Pitfalls in Determining the Number of Lives to be Lost

Most studies of life loss typically derive their estimates for a single targeted event, such as the Richter 8.3 magnitude earthquake situated on the San Andreas fault, 30 miles downtown San Francisco. It is important to note that these estimates are predicated on the assumption that the current level of risk, i.e., the number of unreinforced structures remain unchanged over the period of study. This is a serious flaw in that the building inventory is dynamic and is sensitive to the sequence of intervening sub-events lesser earthquakes, for example, which lead up to the targeted event.

The inventory of structurally unsafe buildings and other assets will change over time. A moderate earthquake in the range of Richter 6 to 7 would render some unreinforced buildings uninhabitable[5]. "Red tagging" of such buildings and their subsequent demolition would reduce the stock of hazardous buildings subject to failure in the event of a catastrophic shock. Therefore, the true expected loss over a 100 year planning horizon is a function of the numerous plausible sequences and their associated probabilities. Two such paths are illustrated in Figure 6.

The importance of the event sequence is easily demonstrated by numerical illustration. Assume that if an earthquake occurs it will be either catastrophic or moderate. The probabilities of each event, its impact on the housing stock and the number of lives lost per hazardous building is summarized in Table 2.

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5 Building inspectors adopted a color coded tagging system after the Loma Prieta earthquake. A red tag indicated that the building was structurally unsafe and was effectively condemned.

