Chapter 16
Indirect Economic Losses

16.1 Introduction

This Chapter is written with several goals in mind. First, it is intended to familiarize the reader with the concept of indirect loss, including a brief discussion of input-output models, the traditional approach for tracing interindustry ripple effects (Sections 16.2 and 16.3).

Second, an algorithm for addressing supply shocks (the engine of the Indirect Loss Module) is developed and explained. Section 16.4 develops a method for computing indirect losses, one that addresses the effects of supply and demand disruptions. The Indirect Loss Module is a computational algorithm which accounts for earthquake induced supply shortages (forward linkages) and demand reductions (backward linkages). The module is a version of a computable general equilibrium model designed to rebalance a region's interindustry trade flows based on discrepancies between sector supplies and demands. The flowchart of the overall methodology, highlighting the Indirect Loss Module and its relationship to other modules is shown in Figure 16.1.

Third, the chapter discusses data requirements and operational issues related to running the module for different levels of analysis. Section 16.5 provides an overview of input data, module operation, and results output in a Default or User-Supplied Data Analysis. It also includes suggestions for approaches to conducting a Advanced analysis.

Finally, a number of experiments are reported to assist the user in interpreting the Module's results. Section 16.6 analyzes how patterns of direct damage, preexisting economic conditions (unemployment, import-export options, and economic structure) and external assistance alter indirect loss. Example solutions based on the Northridge earthquake are provided, along with the results of Monte Carlo simulations. The former is provided to illustrate how the model can be applied, the latter to suggest the wide range of possible outcomes. Lastly, a set of helpful observations are presented.

16.2 What are Indirect Losses?

Earthquakes may produce dislocations in economic sectors not sustaining direct damage. All businesses are forward-linked (rely on regional customers to purchase their output) or backward-linked (rely on regional suppliers to provide their inputs) and are thus potentially vulnerable to interruptions in their operation. Such interruptions are called indirect economic losses. Note that these losses are not confined to immediate customers or suppliers of damaged enterprises. All of the successive rounds of customers of customers and suppliers of suppliers are impacted. In this way, even limited earthquake physical damage causes a chain reaction, or ripple effect, that is transmitted throughout the regional economy.

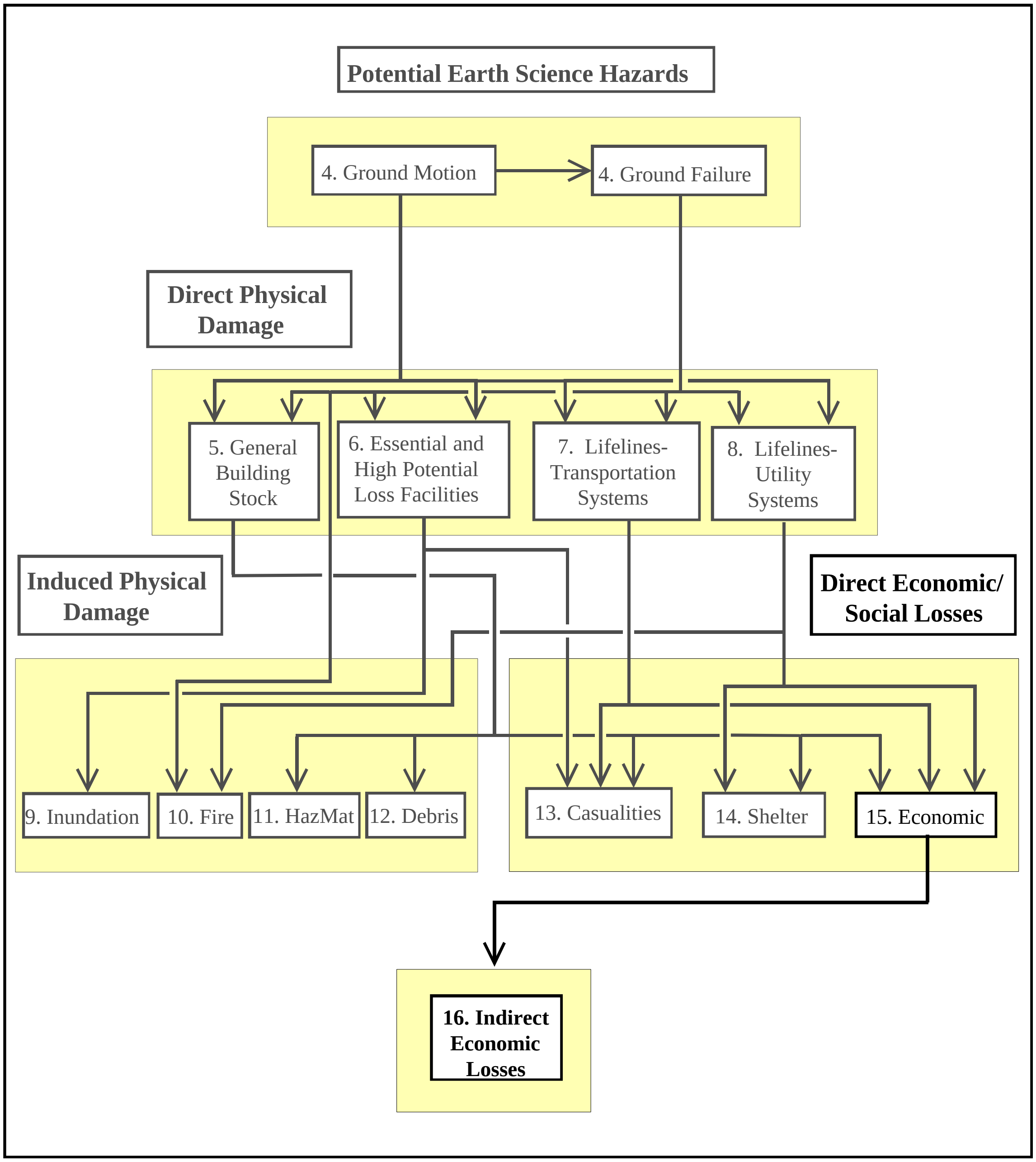

Figure 16.1 Indirect Loss Estimation Relationship to Other Modules in the Earthquake Loss Estimation Methodology

The extent of indirect losses depends upon such factors as the availability of alternative sources of supply and markets for products, the length of the production disturbance, and deferability of production. Figure 16.2 provides a highly-simplified depiction of how direct damages induce indirect losses. In this economy firm A ships its output to one of the factories that produce B, and that factory ships to C. Firm C supplies households with a final product (an example of a final demand, FD) and could also be a supplier of intermediate input demand to A and B. There are two factories producing output B, one of which is destroyed in the earthquake. The first round of indirect losses occurs because: 1) direct damage to production facilities and to inventories cause shortages of inputs for firms needing these supplies (forward-linked indirect loss); 2) damaged production facilities reduce their demand for inputs from other producers (backward-linked indirect loss); or 3) reduced availability of goods and services stunt household, government, investment, and export demands (all part of final demand).

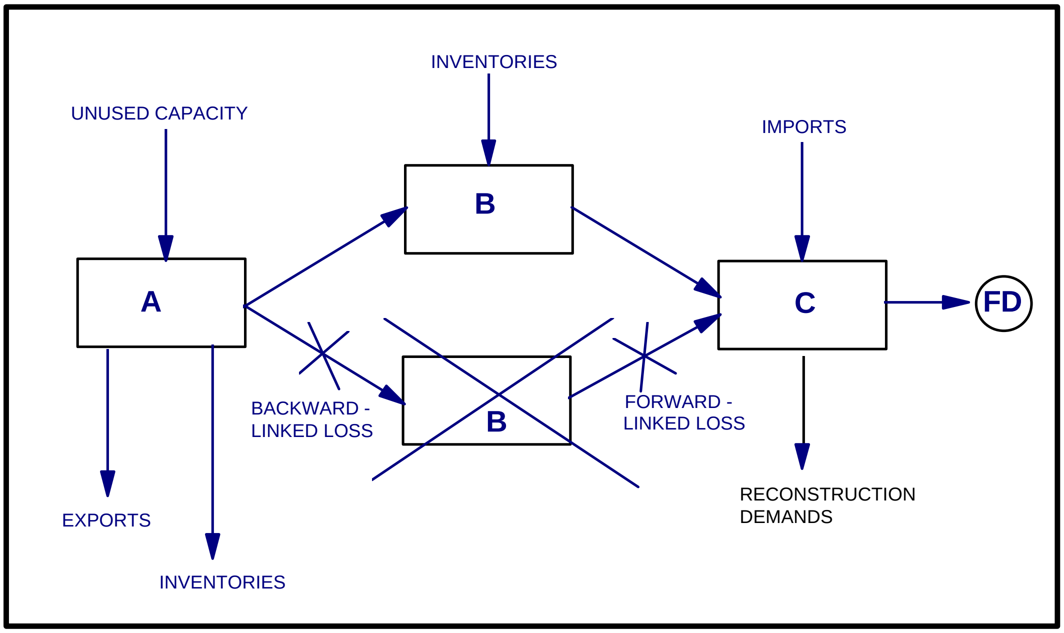

Figure 16.2 Indirect Losses and Adjustments to Lessen Them

16.2.1 Supply Shortages and Forward Linked Losses

The supply shortages caused as a result of reduced availability of input B could cripple factory C, if C is unable to locate alternative sources. Three options are possible: 1) secure additional supplies from outside the region (imports); 2) obtain additional supplies from the undamaged factory (excess capacity); and 3) draw from B's unsold stock of output (inventories). The net effect of diminished supplies are referred to as forward-linked losses, the term forward (often referred to as downstream) implying that the impact of direct damages is shifted to the next stage or stages of the production process.

