained by home owners. The value of the equity market in this country is over $2 trillion. This means that these disasters may have produced a .005 percent change in the capitalized value of corporate America, an insignificant amount to register on the stock exchange. This is not to say that some corporations, such as insurance carriers and resort companies in South Carolina were not

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2 This section borrows heavily from Howe, et al. (1990).

impacted. But, overall the effects were negligible, particularly in contrast to the wild swings in the N.Y. and Tokyo stock exchanges which caused nearly $2 trillion in paper losses combined. Financial assets are therefore omitted from further consideration.

Long-lived assets typically have "book values" in the accounting records of private businesses. Government asset records generally are poor and depreciation accounting is not practiced, so book values of government assets are either non-existent or irrelevant. Long-lived business assets are entered at their purchase price and then depreciated over time according to one of several traditional formulas, the annual depreciation being treated as a business expense and a deduction from the asset value. Because of both general and specific price level increases over time, most book values are irrelevant to damage calculations. Modern management accounting (as opposed to financial accounting--several sets of books frequently are kept) up-dates long-lived asset prices on a "depreciated replacement cost" basis. Table 1 lists some of the major considerations in measuring damages to assets.

Table 1

Analyzing Damages to Man-made Capital Assets

A. Alternative Values for Assets

1. book values (largely irrelevant)
2. depreciated replacement value
3. market values of similar assets

B. Complete Destruction of Long-Lived Assets.

Will it be replaced?

1. Yes --> damages = changes in present value of the firm or agency's investment outlays, or market value of similar asset.

2. No --> damages = present value of value added that will be lost over what would have <u>been</u> the remaining operating life.

C. Partial Destruction of Long-Lived Assets

Will it be rehabilitated?

1. Yes --> damages = changes in present value of investment outlays.

2. No --> damages = present value of reductions in value added due to the partial destruction of the asset.

If an asset is totally destroyed, the first question is whether or not it will be replaced. If the answer is yes, the question is "Replaced with what?" The replacement could be an asset of similar age and depreciation. The theoretically correct measure of damage then would be the change in present value of anticipated capital outlays.

Partial destruction of assets leads to the same question, "Will the asset be rehabilitated?" One must know what is meant by "rehabilitation," but let's assume the objective is to upgrade the damaged asset to the same productivity and remaining life as the original asset had at the time of damage. The cost of such an upgrading appropriately measures the damage.

If a partially destroyed asset is not worth rehabilitating but is still worth keeping in operation, the damage will be captured by the reduction in the present value of the value-added stream caused by lesser productivity or a shortened asset life.

It is important to avoid double counting both income reductions and reduction in the financial value of the damaged assets. For example, suppose a rental property generates a net profit of $ L per year before a natural hazard event and a lesser $ K per year thereafter. One can calculate the present values of the two streams, the difference representing damages due to the event. If, however, there is an active market for such properties, and if the effects of the natural hazard event on the property are pretty well understood by expert property managers, the market value of the property would fall by the same amount. One obviously cannot count both.

The market values of financial assets (stocks, bonds, certificates of deposit, etc.) are determined by the anticipated income streams that will accrue to the assets' owners. If the present value of changes of the underlying value-added stream has been included in event-related damages, one must not also count changes in the market value of the financial assets.