Figure 6

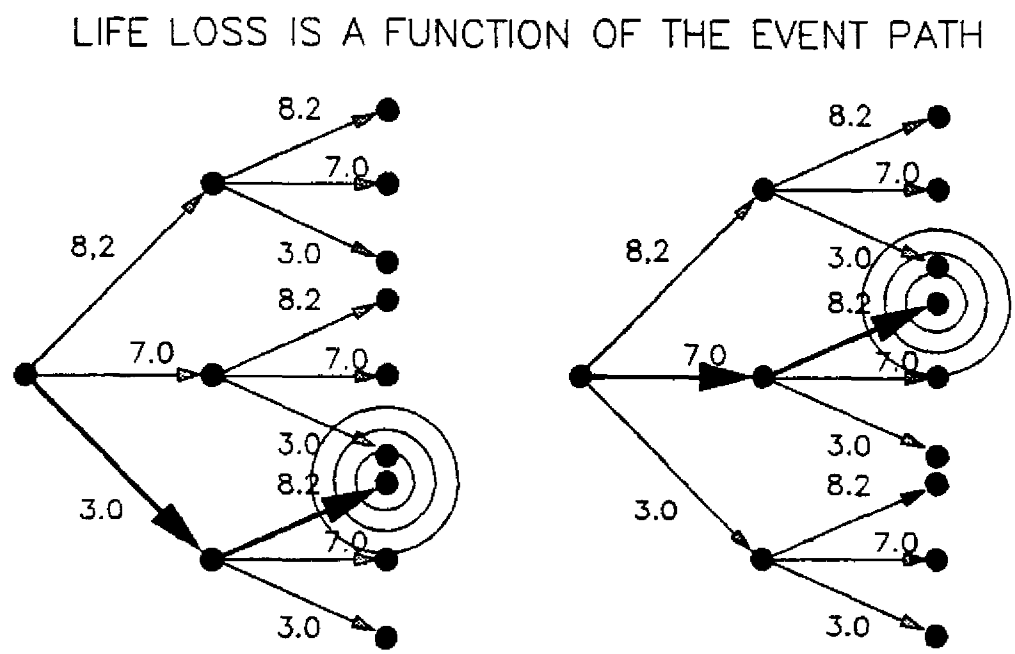


Table 2

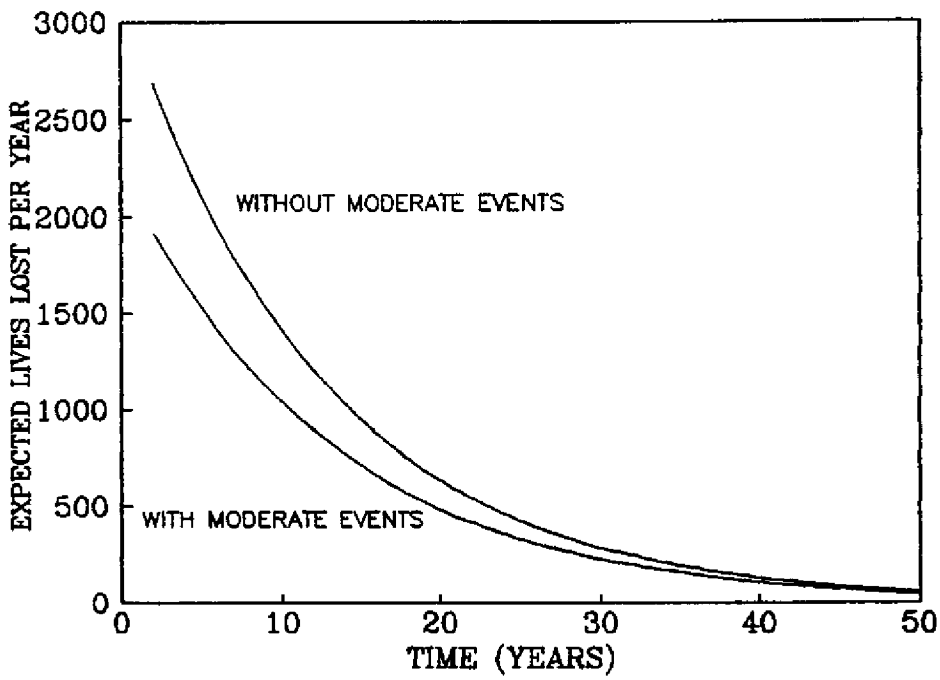
Expected Lives Lost
Considering the Impact of
Smaller Events

Earthquake	Probability	Percent of Buildings Surviving	Lives Lost per Building Destroyed
Moderate	.20	50	1
Catastrophic	.05	0	10

Figure 7 shows the expected number of lives lost per year[6] when taking the effects of moderate events into account.

Figure 7

Lives Lost
in Hazardous Buildings



The results suggest that the event sequence does make a difference. In this example, the inclusion of smaller events reduces the number of hazardous buildings subject to the effects of a catastrophic event. Twenty percent fewer fatalities would be expected as a result.

5.4 Damage to Historic Monuments and Assets

An important area of potential loss from natural hazards is damage to or destruction of historic monuments and other cultural assets. Their contribution to the population's level of well-being is undoubtedly large, but also less direct

6 These results are based on a monte-carlo simulation which computed the annual life loss for 250 different event paths.

and perhaps more abstract than for other kinds of assets. Consequently, their economic value is important to consider yet difficult to assess.

Current practices for the evaluation of such goods are few, even non-existent for many types of assets. For insurance purposes, museums typically value their collections at estimated market prices (based on auction records), yet many museum personnel express the view that some objects are truly priceless, and valuation is pointless. Curators tend to set protection priorities according to their own subjective judgments, and according to their interpretation of the goals of their institutions; rarely are dollar figures used for such purposes. In the case of historic buildings and other monuments, significance is often assessed in qualitative terms, but dollar values are rarely assigned. Economic value is most often discussed in terms of the economic side-benefits that preservation can bring to a community's economy.

In the case of some marketable assets, appraisers can estimate **market values**, but such prices will often understate the full social value of the asset, and this approach cannot be used for non-marketable assets. Therefore, it is necessary to develop proxies for market prices, that is, indirect measures of what people are willing to pay for an asset. One approach is to estimate the **opportunity costs** society has shown itself willing to bear for preservation of the asset. In this case, one must be careful to single out the net value that would be lost by destruction of the asset. Other methods of non-market valuation can be adapted from environmental economics: the **travel cost** method is a variation of the opportunity cost method, and has been refined so that it yields a net measure of value; the **contingent valuation** method uses survey techniques to estimate a population's willingness to pay for an asset.

5.5 Ecosystem Change and Damage

Environmental disturbances are a natural part of ecological systems and may cause change in the system. Earthquakes rearrange coastal wetlands making freshwater habitat more saline; hurricanes uproot trees and fires consume them; and floods destroy vegetation that would have held soil in place. These natural interactions between disturbances and ecosystems have and will continue to take place regardless of how individuals or policy makers value the effects of such events. Whether disturbance events result in **ecological impact** depends upon how society values the changes resulting from the disturbances. Thus, a naturally occurring disturbance is defined as a natural hazard event when it threatens people or something valued by people.