16.2.2 Demand Effects and Backward Linked Losses

Disasters can also produce indirect losses if producer and consumer demands for goods and services are reduced. If, in the example provided in Figure 16.2, firm B has a reduced demand for inputs from A, then A may be forced to scale back operations. As in the case of forward-linked losses, the affected firms may be able to circumvent a weakened market, in this case by either finding alternative outlets such as exports or building up inventory.[1]

The higher rate of unemployment caused by direct damages and subsequent indirect factory slowdowns or closures would reduce personal income payments and could cause normal household demands to erode. However, it is more likely that the receipt of disaster assistance, unemployment compensation, or borrowing, would buoy household spending throughout the reconstruction period. Evidence from recent events (Hurricanes Andrew and Hugo, the Loma Prieta Earthquake and the Northridge Earthquake) confirms that normal household demands are only slightly altered by disaster in the short-run. As a result of this observation, the Indirect Loss Module discussed below delinks household incomes and demands.

16.2.3 Regional vs. National Losses

It has sometimes appeared that natural disasters tend to stimulate employment and revitalize a region. Clearly, the generous federal disaster relief policies in place after the 1964 Alaskan earthquake, the 1971 San Fernando earthquake, and Hurricane Agnes in 1972, served to buoy the affected economies, thereby preventing the measurement of significant indirect losses. From a regional accounting stance, it appeared that the net losses were inconsequential. However, this viewpoint fails to take into account the cost of disasters on both household and federal budgets.

Some, if not most, public and private post-disaster spending is unfunded; that is, it is not paid for out of current tax revenues and incomes. In the case of households this amounts to additional indebtedness which shifts the burden or repayment to some future time period. Federal expenditures are not budget neutral either. As in the case of households, governments cannot escape the financial implications of increased spending for disaster relief. Either lower priority programs must be cut, taxes raised, or the federal debt increased. The first two options simply shift the reduction in demand and associated indirect damages to other regions. Projects elsewhere may be canceled, services curtailed, and/or household spending diminished as after-tax incomes shrink. The debt option provides no escape either, since it, too, places the burden on others, e.g., a future generation of taxpayers.

From a national accounting stance, indirect losses can be measured by deriving regional indirect impacts, adjusted for the liability the Federal government incurs in providing

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[1]Building up inventory is not a permanent solution, since eventually the inventories have to be sold. Firms may be willing to do so on a temporary basis, hoping that market conditions will improve at a later date.

disaster relief, and for offsetting increases in outputs elsewhere. The positive effects outside aid produces for the region are to some degree offset by negative effects produced by the three federal budget options. Since it is impossible to know *a priori* which option the federal government will utilize, it is safest to assume that the two effects cancel, i.e., that the positive outcomes from federal aid are offset by the negative national consequences caused by the budget shortfall.

Since the primary user of the Loss Estimation Methodology is likely to be the local entity involved in seismic design and zoning decisions, the Indirect Loss Module is designed accordingly. That is, it adopts a local accounting stance. One simplistic approach to obtaining a national measure of net loss would be to exercise the Loss Module excluding outside federal assistance.

16.3 Interindustry Models

Input-output techniques are widely utilized to assess the total (direct plus higher-order) economic gains and losses caused by sudden changes in the demand for a region's products. Higher demand for rebuilding and a lower demand for tourism, for example, lend themselves to traditional input-output I-O methods. This technique is relatively simple to apply and is already in widespread use in state and local agencies, though not necessarily those associated with emergency management. However, input-output models compromise realism, primarily in the area of supply bottlenecks. Although the Indirect Loss Module addresses both supply and demand shocks in a more sophisticated manner, it is based on the same foundation as the input-output model—a region's interindustry input requirements. Because the two approaches share a common base, we begin by introducing the principles underlying input-output analysis, with an emphasis on demand disturbances, and then extend the framework to accommodate supply shocks.

Input-output analysis was first formulated by Nobel laureate Wassily Leontief and has gone through several decades of refinement by Leontief and many other economists. At its core is a static, linear model of all purchases and sales between sectors of an economy, based on the technological relationships of production. Input-output (I-O) modeling traces the flows of goods and services among industries and from industries to household, governments, investment, and exports. These trade flows indicate how much of each industry's output is comprised of its regional suppliers' products, as well as inputs of labor, capital, imported goods, and the services of government. The resultant matrix can be manipulated in several ways to reveal the economy's interconnectedness, not only in the obvious manner of direct transactions but also in terms of dependencies several steps removed (e.g., the construction of a bridge generates not only a direct demand for steel but also indirect demands via steel used in machines for its fabrication and in railroad cars for its transportation).

The very nature of this technique lays it open to several criticisms: the models are insensitive to price changes, technological improvements, and the potential for input substitution at any given point in time. However, even with these limitations, I-O techniques are a valuable guide for the measurement of some indirect losses. A very brief technical review is provided for those readers who may be unfamiliar with interindustry modeling.[2]

16.3.1 A Primer on Input-Output Techniques

The presentation is restricted to a simple three industry economy. The shipments depicted as arrows in Figure 16.2 are represented as annual flows in Table 16.1. The *X*'s represent the dollar value of the good or service shipped from the industry listed in the left-hand heading to the industry listed in the top heading. The *Y*'s are shipments to consumers (goods and services), businesses (investment in plant and equipment and retained inventories), government (goods, services and equipment), to other regions (exported goods and services). The *V*'s are the values-added in each sector, representing payments to labor (wages and salaries), capital (dividends, rents, and interest), natural resources (royalties and farm rents), and government (indirect business taxes). The *M*'s represent imports to each producing sector from other regions.

A basic accounting balance holds: total output of any good is sold as an intermediate input to all sectors and as final goods and services:

$$X_A = X_{AA} + X_{AB} + X_{AC} + Y_A \qquad (16\text{-}1)$$

Rearranging terms, the amount of output available from any industry for final demand is simply the amount produced less the amount shipped to other industries.

[2] Input-output and "interindustry" are often used synonymously because of the emphasis in I-O on the sectoral unit of analysis, mainly comprised of producing industries. Strictly speaking, however, interindustry refers to a broad set of modeling approaches that focus on industry interactions, including activity analysis, linear programming, social accounting matrices, and even computable general equilibrium models. Most of these have an input-output table at their core. The reader interested in a more complete understanding of I-O analysis is referred to Rose and Miernyk (1989) for a brief survey; Miller and Blair (1985) for an extensive textbook treatment; and Boisvert (1992) for a discussion of its application to earthquake impacts. For other types of interindustry models applied to earthquake impact analysis, the reader is referred to the work of Rose and Benavides (1997) for a discussion of mathematical programming and to Brookshire and McKee (1992) for a discussion of computable general equilibrium analysis.

Table 16.1 Intersectoral Flows of a Hypothetical Regional Economy (dollars)

To From	A	B	C	Final Demand	Gross Output
A	x_{AA}	x_{AB}	x_{AC}	y_A	x_A
B	x_{BA}	x_{BB}	x_{BC}	y_B	x_B
C	x_{CA}	x_{CB}	x_{CC}	y_C	x_C
V	v_A	v_B	v_C		
M	M_A	M_B	M_C		
Gross Outlay	x_A	x_B	x_C	Y	X

To transform the I-O accounts into an analytical model, it is then assumed that the purchases by each of the industries have some regularity and thus represent technological requirements. Technical coefficients that comprise the structural I-O matrix are derived by dividing each input value by its corresponding total output. That is:

$$a_{AA} = \frac{X_{AA}}{X_A}; \qquad a_{AB} = \frac{X_{AB}}{X_B}; \qquad a_{AC} = \frac{X_{AC}}{X_C}; \tag{16-2}$$

The a's are simply the ratios of inputs to outputs. An a_{AB} of 0.2 means that 20 percent of industry B's total output is comprised of product A.

Equation (16-1) can then be written as:

$$X_A = a_{AA} X_A + a_{AB} X_B + a_{AC} X_C + Y_A \tag{16-3}$$

In matrix form Equation (16-3) is:

$$X = AX + Y \tag{16-4}$$

To solve for the gross output of each sector, given a set of final demand requirements, we proceed through the following steps:

$$(I - A)X = Y \tag{16-5}$$

$$(I - A)^{-1}Y = X \tag{16-6}$$

The term $(I - A)^{--1}$ is known as the Leontief Inverse. It indicates how much each sector’s output must increase as a result of (direct and indirect) demands to deliver an additional unit of final goods and services of each type. It might seem that a $1 increase in the final demand for product A would result in the production of just an additional $1 worth of A. However, this ignores the interdependent nature of the industries. The production of A requires ingredients from a combination of industries, A, B, and/or C. Production of B, requires output from A, B, and/or C, and so on. Thus, the one dollar increase in demand for A will stimulate A's production to change by more than one dollar. The result is a multiple of the original stimulus, hence, the term "multiplier effect" (a technical synonym for ripple effect).