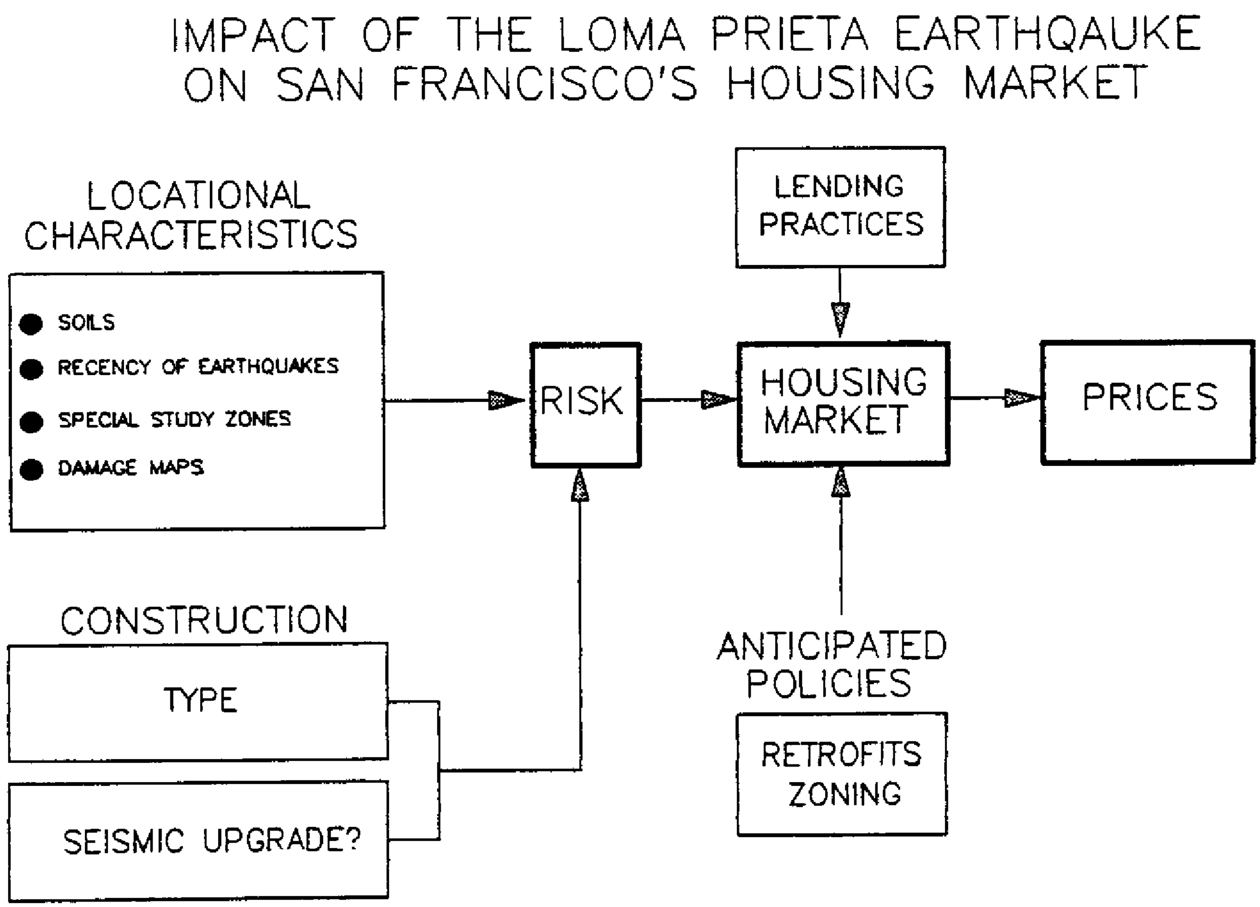
Damage assessments should in most instances exclude the value of land. It is important to distinguish between damage to structures and a possible reduction in the value of building sites. This is clearly a non trivial point. In parts of California such as San Jose, the value of real estate is driven mostly by location, with building improvements contributing only a small percentage of the property's overall value. Occasionally, damage assessments incorrectly utilize the total market value of a residential property in deriving estimates of earthquake losses.

Use of indirect methods to derive ex-ante damages — In some instances it is appropriate to ask what households are willing to pay to avoid the risk of loss from geophysical events. In such cases, the value of safety may be measured indirectly by observing the responsiveness of housing and raw land markets to different degrees of risk. For example, by determining the degree to which real estate prices are influenced by proximity to earthquake faults, floodplains, and mudslide zones, one can intuit the household's assessment of damage. The differential in willingness-to-pay for safe as opposed to unsafe locations reflects a combination of three factors: the differential losses anticipated for a given set of events; the likelihood that these events would occur; and any added compensation to induce households to assume risk, e.g. subsidized insurance. Indirect measurements of this nature are derived from what economists refer to as hedonic pricing techniques.