Ecosystem damage refers to an economic measure of the losses due to the impact. To restate a point made earlier, total environmental damages may not be an appropriate measure from the perspective of policy. The avoidable loss, not the total change, constitute the damage. For example, the destruction wrought by Hurricane Hugo may have left 6.7 billion board feet of saw timber unusable, enough to provide housing for the entire population of the Southeast, but there was no means of preventing the damage. On the other hand, an ecologically based perspective of loss and possible mitigation of the loss must consider the total change in order to evaluate ecosystem effects and what mitigation may be appropriate.

Figure 1, in the problem statement above, places environmental impact assessments into the broader context of damage assessment. Geophysical events impact human populations both directly and indirectly. Similarly, ecological systems respond directly to natural disturbances and to associated secondary events such as landslides, toxic waste discharges and fires. Ecological systems may also show delayed, indirect and cumulative effects from disturbance events. Ecological changes may be considered ecological impacts after humans evaluate the changes. Damage assessment places a value on the loss due to the impact.

6 Summary

I have attempted to cover a wide variety of concepts, ranging from well honed accounting practices for assessing direct and secondary damages, to the more controversial yet promising procedures for valuing historic assets, life loss, and environmental damages. The following briefly summarizes the conclusions reached thus far.

6.1 Conceptual Framework

The policy-making process presumably reflects that subset of natural hazard impacts and monetizable value changes that society, through its legislative and judicial processes, decide are important. The policy process deals both with monetized values and non-monetized impacts through the multiple-objective planning process.

The "with-without" principle is one of the clearest, simplest, and perhaps most important economic principle guiding impact assessments. It is also one which is commonly violated. 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.

The appropriate accounting stance for assessing damages and impacts depends upon the level of government that is making the decision. Policy relevant damages are those damages which are pertinent to the question under investigation. If, for example, the focus is on damage mitigation, then avoidable loss, rather than total loss, is the relevant measure of damage.

6.2 Monetizing Direct Damages

The different ways of measuring direct economic damages center on three types of effects: (1) interruptions of production processes and related income flows; and (2) damage to assets. The damages caused by lost or delayed production is equivalent to the present value of delayed profits, wages, interest, salaries and rents. Depreciated replacement value is the appropriate basis for assessing damages to assets. If the asset is completely destroyed and replaced, then damage is measured as the present value of the investments required replace it. In some instances the new capital will embody technologies that will make production more efficient. Positive by-products from investing in such advanced technology lessen the loss.

There are several ways in which the these principles could be incorrectly applied. The following points should prove helpful in avoiding this possibility.

Potential sources of double counting -- Care must be exercised to avoid double counting changes in income flows and loss of asset values. The destruction of plant and equipment will trigger financial markets to reexamine the value of the firm's equity shares. To include both the loss of equity value and direct damages double counts the loss.

Calculating the damages resulting from public sector production interruptions -- administrative services valued at their cost plus services directly sold to the public (health, transportation, utilities, etc.) valued by prices charged or costs of service, whichever is greater. If government costs are used as a proxy for value of lost government services, then lost source of government revenue cannot also be included. Government revenue is derived from income (sales and income taxes) and property value. To count both the loss of value added and loss of government revenues would involve double counting.

Calculate ex ante expected asset losses based on a dynamic analysis of the building stock. -- The composition of the building stock will be reshaped by normal attrition and the occurrence of smaller hazard events which weaken structures sufficiently to warrant their condemnation. Loss studies designed to measure the expected value of building damages should incorporate this factor.

Use of simple hedonic measures for assessing ex ante losses -- Simple indirect methods, such as the repeat sales approach, are useful tools for measuring how much society is willing to pay for additional safety from hazard events. The results of such studies must be interpreted with care, however. The hedonic equations could reflect: 1) poor information; 2) prior knowledge of the risks; or 3) the costs of protective measures rather than the value of safety. In such cases, it would be incorrect to interpret the findings as a measure of damage.

6.3 Monetizing Secondary Damages

What to legitimately include as secondary damages depends on the accounting stance taken, the mobility of the affected region's resources and the nature of the economic linkages prevalent in the region. The extent, and even the sign of net secondary damages depend upon the amount of outside assistance received. From a national perspective, however, they must be zero or negative.

The points put forward in the paper can be condensed into several fundamental principles:

Secondary damage is equivalent to the change in total value added (as computed from an Input-Output model) less direct damages of the disaster, less any temporary income earned from other sources.

+	Lost labor income
+	Lost profits + lost rents and interest
=	Total losses of value added
-	Direct losses - temporary incomes
=	Secondary losses

Do not add lost incomes and expenditures -- Since household spending (consumption) is derived from incomes, production interruptions (which implies a suspension in the flow of income) leads to a change in spending. Either form of interruption could be included in a damage assessment, but not both.