Given the assumed regularity in each industry's production requirements, the Leontief Inverse need only be computed once for any region (at a given point in time) and can then be used for various policy simulations reflected in changes in final demand (e.g., the impact of public sector investment) as follows:

$$(I - A)^{-1}DY = DX \qquad (16\text{-}7)$$

More simply, the column sums of the Leontief Inverse are sectoral multipliers, *M*, specifying the total gross output of the economy directly and indirectly stimulated by a one unit change in final demand for each sector. This allows for a simplification of Equation (16-7) for cases where only one sector is affected (or where one wishes to isolate the impacts due to changes in one sector) as follows:[3]

$$M_A DY_A = DX \qquad (16\text{-}8)$$

Under normal circumstances final demand changes will alter household incomes and subsequently consumer spending. Thus, under some uses of input-output techniques, households (broadly defined as the recipients of all income payments) are "endogenized" (included within the *A* matrix) by treating it as any other sector, i.e., a user (consumer) of outputs and as a supplier of services. An augmented Leontief inverse is computed and yields a set of coefficients, or multipliers, that capture both “indirect” (interindustry) and subsequent “induced” (household income) effects. Multipliers are computed from a matrix with respect to households. These are referred to as Type II multipliers in contrast to the Type I multipliers derived from the “open” I-O table, which excludes households. Of course, since they incorporate an additional set of spending linkages, Type II multipliers are larger than Type I, typically by around 25%.

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[3] Note that the previous discussion pertains to demand-side (backward-linked) multipliers. A different set of calculations is required to compute supply-side (forward-linked) multipliers. (Computationally, the structural coefficients of the supply-side model are computed by dividing each element in a given row by the row sum.) Though mathematically symmetric, the two versions of the model are not held in equal regard. There is near universal consensus that demand-side multipliers have merit because there is no question that material input requirements are needed directly and indirectly in the production. However, the supply-side multipliers have a different connotation—that the availability of an input stimulates its very use. To many, this implies the fallacy of “supply creates its own demand.” Thus, supply-side multipliers must be used with great caution, if at all, and are not explored at length here. For further discussion of the conceptual and computational weaknesses of the supply-side model, see Oosterhaven (1988) and Rose and Allison (1988).

Note also that the multipliers discussed thus far pertain to output relationships. Multipliers can also be calculated for employment, income, and income distribution effects in analogous ways. Also note that sectoral output multipliers usually have values of between 2.0 and 4.0 at the national level and are lower for regions, progressively shrinking as these entities become less self-sufficient and hence the endogenous cycle of spending is short-circuited by import leakages. Sectoral output multipliers for Suffolk County, the core of the Boston Metropolitan Statistical Area, are for the most part in the range of 1.5 to 2.0.

16.3.2 An Illustration of Backward Linked Losses

Conventional input-output models provide a starting point for measuring indirect damages that are backward-linked, providing that the disaster does not significantly alter the region's input patterns and trade flows. In the next section, we will discuss modifications of the methodology for such changes. The calculation of indirect damages for the more simple case is illustrated in the following example beginning with the input-output transactions matrix presented in Table 16.2.

Table 16.2: Interindustry Transactions

To From	A	B	Households	Other Final Demand	Gross Output
A	20	45	30	5	100
B	40	15	30	65	150
Households	20	60	10	10	100
Imports	20	30	30	0	80
Gross Outlay	100	150	100	80	430

This simplified transactions table is read as follows: $20 of industry A's output is used by itself (e.g., a refinery uses fuel to transform crude oil into gasoline and heating oil). $45 of output A is shipped to industry B. $30 is marketed to the household sector and $5 is sold to government, used in investment, or exported to another region. $20 worth of household services is required to produce $100 of output A, and $60 is needed for $150 of B. According to the table, 30 percent of the consumer's gross outlay is allocated to the purchase of A, 30 percent to B, 10 percent to household services, and 30 percent to imports.

Assume that the input-output tables shown above represent a tourist-based seaside economy. Industry A represents construction while B represents tourism. What would happen to this economy if an earthquake destroyed half the region's beachside hotels? Direct economic losses are comprised of manmade assets destroyed in the earthquake plus the reductions in economic activity[4] in the tourist sector. Assume that the damage to hotels influences some tourists to vacation elsewhere the year of the disaster, reducing the annual $95 million demand for hotel accommodations by $45 million.

For the purposes of this illustration, household spending and demands are linked. Therefore, a Type II multiplier would be utilized to assess the income and output changes

[4] Economic activity can be gauged by several indicators. One is Gross Output (sales volume). Another is Value-Added, or Gross National Product (GNP), which measures the contribution to the economy over and above the value of intermediate inputs already produced, thereby avoiding double-counting (note the "Gross" in GNP simply refers to the inclusion of depreciation and differs from double-counting meaning of the term in Gross Output.) Specifically, Value-Added refers to returns to primary factors of production: labor, capital, and natural resources. The concept is identical to the oft used term National Income, which is numerically equal to GNP.

anticipated. The effect of declining tourism on the region's economy is easily derived from the initial change in demand and the Type II multipliers presented in Figure 16.3. Each tourist dollar not spent results in a loss of $1.20 and $2.03 worth of production from A and B, respectively.

The resultant total (direct plus indirect) decline in regional household income is $1.17 per tourist dollar lost (row 3 column 2 of the closed Leontief Inverse). If nothing else changed (including no pick up in construction activity), the regional income lost for the year is $52.65 million ($45 million times 1.17). Of this total, $18 million (40 cents of lost income for each tourist dollar lost, or .4 times $45 million) is directly traceable to the disaster, while the other $34.65 million in regional income loss represents indirect income losses cause by reduced demands for intermediate goods and consumer items via backward interindustry linkages and normal household spending.

TOTAL COEFFICIENTS (TYPE II MULTIPLIER)

	CONSTRUCTION	TOURISM	HOUSEHOLD
	2.12	1.20	1.11
	1.29	2.03	1.11
	1.04	**[1.17]**	1.85

$$(I-A)^{1-} = \begin{bmatrix} 2.12 & 1.20 & 1.11 \\ 1.29 & 2.03 & 1.11 \\ 1.04 & \boxed{1.17} & 1.85 \end{bmatrix}$$

x $45 MILLION
= $52.65 MILLION
DIRECT, INDIRECT, INDUCED INCOME LOSSES

DIRECT COEFFICIENTS

	CONSTRUCTION	TOURISM	HOUSEHOLD
	.2	.3	.3
	.4	.1	.3
	.2	**[.4]**	.1

$$A = \begin{bmatrix} .2 & .3 & .3 \\ .4 & .1 & .3 \\ .2 & \boxed{.4} & .1 \end{bmatrix}$$

x $45 MILLION
= $18 MILLION
DIRECT INCOME LOSSES

SECONDARY INCOME LOSS = $52.65 MILLION minus $18 MILLION
= $34.65 MILLION

Figure 16.3 Illustrative Computation

16.3.3 The Impact of Outside Reconstruction Aid on the Region and the Nation

Negative effects would be countered by the stimulative impact of state and federal disaster aid and insurance settlements. Whether these positive forces completely offset the negatives produced by the reduction in tourist trade hinges on the magnitude of the direct effects and the associated multipliers for these two activities. Assume, for example, that $50 million of outside reconstruction funds pour into the community in the first year. The Type II income multiplier for the construction industry is 1.04. The net regional income loss the year of the disaster is, therefore: ($50 million x 1.04) - ($45 million x 1.17), or a net loss of $0.65 million.

Indirect income changes in this case are very significant and can be computed as the difference of total income impacts and direct income impacts. We know from the direct coefficients matrix that household income changes directly by 20 and 40 cents, respectively, for each dollar change in construction and tourist expenditures. The net indirect regional impact from the reduction in tourism, and the aid program are therefore: ($50 x 1.04 - $50 x .2) - ($45 x 1.17 - $45 x .4), or a net gain of $7.35 million.

This is what the region loses; however, national impacts are quite different. The $50 million of federal assistance injected into the region must be paid for either by cutting federal programs elsewhere, raising taxes, or borrowing. Each option impacts demand and outputs negatively. Although it is unlikely that they will precisely offset the gains the region enjoys, it is safe to assume that they will be similar in magnitude. If so, indirect losses from a national perspective is the net regional loss with the positive effects from federal aid omitted. The national net income loss will then remain $52.65 million.

The foregoing analysis was limited to the year of the disaster and presupposed that unemployed households did not dip into savings or receive outside assistance in the form of unemployment compensation, both of which are often the case. In terms of the summation of impacts over an extended time horizon, results do not significantly change if alternative possibilities are introduced. For example, if households choose to borrow or utilize savings while unemployed or to self-finance rebuilding, future spending is sacrificed. Therefore, even though an unemployed household may be able to continue to meet expenses throughout the reconstruction period, long-term levels of expenditure and hence product demand, must decline.

In the preceding analysis, indirect losses were derived from demand changes only. This approach lends itself to events in which supply disruptions are minimal, or where sufficient excess capacity exists. A different method is required when direct damage causes supply shortages. The Indirect Loss Module, to which we now turn, modifies the basic I-O methodology to accommodate both supply and demand disruptions.