Hedonic pricing has been employed with mixed success since Ridker and Henning first introduced its use in 1967. It has been applied to problems of nuclear safety (Nelson, 1981); airport noise (Nelson, 1979); earthquake risk (Brookshire, et al., 1985, 1980); flood risk (MacDonald, et al., 1987); and air pollution (Brookshire, et al., 1982, Harrison and Rubinfeld, 1978). A number of these studies showed that higher risks impacted markets negligibly (Nelson, 1981) or anomalously (Harrison and Rubinfeld, 1978). Others detected a significant relationship between risk and real estate prices (Brookshire, et al., 1985, 1980).

The relationship between perceived risk, the factors that alter that risk, and housing prices are summarized in Figure 3. This framework is currently being used[3] to assess the extent to which the Loma Prieta Earthquake disturbed the San Francisco housing market. The results, indicating the extent to which the price of unsafe structures, or structures located proximate to known faults, should help policy makers determine the extent to which the public is willing to accept stricter building codes.

Figure 3



3 "The Impact of the Loma Prieta Earthquake on the San Francisco Housing Market", grant from the National Science Foundation (1990), H. Cochrane, Principle Investigator.

An initial analysis of post-earthquake sales of single family units in San Francisco revealed that proximity to damage depressed housing values by almost 10 percent (Cochrane, 1990). A fuller explanation of the results and the technique used is provided in the Appendix. This result suggests that the newly perceived risk of damage is indeed reflected in the housing market. Further analysis will separate the influence of location and structural design.

It is interesting to note that the publication of earthquake risk zones (Special Study Zones, Alquist Priola Act) have had a similar, albeit a smaller effect on housing prices. In studying these zones, Brookshire, et al. (1982) found that structures located in known zones sold for seven percent less than those outside the zones. These results have been independently confirmed (Cochrane, 1990) for the year after the zones were first designated (1976). However, the risk price differential disappeared in 1979, and as of 1990, has not reemerged. This observation, although tentative, deserves careful consideration.

5.2 Secondary Economic Damages

The so called secondary effects of disaster are often confused with the direct impacts. By direct, I mean the loss of plant and equipment which stems directly from damages sustained in the event plus any associated loss of employment. These losses may produce supply bottlenecks which result in an economic ripple effect, inducing layoffs in related but undamaged industries. Reductions in household incomes resulting from layoffs, bankruptcies, and bad loans, would produce a separate set of economic effects, referred to as induced or multiplier effects. These too are lumped under the category secondary effects.

Many have speculated about the real effects of disaster, but these effects have been seldom observed. I can only think of several instances where a natural disaster has triggered a depression. The dust bowl period of the 1930s in this country and the Managua earthquake (1972) come to mind. But even in these instances, the natural event was accompanied by man made events, the stock market crash and political revolution, respectively. Counter examples are clearly more plentiful.

So, why do some disasters trigger, or at least accompany, severe economic contractions and others do not? The answer lies in the underlying strength of the economies impacted. We have learned from the Managua event that disasters tend to accelerate ongoing economic and social processes which were at work prior to the event. Failing economies experience a sudden collapse, whereas robust economies experience a boom. But, even in the case of a disaster triggered economic expansion, one must account for all effects, both regional and national.

The effects of disaster can be shifted to other regions or to another time period, possibly to other generations. In a world of federal budget limitations, increased aid to help disaster victims means either 1) tax increases for the general population or 2) a reduction in spending somewhere else in the nation. Even if lawmakers can keep the aid off the budget, as they did with the recent bank crisis in the United Sates, the nation is still left with the tax liability, amounting to the amount of newly acquired debt. In this instance, the costs reconstructing an earthquake torn city is left to our children. Multiplier effects and related secondary losses are, therefore, either pushed onto other regions or shifted in time. They are not eliminated. This interplay between regional and national burdens is summarized in Figure 4.

Elements of one or more of these linkages were evident after both the Loma Prieta Earthquake (October 17, 1989) and Hurricane Hugo (September 22, 1989). The northern California cities of Santa Cruz and San Francisco faltered at least temporarily as a direct result of damage to public and private facilities. South Carolina's coastal counties (Charleston, Horry, and Georgetown) were initially reported to suffer a similar fate.