Do not restrict loss measurements to the year of the disaster or to the region-- Households, businesses and government can spread losses over time. The provision of public aid transfers the effects to the general taxpayer.

A post-disaster change in regional income and sales may not reflect true secondary damages -- A hazard event can both stimulate (through rebuilding) as well as dampen (through direct damages) economic activity. The net effect may be positive or negative, depending upon the relative magnitude of each. To focus on the year of the disaster, and ignore the possibility that burdens may be shifted from region to region and over time clouds the analysis. This has been, and continues to be, a major source of error.

Direct damages must produce secondary effects if excess capacity does not exist -- It follows that regional and to some extent national secondary losses must exist. They may be masked but not eliminated by the effects of rebuilding.

Be sure not to count lost sales which reflect imports into the region -- They have value elsewhere.

6.4 Monetizing the Loss of Cultural Assets

Cultural assets are valued at many levels. Direct experience produces use values. Some attach value to preserving the option of experiencing these sites. Other attach value to the ability to pass on the asset as a bequest to future generations. In addition, some cultural assets contribute to the integrity of and continuity of social identity, qualities which yield tradition or existence value.

Market values derived through appraisals will often understate the true social value of a cultural asset. Indirect measures of market price must be developed for historical and cultural assets which are not traded in the market place. In such cases the opportunity cost of, or travel cost to the asset would provide a bench mark measure of its value. However, an asset's value is an inaccurate indicator of the loss sustained in the event of its destruction. The site still has value in other uses, or households can travel to see other historic landmarks. Therefore, both methods require that only net values, i.e., the value over and above travel and opportunity costs, be considered. Contingent valuation method adapted from environmental economics provide an alternative for measuring the population's willingness to pay to preserve historical and cultural assets.

6.5 Valuing Life Loss

The loss of human life is not monetizable after the fact. However, before the occurrence of a natural disaster, decision makers may wish to attach a monetary value to the number of statistical lives which may be saved through damage mitigating measures.

The costs of preventing life loss in the event of disaster must be weighed against other equally pressing and life threatening social problems. Every dollar spent on hazard reduction implies that one less dollar will be available for crime prevention, AIDS research, and drug addiction. The use of dollars to value a statistical life simply helps to insure that the full spectrum of risks are treated in a balanced way.

Economists have developed a number of techniques for valuing a statistical life. The earliest approach focused on forgone earnings, a technique which is still widely utilized to arrive at monetary settlements in wrongful death suits. More recently, economists have turned to the amount people are willing to pay for risk reduction. Labor market studies provide an indication of the compensation workers require to induce them to under-take risky tasks. Consumer market studies focus on the amount people are willing to spend to reduce the risk of accident. Although these methods are not without controversy, the results suggest that the value of a statistical life is approximately $3 million.

6.6 Environmental disturbances may or may not result in environmental damages

Environmental disturbances are a natural part of ecological systems. The effects of particular events are site-specific and the systems affected are dynamic and complex. Whether disturbance events result in environmental damage depends upon how society values the effects of and the time required for recovery from disturbances. Effects may be directly observable or may be delayed, indirect, or cumulative and therefore require prediction.

6.7 Synopsis of the Principles

The main damage assessment principles are bulleted in the following chart.

Figure 8

LOSS MEASUREMENT PRINCIPLES

MEASURE LOSS WITH AND WITHOUT THE EARTHQUAKE NOT BEFORE AND AFTER

DO NOT DOUBLE COUNT IMPACTS

DAMAGE ASSESSMENTS SHOULD EXCLUDE LAND AND DEPRECIATION

EXPECTED LOSSES SHOULD BE DERIVED FROM A DYNAMIC BUILDING STOCK

MITIGATION POLICY SHOULD BE BASED ON AVOIDABLE NOT TOTAL LOSS

FEDERAL PRIORITIES SHOULD BE BASED ON NATIONAL NOT REGIONAL IMPACTS

LIFE, HEALTH, AND "IRREPLACEABLE" ASSETS CAN BE VALUED

USEFUL RESULTS CAN BE OBTAINED FROM SIMPLE APPROACHES

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8 Appendix — Heonic Methods and the Repeat Sales Approach