16.4 The Indirect Loss Module

The foregoing example illustrated how *demand* shocks filter through the economy to produce indirect losses. As indicated, supply shocks require a different treatment. Most *supply* shock models begin with the same trading pattern which produced the A matrix and subsequent multipliers inherent in the input-output method. However, once damage to buildings and lifelines constrain the capacity of each economic sector to ship its output to other sectors, or receive shipments, the trading patterns have to be readjusted. There are several ways to accomplish this. The simplest (Cochrane and Steenson, 1994) is to estimate how much each sector's output will decline as a result of direct damage and then address how the resultant excess demands and/or supplies will be filled and or disposed of. In the event that the sum of all interindustry demands and final demands exceed the post-disaster constraint on production, then available imports and inventory changes could temporarily help to rebalance the economy. In some sectors excess supplies might exist. If so, inventories may be allowed to accumulate or new markets might be found outside the affected region. Surviving production is reallocated according to the interindustry direct coefficients matrix until all sector excess supplies and demands are eliminated. At this point, a new level of regional output, value added and employment is computed and contrasted with the levels observed prior to the disaster. The difference between these levels approximates indirect loss.[5]

16.4.1 Damage -- Linkage to the Direct Loss Module

The Indirect Economic Loss module is linked to preceding modules through three channels in which damage, the direct shock, is introduced. First, building damage causes a certain degree of loss of function to each sector, forcing them to cut output. A vector of loss of function by industry in the first year of the disaster provides a set of constraints to the Indirect Loss module that is related to the general building stock damage levels. Loss of function is based upon the time needed to clean up and repair a facility or to rent an alternative facility to resume business functions (see Section 15.2.4). Loss of function is calculated for each occupancy class. Table 16.3 links the sectors in the Indirect Loss Module to the occupancy classes in the Direct Loss Module. Loss of function associated with lifeline disruption is not evaluated.

Table 16.3 NIBS Occupancy Classes and Indirect Loss Module Economic Sectors

Direct Loss Module	Indirect Loss Module
IND3	Agriculture (Ag)
NONE	Mining (Mine)
IND6	Construction (Cnst)
IND 1,2,3,4,5 (AVG.)	Manufacturing (Mfg)
COM3	Transportation (TRANS)
COM 1,2 (AVG.)	Trade (Trde)
COM 5,4 (AVG.)	Finance, Insurance and Real Estate (FIRE)
(COM 2,4,6,7,8,9; RES 4,6; REL; ED 1,2) (AVG.)	Service (Serv)
GOV1	Government (Govt)
NONE	Miscellaneous (Misc)

Second, post-disaster spending on reconstruction, repair and replacement of damaged buildings and their contents causes a stimulus effect in the Indirect Loss Module. This stimulus is based on the total dollar damage to buildings and contents. Third,

[5]This approach relies on both the existence of regional input-output tables and several assumptions regarding: inventory management, importability of shortages, exportability of surpluses and the amount of excess capacity existing in each sector. It does not accommodate the effects of relative price changes on final demands, nor does it entertain the degree to which labor and capital are substitutable in the underlying production functions. Treatment of these issues require a more sophisticated approach, one which is discussed in the literature under the topic heading Computable General Equilibrium (CGE) Systems.

reconstruction inputs for transportation and utility lifeline damage also provide a stimulus effect to the module.

Total levels of reconstruction expenditures are equivalent to damage estimates, but two modifications are needed before they can be incorporated into the analysis. One modification is the timing of the reconstruction in terms of weeks, months, or years after the earthquake. The distribution of reconstruction expenditures over time is discussed in Section 16.5.1.1 in relation to user inputs to the module.

The other modification is the itemization of expenditures by type (plant, equipment, etc.) so that this spending injection is compatible with the economic model used to determine indirect effects. The input-output (I-O) model at the core of the module disaggregates the economy into sectors according to one-digit Standard Industrial Classification (SIC) codes. The brunt of the reconstruction expenditures will be assigned to Manufacturing and Construction sectors.

One idiosyncrasy of the I-O model is the role of Wholesale and Retail Trade and of Transportation. These sectors are based on the concept of a "margin," i.e., the cost of doing business (labor, insurance, electricity, gasoline, office supplies) plus profits, but does not include the items sold or shipped (which are merely a pass-through in any case).[6] Those expenditures assigned to Construction require no adjustment, but when spending on manufactured goods is inserted into the model, portions of the total should be assigned to the Wholesale/Retail Trade sector and to the Transportation sector. For very large items bought directly from the factory, there is no Trade sector activity, but for smaller items (e.g., office equipment, trucks), the adjustment is necessary. Generally, the Wholesale margin is 80%. Whether purchased from the factory or from the Trade sector, the Transportation margin is always applicable and is typically equal to 20%.

A similar adjustment is necessary in nearly all cases for consumer spending for replacement of contents. In this case, it is more appropriate to use the Retail Trade margin of 80%. Again, the Transportation margin of 20% would be applicable to purchases of larger items.

In cases where the margin adjustment is required, the user simply applies the following formulas:

$$\frac{\Delta L}{1+tm} = \Delta Y_M \tag{16-9}$$

$$\Delta L - \Delta Y_M = \Delta T \tag{16-10}$$

[6]The reason for this device is that many items are sold through wholesale and retail outlets and transported commercially, and, if included as "inputs" to these sectors, the linkage between buyers and sellers would be lost, i.e., it would appear that most purchases were from Wholesale/Retail Trade or Transportation, as if these sectors produced most items in the economy.

where:

ΔL = Portion of loss estimate (reconstruction/replacement) to which margin adjustment applies.

ΔY_M = Manufacturing expenditures after margin adjustment.

ΔT = Retail/wholesale, trade or transportation expenditures.

tm = Retail/wholesale, trade or transportation margin.

16.4.2 Supply-Side Adjustments and Rebalancing the Economy

The Indirect Loss Module is a computational algorithm that utilizes input-output coefficients to reallocate surviving production. The algorithm computes post-event excess demands and supplies. It rebalances the economy by drawing from imports, inventories, and idle capacity when supplies are constrained. It allows for inventory accumulation, production for export (to other regions) and sales to meet reconstruction needs in the event that normal demands are insufficient to absorb excess supplies The process of reallocation is governed by the amount of imbalance detected in each of the economy's sectors. Rebalancing is accomplished iteratively by adjusting production proportionately until the discrepancy between supplies and demands is within a tolerable limit.[7] A simple schematic of the process is provided in Figure 16.4.

[7] The tolerable limit is the degree to which the solution values vary from one iteration to the next.

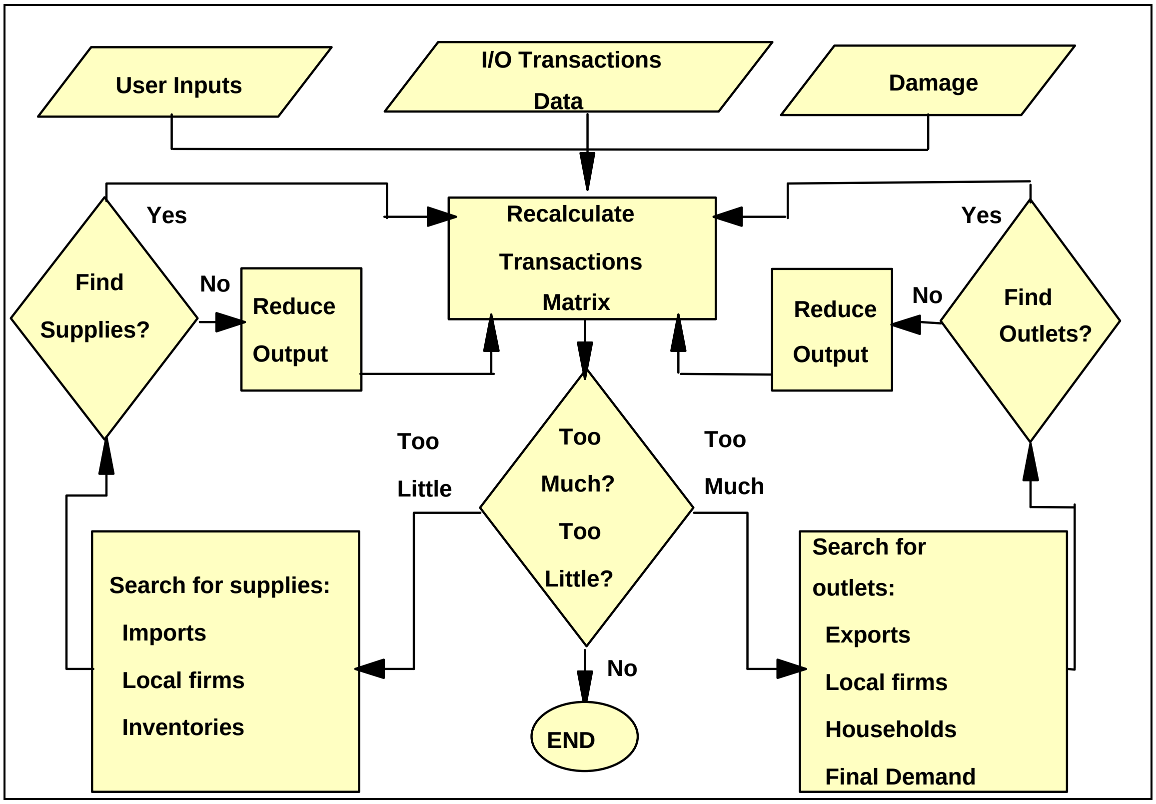

Figure 16.4 Indirect Loss Module Schematic

This section illustrates how the model adjusts to supply-side constraints when a disaster causes disruption in the level and pattern of local production.