However, the recovery following the two disasters is startlingly different. The secondary impact triggered by Hurricane Hugo is particularly instructive. The following chart, Figure 5, shows the change in taxable sales (a proxy for economic activity) for two counties along the South Carolina coast, Charleston and Horry. Charleston experience both a decline in tourisn and heavy damage, whereas Horry suffered from negative publicity, but sustained much less direct damage.

Figure 4

NATIONAL AND REGIONAL SECONDARY LOSSES

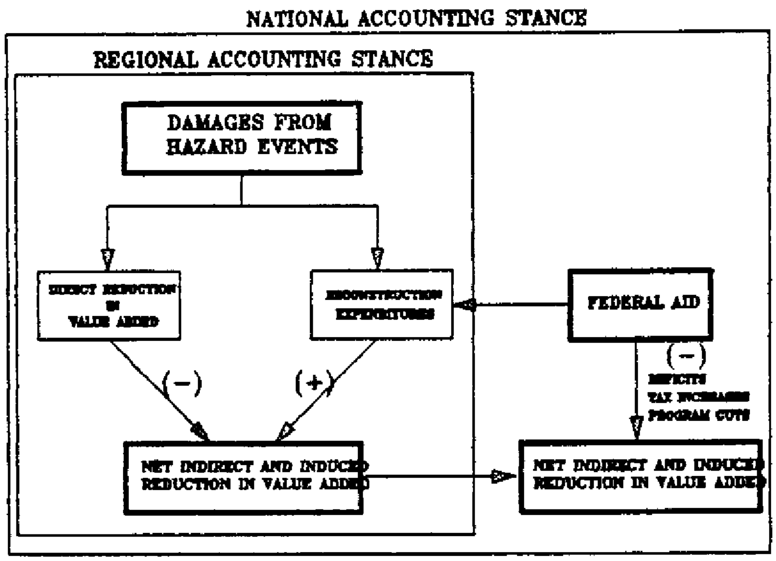
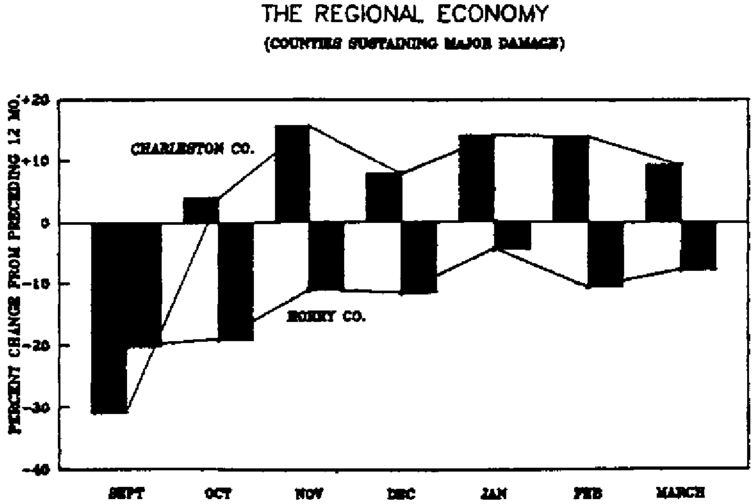


Figure 5

IMPACT OF OF HURRICANE HUGO ON
THE REGIONAL ECONOMY



The pattern indicates that, in the case of Charleston, the negative consequences resulting from a decline in tourism was more than offset by the stimulative effects of reconstruction. Hence, Charleston's economy exhibited a post disaster boom. In Horry county, however, only the negative impact of declining tourism could be observed.

From a national accounting stance as opposed to the regional stance just discussed, secondary losses should be measured by deriving regional secondary impacts, adjusted for the liability the Federal government incurs in providing disaster relief, and for offsetting increases in outputs elsewhere. The positive effects outside aid produces for the region would in all likelihood be counter-balanced by negative effects produced by the three budget options previously discussed. Whether the overall net effect is positive or negative depends upon the resultant regional demand changes and their associated multipliers. Since it is impossible to know *a priori* which option the government will utilize, it is safest to assume that the secondary effects cancel[4], i.e, the positive outcomes from federal aid and expanded external production are precisely offset by the negative regional secondary effects and the secondary effects produced by the budget shortfall.