The studies referred to in the body of the paper describe two ways in which hedonic methods can be employed to assess what households are willing to pay to avoid risks posed by natural and man-made hazards. First, market prices can be analyzed through regression analysis, where a risk variable is identified (implied by location in or out of the risk zone), the structure's internal attributes (square footage, type of construction, etc.), and external attributes (nearness to schools, crime rate, etc.). Those structures outside the hazard zone, and those inside the zone, prior to the time when the risks were made known to the market, represent "safe" properties. This provides a "with-without" test, where the risk (location) variable reflects the degree to which the market has internalized information about the hazard. Second, one might also conduct a "with" and "without" test similar to that just described, but examine each attribute's coefficient to determine whether the release of information changed the model's structure. It could turn out that for some hazards, e.g., earthquakes, several attributes may prove to be risk sensitive. For example, the type of heating system installed (natural gas vs. electric) may produce a set of secondary hazards which households may have evaluated.

Key to either of the above approaches is the inclusion of sales which have occurred prior to the release of information about the hazard. This is critical, particularly when a single locational variable can have either a positive (scenery) or negative (risk) value. Given this possibility, the sign and magnitude of the "risk" variable could be highly misleading, since scenery may exhibit a powerful influence on land values. This is particularly apparent in the case of landslide risk (Cochrane, 1990). Therefore, it would be unwise to conduct an hedonic study, focusing solely on hazard zones, without first checking this possibility.

The Repeat Sales Approach -- The hedonic approaches described above are attractive candidates if sufficient observations are available. However, this may not always be the case, and a simpler approach, such as the use of repeat sales, would be helpful. It will be shown that this alternative preserves the essence of the "with" and "without" test described above, but requires less than 30 observations. This approach is based on the facts that (1) the market price of a house prior to the discovery of a hazard reflects only the valuation of the internal and external attributes, and (2) the market price after disclosure introduces the effect of risk and "normal" appreciation in the value of other attributes.

A comparison of before and after sales data, normalizing for time between sales and depreciation, should reveal the extent to which the public is willing to pay to avoid the hazard. By making the presence of the hazard public information, both the perceived probability of the event as well as its consequences are altered. The combined effect of these changes filtered through risk preferences is what produces a change in value. An example of repeat sales analysis is given in the following equations:

$$P_t = b_1 P_0 e^{rt} b_2^Z e^{\epsilon}$$

Where: P_t is the sales price after the risk is made known

P_0 is the sales price at a point in time prior to when the risks are known

t is time between sales in years

Z is a dummy variable reflecting the presence of a hazard (1 means in the hazard area, 0 means outside)

ϵ is the error term

P_0 incorporates only the household's valuation of the structure's attributes. At this point, the buyer may be unaware of the hazard. New information, available by time t, permits the household to trade-off risk against other attributes. Hence, P_t reflects the same internal and external attributes, but now includes the effect of risk. Since the attributes are assumed to remain unchanged over the period 0 to t, they can be omitted from the equation. b_2 measures the sensitivity of the property's value to the publication of hazard information. In the event the buyers are initially unaware of the hazard, b_2 represents how much the safety attribute is worth.

This approach may be criticized on the grounds that it involves the use of longitudinal data and emphasizes a before and after comparison. It is true that housing prices may be influenced by factors such as interest rates and income, which are clearly unrelated to the presence of a hazard. However, so long as these influences produce identical price effects in both hazardous and safe zones, the fact that time has elapsed should be of little concern. Time between sales captures the combined influence of the outside factors shifting housing demand and supply, and depreciation. Since the purpose of the method is to isolate the effect of a hazard on housing prices, it is unnecessary to know precisely the influence of changing incomes and interest rates. It is safe to conclude that exogenous forces simply shift the rent gradient function without significantly altering its slope.

Hedonic Results Should be Interpreted With Caution -- The use of the repeat sales approach or the more elaborate hedonic methods discussed earlier can provide planners important information, but the results should be interpreted carefully. For example, a small or zero risk value in the estimated hedonic equation could mean several things. It may mean that buyers and sellers of real property believe that losses are relatively unimportant. It may be that the full meaning of a risk has not been conveyed or understood. A third explanation is that risk may have been known prior to official announcement.

A non-zero value of b_2 usually is attributed to the losses expected as a result of locating in hazardous regions (floodplains, earthquake special study zones, etc.). b_2 may also include the effects of the added cost of upgrading the structural integrity of buildings situated in such zones. Providing these protective measures are highly effective, the risk coefficient will reflect only the added costs of locating in the zone. In such a case, residual damages will be inconsequential.