Table 16.4 illustrates a simple economy with three industries: construction, manufacturing, and trade. There are also two rows for payments to households from those industries and imports which those industries require, plus two columns that represent household demands and exports. Households make no purchases from other households. All amounts in the table are in dollars. In the economy's initial state, the row and column sums are equal.

Table 16.4 Initial Transactions

From/To	Constr	Mfg	Trade	HH	Export	Sum
Constr	10	30	20	20	35	115
Mfg	20	20	10	30	80	160
Trade	15	20	5	40	5	85
HH	30	40	20			90
Import	40	50	30			120
Sum	115	160	85	90	120	

Table 16.5 shows how the economy changes due to the direct impact from a disaster. In this case, there is a 10% loss of manufacturing output as the result of damage to manufacturing facilities. Corresponding to this loss, both the purchases and sales of the

manufacturing sector fall by 10%, as reflected in the row and column sums. The transactions directly affected are highlighted in bold type in the table. A new column, named "Lost HH," has been added to this table to reflect manufacturing output that is unavailable to households because of the earthquake.

Table 16.5 10% Direct Loss in Manufacturing

From/To	Constr	**Mfg**	Trade	HH	Export	Sum	Lost HH
Constr	10	**27**	20	20	35	112	
Mfg	**18**	**18**	**9**	**27**	**72**	**144**	**3**
Trade	15	**18**	5	40	5	83	
HH	30	**36**	20			86	
Import	40	**45**	30			115	
Sum	113	**144**	84	87	112		

Table 16.6 illustrates the first example of the indirect response to this situation. This is a "fully-constrained" economy, characterized by no more than 2% unemployment, 0% import replacement, 0% inventory availability or replacement, and 0% additional exports. This means that there are no ways for manufacturers to replace inputs that were disrupted by the disaster.

Under these circumstances, construction and trade firms must cut their previous manufacturing by 10%. There is full employment in the local economy, meaning that other firms in manufacturing cannot increase output to meet the desired purchases by construction and trade. Further imports are not allowed, and there are no inventories of manufacturing output to use. Construction and trade firms, faced with an irreplaceable 10% loss in manufactured goods have no choice but to reduce their production by 10%. The net result is that the 10% direct loss in manufacturing translates into a 10% loss throughout the entire economy. Portions of the table affected by indirect loss are highlighted in italics. The row and column sums are once again in balance. Household consumption is decreased for all three sectors, and there is no way to make up for it.

Table 16.6 Response to Loss with Fully Constrained Economy

From/To	Constr	**Mfg**	Trade	HH	Export	Sum	Lost HH
Constr	*9*	**27**	*18*	*18*	*31.5*	*103.5*	*2*
Mfg	**18**	**18**	**9**	**27**	**72**	**144**	**3**
Trade	*13.5*	**18**	*4.5*	*36*	*4.5*	*76.5*	*4*
HH	*27*	**36**	*18*			*81*	
Import	*36*	**45**	*27*			*108*	
Sum	*103.5*	**144**	*76.5*	*81*	*108*		

The fully constrained economy is an extreme case, and most economies are characterized by some flexibility, or slack, so that inputs can be replaced and outputs can be sold. We illustrate this by raising the potential level of additional imports by 10%, and the potential level of additional exports by 40%. This is insufficient to ensure that construction and trade can acquire the supplies they need to meet local demands and sell products that are no longer being bought by manufacturing.[8] Sectors not suffering direct losses return to their pre-event levels of production.[9] Manufacturing might import additional manufactured inputs where needed to replace its own direct losses, but labor is not available due to the low unemployment rate and the assumption that the temporarily unemployed labor in manufacturing will not be available to other firms in the sector. Manufacturing losses will only be replaced as damaged manufacturing facilities return to production.

In Table 16.7, the underlined values show where the important changes have occurred. Both construction and trade were allowed to import the manufactured inputs they lost as a result of the earthquake. Also, construction and trade exported that portion of their output that manufacturing no longer purchased. Because of these two factors, there is no indirect loss in the case illustrated in Table 16.7.

The same results may be obtained in other ways. Instead of increasing imports, there might be some unemployment in the local economy. In this case, other firms in the manufacturing sector could hire some of the unemployed resources to make up the shortfall. Alternatively, there might be inventories of manufactured goods, either at the manufacturers or in storage at the construction and trade firms that require those goods. On the output side, firms faced with a reduction in purchases from the manufacturing sector may decide to continue production and store the resulting product in inventory until the disrupted facilities are back in production or until they can find new export markets.

Table 16.7 Response to Loss with Relaxed Import and Export Constraints

From/To	Constr	**Mfg**	Trade	HH	Export	Sum	Lost HH
Constr	*10*	**27**	*20*	*20*	<u>*38*</u>	*115*	
Mfg	**18**	**18**	**9**	**27**	**72**	144	**3**
Trade	*15*	**18**	*5*	*40*	<u>*7*</u>	*85*	
HH	*30*	**36**	*20*			*86*	
Import	<u>*42*</u>	**45**	<u>*31*</u>			*118*	
Sum	*115*	144	*85*	*87*	*117*		

In Table 16.7, manufacturing remains at its immediate post-disaster level because the situation being illustrated is immediately after the event, before reconstruction can take place. If the slack in the system came from unemployment instead of imports, the results would be different. That portion of the manufacturing sector undamaged by the earthquake could hire additional resources and make up the direct losses. Overall production would regain its pre-disaster levels. Therefore, unlike the example illustrated

[8] Construction only needs to increase its level of imports by 2, 5% of its initial imports of 40, and trade only requires an increase in imports of 1, or 3.3% of 30. Construction requires additional exports of 3, or 8.6% of original exports. The limiting sector is trade, required to find export markets for 2 units, 40% of the 5 units it originally exported.

[9] Even if the slack assumptions are set higher, the algorithm limits sectoral production to be no higher than prior to the earthquake (unless there is a positive counter-stimulus from, say, reconstruction activity).

which shows no net indirect change, there would be a net indirect increase in sales that would be equal to the direct loss, making for a net economic change of zero.

Tables 16.6 and 16.7 show an important way in which this algorithm departs from traditional I-O analysis. The technical coefficients for both Tables are different from those of the original economy. This is because imports and exports have been allowed to replace lost supplies and sales in the system. The usual technical coefficients in an I-O table assume that the relationships between imports and intermediate inputs are fixed, as well as assuming that the relationships between exports and intermediate outputs are fixed. Though these assumptions are convenient for the purposes of I-O analysis, they are a departure from reality in general, and especially so in emergency situations. Also note, from Table 16.7, that the household and import/export sectors are no longer balanced in terms of row and column sums. This is due to the short-run nature of the problems being solved in the model. In the longer run, households must repay their borrowing, and exports must rise to repay the short-run imports, unless government disaster aid or some other form of external financing is used to pay for the short-run consumption and imports.

Tables 16.6 and 16.7 illustrate the two extremes that the model can reflect in responding to pure supply-side disruptions. In its fully functional implementation, the model adjusts simultaneously for multiple shocks of varying amplitude in any number of sectors, while also accounting for demand-side (final demand) increases that typically accompany disasters.

16.4.3 The Time Dimension

The model is evaluated at various levels of temporal resolution for the fifteen (15) year period following the earthquake. For the first two (2) months after the earthquake, weekly time intervals are used. Between two (2) months and twenty four (24) months, the economy is evaluated on a monthly basis. From two (2) years to fifteen (15) years, the economy is evaluated annually. It is made dynamic by considering how industry loss of function is restored and reconstruction expenditures are made over the time windows. Thus while the inputs to the Indirect Economic Loss module differ with each time interval, the rebalancing algorithm for the economy and adjustment factors (e.g., availability of supplemental imports to make up for lost production) do not change. The time patterns of functional restoration and reconstruction are user inputs and are discussed in Section 16.5.

16.4.4 The Effects of Rebuilding and Borrowing

Borrowing impacts the model in that future demands are reduced in proportion to the temporal payments for rebuilding. In the case of Northridge this amounted to less than 50 percent. Federal assistance and insurance settlements provided the bulk of the financial resources for reconstruction. The importance of refinancing lies in longer-term effects of repayment. If the affected region receives no assistance then the stimulative effects of rebuilding are only temporary. The region will eventually have to repay loans and future spending will suffer. This is accounted for in the model as follows.

1. It is assumed that all loans mature 15 years *from the time of the earthquake*. Therefore, the first year's loans are for 15 years. The second year's loans are for 14 years, and so on.
2. Tax implications are ignored. Interest is not tax deductible.
3. Borrowing costs are assumed to be 6 percent. This is a real interest rate (inflation free). The discount rate is assumed to be 3 percent. It too is inflation free.