The foregoing discussion provides one more reason why regional secondary losses are so difficult to detect; they may be displaced geographically and over time. Wright, et al. (1979), for example, identified 3,102 counties for which census tract data could be obtained for the period 1960 and 1970. According to their analysis, the long term impacts of disasters on population growth, the housing stock and overall economic activity was minimal.

> "For the period 1960 to 1970, there are no discernible effects of the natural disasters events occurring in that period which materially altered population and housing growth, trends for counties and census tracts." (Wright, et al., 1979, 27)

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4 A weighted average (based on a market basket of typical consumer expenditures) value added multiplier was derived for personal consumption expenditures was compared with the construction multiplier. The difference between the two turned out to be minimal, 1.38 vs. 1.30. We, therefore, conclude that the two effects are approximately equal and, therefore, cancel.

The study goes on to recognize that the role of outside aid in suppressing long term impacts.

> "Likewise, the large scale, nontrivial events should not be expected to produce long term effects - first because they strike the most resourceful communities and second because they generate large amounts of outside aid." (Wright, et al., 1979, 207)

These results have been commonly interpreted to mean that secondary effects are uncommon. A more accurate interpretation is that secondary effects are seldom observed at the regional level. The fact that disaster stricken communities eventually rebuild has little to do with the magnitude of these secondary effects.

5.3 Valuing the Loss of Life

What is a Life Worth?

The loss of human life in natural disasters is not monetizable after the fact. However, before a natural disaster occurs, decision-makers who are considering mitigation programs that can reduce risks to life need some guidance in determining how much to spend on risk reduction, particularly when spendinthat cg on safety competes with spending on other services as part of a limited budget. The general rule that economists follow is that risks should be reduced up to the point where the costs of providing an additional small amount of safety are equal to the benefits of that extra safety. The measurement of these benefits is by no means a simple task, since it involves placing a dollar value on the number of additional lives saved.

The economic literature often refers to this dollar value as the "value of life". This term gives the misleading impression that society is willing and able to place a price on saving a particular individual from certain death. Experience shows that when a baby falls down a well, or a hiker is lost in the wilderness, no expense is spared to bring about a rescue. The "value of life" properly applies only to anonymous, statistical lives within a large population, not to particular lives (Schelling, 1968). The "value of reductions in risks to life" or the "value of improvements in safety" might be more appropriate terms. In effect, a reduction in risk from, say, five deaths per ten thousand people to four deaths per ten thousand can be expected to save one life in a group of that size, although no one knows whose life will be saved; the "value of life" is equal to the value of this reduction in risk.

In the past, the benefits of reductions in risk were evaluated in terms of the discounted present value of a person's expected future earnings, that would be lost if the safety improvements were not in place. This method of evaluation, often misnamed the "human capital" approach in the literature, in effect places a very low value on the lives of the very young, the old, and the poor, whose discounted expected future earnings are small. In addition, the method assumes that life has value only for production, and ignores the many other aspects of life that people value. Variations on this approach include subtracting the discounted present value of future consumption from future earnings, which reduces the value of life to a person's contributions to society's total wealth (and implies that some lives are less than worthless). Another variation is to add in the medical or burial costs that would be incurred if the risk reduction were not in force. These methods yield an estimated value of life that is on the order of tens of thousands of dollars, which probably understates the amount of safety that people actually want. They are also inconsistent with generally accepted economic theory.

Although the techniques for estimating the value of risk reduction that have been discussed in the literature are imprecise and subject to dispute, recent research results appear to be converging enough to provide a tentative estimate for policy-making purposes, at least within an order of magnitude. A value on the order of $3 million per expected life saved, associated with reductions in risk on the order of one in ten thousand, would be an appropriate baseline, with much leeway in either direction. This estimate does not apply to large reductions in risk, or to situations where risk is high to begin with; research in these areas has not been performed. However, in the proper context the $3 million figure appears to be valid. No research supports spending more than three times that amount on improvements in safety per expected life saved. When considering projects that reduce risk at such a high cost, decision-makers would be well advised to consider spending their budgets elsewhere.