The loan payments are computed as follows (Table 16.8).

Table 16.8 Annual Borrowing Costs

Year	1	2 through 15
Annual Payment	$\left[\frac{r}{(1-(1+r)^{(-15+1)})}\right] loan1$	$\left[\frac{r}{(1-(1+r)^{(-16+t+1)})}\right] loan_t + Pay_{t-1}$
Explanation	loan 1 times the annual payment factor (r is real interest)	payment from t-1 plus loan t times the annual payment factor

Future demands are reduced by the annual payments times the percentage households spend on each sector’s output. For example, if households are paying back $50 million in year 1 then spending from all categories decline as shown in the following table. The second column in Table 16.9 is the pre-disaster spending pattern. For example, 0.2

percent of household income was spent on agricultural products; 24.6 percent was spent on services. This percentage times $50 million loan repayment cost yields the reduction in household spending by sector in year 1.

Table 16.9 The Effect of Loan Repayment on Household Demands

Sector	Household Spending (% spent on each sector)	Reduced Demand in $ millions (% times loan payment)
Ag	0.2%	0.08
Mine	0.0%	0
Cnst	11.2%	5.59
Mfg	7.5%	3.75
Trns	6.2%	3.08
Trde	21.6%	10.82
FIRE	23.2%	11.59
Serv	24.6%	12.3
Govt	5.3%	2.63
Misc	0.3%	0.15

Exercising the module sequentially using average values over the reconstruction period derives time dependent indirect losses.

16.4.5 The Issue of Aggregation

Study regions may consist of single counties, higher levels of aggregation such as several counties comprising a metropolitan area, or lower levels of aggregation such as a group of contiguous census tracts. In principal, the methodology underlying the Indirect Economic Loss module is applicable regardless of the level of aggregation. However, its accuracy is likely to be greater for study regions that represent cohesive economic regions, often called “trading areas” (e.g., cities or metropolitan areas) than for those at lower levels of aggregation because of the ability of the core Input-Output model to meaningfully represent the region’s economic structure. Furthermore, in evaluating regional employment impacts, the module requires input data on the number of jobs located within the study region -- that is, data on employment by place of work rather than by place of residence. While this information can be obtained at the county level, its availability and reliability at lower levels of aggregation are much more problematic. Similar problems are associated with other input data such as unemployment rates. More generally, the user should also be aware that some of the input assumptions to the model (such as the availability of alternate markets) are related to the study region’s level of aggregation. By adjusting the nature of the economy and the linkage to surrounding regions, the analyst can get a “ball park” estimate of what the real indirect losses and gains might be. Tracing the effects to a specific geographic area (beyond that directly impacted by the earthquake) is problematic. Section 16.5 below provides some discussion of appropriate input data and assumptions to the module.

16.5 Running the Module

This section describes operational issues related to the methodology's Indirect Economic Loss module, including data inputs, the operation of the software module, and the format and interpretation of the output. Default Data Analysis utilizes primarily default data and requires minimal user input. In User-Supplied Data Analysis, while the same types of data are required, the user provides information specific to the economy of the study region and the disaster being modeled. Advanced Data and Models analysis assumes expert participation and may involve expanding the module framework or applying alternative frameworks.

16.5.1 Default Data Analysis Inputs, Operation and Output

16.5.1.1 User Inputs and Default Data

Running the Indirect Economic Loss module requires a number of user inputs. While default values are provided for all of these inputs, as discussed below, it is advisable even in a Default Data Analysis to override certain of them with data for the study region where available. Table 16.10 describes the inputs required and their default values.

HAZUS™ provides default values for the current employment based on Dun & Bradstreet data and income levels for the region based on County Business Pattern data. Note that in contrast to some other sources of regional employment data, this estimate of workers represents the number of persons who work within the study region, rather than the number of employed persons who reside there. Employment by place of work is appropriate in this type of analysis because the model will estimate job loss within the study region due to physical damage there from the disaster. It is recommended that the Default Data Analysis user review the default values provided and replace them if more accurate or recent data is available. Note that in User-Supplied Data Analysis, where a user-provided IMPLAN Input-Output table is used instead of a synthetic table, the current employment and income levels are read in from the IMPLAN files and override the default values.

The type or composition of the economy, together with the employment level, is used by the module to automatically select a synthetic Input-Output transactions table to represent the study region economy. Default Data Analysis utilizes a synthetic transactions table aggregated from three basic classes of economies: 1) primarily manufacturing, 2) primarily service, secondarily manufacturing, and 3) primarily service, secondarily trade. These 3 archetypical economies represent approximately 90 percent of the 113 transactions tables used to construct the three synthetic tables. Each type is broken into four size classifications: super (greater than 2 million in employment), large (greater than 0.6 million but less than 2 million), mid range (greater than 30 thousand but less than .6 million) and low (less than 30 thousand). Appendix 16A provides examples of regions in each type and size class. While type 1 (manufacturing) is the default, the user should revise this as appropriate. Appendix Tables A2, A3, and A4 can be used as a guide.

Supplemental imports, inventories (demands), inventories (supplies), and new export markets represent available channels for excess supply or demand that can help reduce the bottleneck effects in the post-disaster economy. As mentioned above, appropriate values depend in part on the level of aggregation of the study region. Default values are set at 0 for inventories supply and demand for all industries. Default values for imports and exports are set at values considered appropriate for a "distinct" or self-contained study region such as a metropolitan area. The default values are presented, together with discussion of how they can be modified in a User-Supplied Data Analysis, in Section 16.5.2.2.

The supplemental imports variable, due to limitations on available data, needs further explanation. Data on the amount of imports per sector are available only in the aggregate. For any one sector in the economy, the total amount of intermediate products imported is known, but the amount of these imports that comes from any individual sector is not known. The amount of new imports that may be allowed must be set to a very small level. Otherwise, the amount of products that may be imported will almost always replace any intermediate goods lost from local suppliers, and no indirect output losses will be observed. The level of supplemental imports also needs to be kept low because of factor homogeneity problems. There will be cases when there are no substitutes for locally obtained intermediate goods. In such cases, allowing imports would unreasonably eliminate indirect losses. Being conservative in the amount of imports allowed helps avoid both of these problems. The default values for imports have been tested in the model, and are felt to yield realistic results.

Table 16.10 User **Supplied Inputs for Indirect Economic Module**

Variable	Definition	Units[(a)]	Default Value
Current Level of Employment	The number of people gainfully employed, by place of work (not residence).	Employed persons	Region-specific
Current Level of Income	Total personal income for the study region.	Million dollars	Region-specific
Composition of the Economy (Default Data Analysis only)	1. Primarily manufacturing 2. Primarily service, secondarily manufacturing. 3. Primarily service, secondarily trade.	1, 2, or 3	1
Supplemental Imports	In the event of a shortage, the amount of an immediate product unavailable from local suppliers which may be obtained from new imports.	Percent of current total current annual imports (by industry)	Defaults for "distinct region"
Inventories (Supplies)	In the event of a shortage, the amount of a good that was supplied from within a region that can be drawn from inventories within the region.	Percent of annual sales (by industry)	0 (for all industries)
Inventories (Demand)	In the event of a surplus, the amount of a good placed in inventory for future sale.	Percent of current annual sales (by industry)	0 (for all industries)
New Export Markets	In the event of a surplus, the amount of a good which was once sold within the region that is now exported elsewhere.	Percent of current annual exports (by industry)	Defaults for "distinct region"
Percent Rebuilding	The percent of damaged structures that are repaired or replaced	Percent	95%

Unemployment Rate	The pre-event unemployment rate as reported by the U.S. Bureau of Labor Statistics	Percent	6%
Outside Aid/Insurance	The percentage of reconstruction expenditures that will be financed by Federal/State aid (grants) and insurance payouts.	Percent	50%
Interest Rate	Current market interest rate for commercial loans.	Percent	5%
Restoration of function	The percent of total annual production capacity that is lost due to direct physical damage, taking into account reconstruction progress.	Percent (by industry, by time interval for 5 years)	Defaults for moderate-major event
Rebuilding (buildings)	The percent of total building repair and reconstruction that takes place in a specific year.	Percent (by time interval for 5 years)	70% (yr.1), 30% (yr.2)
Rebuilding (lifelines)	The percent of total transportation and utility lifeline repair and reconstruction that takes place in a specific year.	Percent (by time interval for 5 years)	90% (yr.1), 10% (yr.2)
Stimulus	The amount of reconstruction stimulus anticipated in addition to buildings and lifelines repair and reconstruction.	Percent (by industry, by Time interval for 5 years)	0% (for all)

Notes: (a) Percent data should be entered as percentage points, e.g. 60 for 60%.
(b) **HAZUS** provides a default value for the counties in the study region.
(c) See Section 16.5.2.2.

The variables for percent rebuilding, unemployment rate, percent outside aid, and interest rate all influence how the economy is expected to react to the disaster, in particular the reconstruction stimulus, the available slack or unused capacity in the economy, and the associated indebtedness that would be incurred from reconstruction financing. The user is recommended to revise the unemployment and interest rates as appropriate. However, all of these variables can be adjusted for purposes of "what-if" scenario modeling. For example, how would regional indirect economic losses change if only 20 percent of reconstruction was financed by sources outside the region such as insurance or federal disaster aid?

Parameters for functional restoration, as well as rebuilding for both buildings and lifelines, are associated with the anticipated speed of reconstruction and recovery. To specify functional restoration, user inputs are required for the percent of each industry's production capacity that is lost as a result of physical damage in each year for the first 5 years after the disaster. Default parameters are provided that are designed to be consistent with a "moderate-to-major" scale of disaster. These parameter values and suggestions for modifying them in a User-Supplied Data Analysis are provided in Section 16.5.2.2 below.

In terms of rebuilding, the module requires user inputs as to the percent of total rebuilding expenditures for buildings and lifelines respectively that are expected to be made in each of the first 5 years following the disaster. Table 16.11 provides an example. Note that the total dollar amount required to fully rebuild damaged and destroyed public and private capital is provided by the Direct Economic Loss module. The percent of this total that is actually rebuilt is specified by the user input on "percent rebuilding" and may be less than 100 percent if not all of the damage is repaired or replaced. The annual percents for rebuilding buildings and lifelines as shown in Table 16.11 provide the timeline over which the reconstruction expenditures are made and should therefore sum to 100 percent over the 5-year period.

Table 16.11 Rebuilding Expenditures Example

Year	1	2	3	4	5	Total
% of Total Rebuilding Expenditures (Buildings)	70	30	0	0	0	100
% of Total Rebuilding Expenditures (Lifelines)	90	10	0	0	0	100

Reconstruction speed is also to a large extent related to the scale of the disaster. In general, lifeline reconstruction is expected to proceed much more quickly than building reconstruction, as has been the experience in previous disasters. For a Default Data Analysis, default parameters are provided that are designed to be consistent with a "moderate-to-major" scale of disaster. Modifying these parameters would be appropriate in a User-Supplied Data Analysis, and guidelines are provided in Section 16.5.2.2 below. These parameters can also be adjusted in Default Data Analysis for purposes of "what-if" scenario modeling for faster or slower paces of reconstruction.

The additional reconstruction stimulus parameters can also be adjusted for "what-if" evaluations.

16.5.1.2 Calculation of Indirect Loss

A direct shock is introduced into the Indirect Loss Module by adjusting the outputs and purchases in proportion to a sector's loss of function. Restrictions on shipments (forward linkages) and purchases (backward linkages) are computed and the resultant excess demands or supplies are derived. See Figure 16.5. The sample transactions table provided in Table 16.20 (Section 16.6.2) is used to illustrate. The first two rows above the table indicate the total direct shock and associated indirect losses, which are initially zero. The first round effects are simply the direct loss of function times the inputs to that sector (backward links) and shipments from that sector (forward links). In the event of a 30 percent loss of function in the transportation sector, for example, demand for manufactured goods would fall by 15.6 (0.3 times 51.9). The remainder of the column effects is computed similarly.

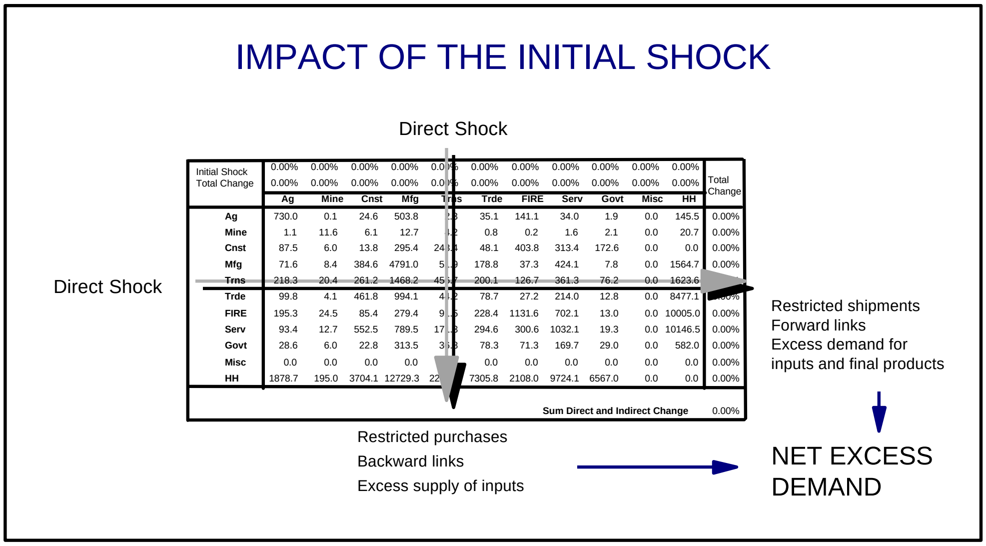

Figure 16.5 Initial Effects of the Shock

The same 30 percent shock would limit shipments to other sectors; finance, insurance, and real estate, for example, will initially receive 38.0 less (0.3 times 126.7) in services from transportation.

These first round effects produce excess demands and supplies that trigger a search for markets and alternative supply sources.

In building the model, several critical choices had to be made regarding post-event household spending patterns, labor mobility, elasticity of supplies from the construction industry, and the potential for product substitutions due to relative price changes. Evidence from previous disasters (summarized in the User's Manual) suggests that: 1) normal spending patterns are not significantly altered; 2) the workforce is highly mobile, particularly in the construction sector; and 3) relative prices do not change appreciably. Therefore, labor and construction sales are not constrained, and normal household spending is fixed and independent of current income. Given these conditions, the model assesses the net excess supplies (output less the sum of intermediate and final demands). A positive net value implies an excess supply; a negative indicates excess demand. It then attempts to resolve sectoral imbalances through a series of adjustments. If excess demand is detected, the algorithm checks to see if sufficient capacity exists in a sector. Excess capacities are a function of user defined level of unemployment and is calculated within the model using the following equation.

$$AC = 2.36 \times (UR - .02) \qquad (16\text{-}11)$$

Where:

AC is available production capacity and expressed as a percentage (measured as a decimal) of the pre-event capacity

UR is the unemployment rate (e.g., .05).

If idle capacity is insufficient to meet excess demand then the model explores the potential of importing and/or drawing down inventories. These options are also provided by the user and are expressed as a percent of pre-event capacities.

Disposal of excess supplies is logically similar. Two options, inventory accumulation and exports, are explored. As in the case of the previous options, both are expressed as a percentage and are determined by the user. In most cases excess supplies are not critical to the model's, operation, particularly when reconstruction spending looms large. Much of the excesses are drawn into the rebuilding process.

After completing the first iteration of output adjustments, the algorithm recalculates the intermediate supplies and demands and then reinvestigates the adjustment options previously explored. Outputs are revised in proportion to the amount each sector is out of balance. A moving average of previously attempted outputs is used to initialize each iteration's search. The search is terminated once the sum of the absolute sectoral output differences diminishes to a specified level; the default is set at .00001.

Indirect income loss is calculated as using the following formula.

$$\sum_{t=1}^{T} \sum_{i=1}^{j} \frac{(td_{i,t} - dd_{i,t})Y_i}{(1+r)^t} \qquad (16\text{-}12)$$

where: $td_{i,t}$ is the total percent reduction in sector i income during period t.
Y_t is income of sector i.
$dd_{i,t}$ is the direct percent reduction in sector i income during period t.
r is the real interest rate to discount the indirect losses
j is the number of sectors

dd is computed in the model by multiplying the initial sectoral income by the respective loss of function. The variable td is the total percentage reduction in income caused by the combination of direct loss and forward and backward linked losses. The difference between the two is then the percentage reduction in income attributable to indirect effects. The difference is pure indirect loss. This percentage when multiplied by sectoral incomes yields indirect income lost. A similar formula to Equation 16-12, without discounting, is used to evaluate indirect employment loss.

16.5.1.3 The Format of the Output

The module produces two summary reports on the results. The first, whose layout is indicated in Table 16.12, shows the percent and level of indirect economic impact for the study region economy in terms of employment and income effects. Note that impacts may be either losses (negative numbers) or gains (positive numbers). Results are given by time interval for the first 5 years. Average figures are also provided for years 6 to 15 and for the entire 15-year post-disaster period of analysis. All incomes are discounted at the rate of 3 percent. In the case of income, Year 6 to Year 15 losses or gains are discounted to the present. Employment loss or gains are shown as numbers of workers.

Table 16.12 Summary Tables for Indirect Economic Impact

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6 to 15	Average
% Net Indirect Employment Impact							
% Net Indirect Income Impact							
Net Indirect Employment Impact							
Net Indirect Income Impact in Millions $							

The second summary table breaks down the net indirect employment and income impacts by the 10 major industries. Differences in impacts and recovery trends typically are very significant between industries, in part because much of the gains from the reconstruction stimulus accrues to the construction industry (and to some extent the manufacturing and trade industries).

It is important to note that to get a complete picture of the economic impact of the disaster, both the direct and indirect economic losses or gains should be considered.

16.5.2 User-Supplied Data Analysis

This level of Analysis differs from the Default Data level of analysis in two main respects: (1) interindustry trade flows, as represented in the Input-Output model of the economy, and (2) specification of restoration and rebuilding parameters. Rather than selecting from built-in synthetic Input-Output transactions tables, the user should obtain specific tables for the study region from a standard source, the Minnesota IMPLAN Group. In terms of specifying restoration and rebuilding parameters, the user can replace the built-in data with suggested parameter “packages” appropriate to the disaster being modeled. In addition, other parameters such as the availability of supplementary imports can also be modified.

16.5.2.1 IMPLAN Input-Output Data

HAZUS requires three files from the IMPLAN input-output data set (the asterisk in each of the following file names refers to the IMPLAN model name. Therefore, a model for Jackson County would produce a file named JACKSON.402):

- *.402 This is the transactions matrix.
- *.403 This is a file of final demands information.
- *.404 This is a file of final payments information.

Details regarding the operation of the IMPLAN program and the construction of these files can be obtained from the technical documentation for the system. IMPLAN is currently sold and supported by the Minnesota IMPLAN Group; the Group can be reached at:

Minnesota IMPLAN Group, Inc. (MIG)
1940 S. Greeley, Suite 201
Stillwater, MN 55082
Voice 612-439-4421 FAX 612-439-4813
e-mail linda003@maroon.tc.umn.edu

Software and data for any county in the United States can be obtained from the IMPLAN group. When requesting data, regions can also be defined by specifying a zip code aggregation.

The user can either request the three data files for the study region from MIG or obtain the software and database to construct the files. In the former case, the user should specify that the required industry aggregation scheme is essentially a one-digit Standard Industrial Classification (SIC) grouping that maps detailed IMPLAN industries into the ten industry groups used in the methodology. Table 16.13 describes the correspondence between IMPLAN and **HAZUS™** industry classes.

Table 16.13 Industry Classification Bridge Table

IMPLAN	**HAZUS**
1-27	AG (Agriculture)
28-47	MINE (Mining)
48-57	CNST (Construction)
58-432	MFG (Manufacturing)
433-446	TRNS (Transportation)
447-455	TRDE (Trade)
456-462	FIRE (Finance, Insurance and Real Estate)
463-509	SERV (Service)
510-523	GOVT (Government)
524	MISC (Miscellaneous)

If the user obtains the IMPLAN software, the three data files can be constructed by following the instructions and constructing an aggregated Input-Output account using an existing or built-in template for 1-digit SIC classification.

16.5.2.2 Specifying Indirect Loss Factors

In addition to applying IMPLAN Input-Output data for the study region, a User-Supplied Data Analysis can involve adjusting module parameters to more closely fit the study region and disaster being modeled. Parameter sets and selection algorithms are suggested below for both the four indirect loss "factors" -- supplemental imports, new export markets, inventories supply, and inventories demand -- and industry restoration and rebuilding.

As previously noted in the Default Data Analysis discussion, availability of supplemental imports and new export markets is related in part to the size or level of aggregation of the study region and its geographic situation. A single county making up part of a large metropolitan area would have a much higher new import/export capacity (i.e., to neighboring counties) than would a single-county city that was geographically a distinct urban area and at some distance from other urban areas. Table 16.14 suggests two possible sets of factor values for geographically "distinct" and "component" study regions based on expert opinion.

Table 16.14 Suggested Indirect Economic Loss Factors
(percentage points)

	Distinct Region				Component Region			
Industry	Imports	Inv. Supply	Inv. Demand	Exports	Imports	Inv. Supply	Inv. Demand	Exports
AGR	5	0	0	20	6	0	0	35
MINE	5	0	0	30	6	0	0	45
CON	999	0	0	10	999	0	0	25
MFG	4	1	1	30	6	1	1	45
TRNS	2	0	0	0	4	0	0	0
TRDE	3	1	1	0	5	1	1	0
FIRE	3	0	0	0	5	0	0	0
SVC	3	0	0	0	5	0	0	0
GOVT	3	0	0	0	5	0	0	0
OTHER	4	0	0	0	6	0	0	0

Selection of appropriate restoration and rebuilding parameters presents a more complex problem because of the need to link these values to physical damage levels in the disaster. Industry functional restoration and rebuilding will generally proceed more slowly with increasing severity of the disaster and extent of physical damage. For this reason, it is recommended that to run a User-Supplied Data Analysis for Indirect Economic Loss that the user first run all of the preceding modules in **HAZUS**, examine the damage results, modify the restoration and rebuilding parameters as appropriate, and then finally run the Indirect Loss module. Several example restoration and rebuilding parameter sets designed based on expert opinion to represent different scales of disaster are presented below, together with a suggested algorithm for the user to select the most appropriate one.

The following suggested procedure attempts to provide a rough but simple and credible link between restoration and rebuilding parameters in the Indirect Loss module and **HAZUS** results on physical damage. Lifeline rebuilding and transportation industry functional restoration are linked to highway bridge damage. Manufacturing industry restoration is linked to industrial building damage. Buildings rebuilding and restoration for all other industries is linked to commercial building damage. The values of the industry functional restoration parameters are intended to reflect not only facility damage levels but also each industry's resiliency to damage to its facilities, such as for example its ability to relocate or utilize alternative facilities. These parameters were derived judgmentally with consideration of observations from previous disasters. Note that values for "restoration" in **HAZUS** represent the percent *loss of industry function* averaged over the year.

STEP 1. Calculate damage indices for highway bridges and commercial and industrial buildings, respectively. The damage index consists of the percent of structures in the "extensive" or "complete" damage states. For example, if results indicate that 5 percent of bridges will suffer "extensive" damage and 3 percent "complete" damage, the damage index is 8 percent. Damage results for bridges can be found in the **HAZUS** summary report on Transportation Highway Bridge Damage. Damage results for commercial and industrial buildings can be found in the **HAZUS** summary report on Building Damage by General Occupancy.

STEP 2. Select transportation industry restoration parameters and rebuilding parameters for lifelines. Use the highway bridge damage index from Step 1 to read off parameters from Table 16.15.

STEP 3. Select manufacturing industry restoration parameters. Use the industrial building damage index from Step 1 to read off parameters from Table 16.16.

STEP 4. Select restoration parameters for all other industries and rebuilding parameters for buildings. Use the commercial building damage index from Step 1 to read off parameters from Table 16.17.

Table 16.15 Transportation Restoration and Lifeline Rebuilding Parameters
(percentage points)

Highway bridge damage index	Impact description	Parameter Set	Year 1	Year 2	Year 3	Year 4	Year 5
0%	None/ minimal	Restoration function - TRNS Ind.	0	0	0	0	0
		Rebuilding expenditures - Lifelines	100	0	0	0	0
0-1%	Minor	Restoration function - TRNS Ind.	2	0	0	0	0
		Rebuilding expenditures - Lifelines	100	0	0	0	0
1-5%	Moderate	Restoration function - TRNS Ind.	5	0	0	0	0
		Rebuilding expenditures - Lifelines	95	5	0	0	0
5-10%	Mod.-major	Restoration function - TRNS Ind.	10	2	0	0	0
		Rebuilding expenditures - Lifelines	90	10	0	0	0
10-20%	Major	Restoration function - TRNS Ind.	15	3	0	0	0
		Rebuilding expenditures - Lifelines	85	15	0	0	0
>20%	Catastrophic	Restoration function - TRNS Ind.	20	5	0	0	0
		Rebuilding expenditures - Lifelines	80	20	0	0	0

Table 16.16 Manufacturing Restoration Parameters
(percentage points)

Industrial building damage index	Impact description	Parameter Set	Year 1	Year 2	Year 3	Year 4	Year 5
0%	None/minor	Restoration function - MFG Ind.	1	0	0	0	0
0-1%	Moderate	Restoration function - MFG Ind.	2	0	0	0	0
1-5%	Mod.-major	Restoration function - MFG Ind.	4	0	0	0	0
5-10%	Major	Restoration function - MFG Ind.	8	2	0	0	0
>10%	Catastrophic	Restoration function - MFG Ind.	20	10	5	0	0

Table 16.17 All Other Industries Restoration and Buildings Rebuilding Parameters
(percentage points)

Commercial bldg. damage index	Impact description	Parameter Set	Year 1	Year 2	Year 3	Year 4	Year 5
0%	None/minor	Restoration function - AG Ind.	0	0	0	0	0
		Restoration function - MINE Ind.	0	0	0	0	0
		Restoration function - CNST Ind.	0	0	0	0	0
		Restoration function - TRDE Ind.	1	0	0	0	0
		Restoration function - FIRE Ind.	0	0	0	0	0
		Restoration function - SERV Ind.	1	0	0	0	0
		Restoration function - GOVT Ind.	1	0	0	0	0
		Restoration function - MISC Ind.	1	0	0	0	0
		Rebuilding expenditures - buildings	100	0	0	0	0
0-1%	Moderate	Restoration function - AG Ind.	0	0	0	0	0
		Restoration function - MINE Ind.	0	0	0	0	0
		Restoration function - CNST Ind.	1	0	0	0	0
		Restoration function - TRDE Ind.	2	0	0	0	0
		Restoration function - FIRE Ind.	1	0	0	0	0
		Restoration function - SERV Ind.	2	0	0	0	0
		Restoration function - GOVT Ind.	2	0	0	0	0
		Restoration function - MISC Ind.	2	0	0	0	0
		Rebuilding expenditures - buildings	80	20	0	0	0
1-5%	Mod.-major	Restoration function - AG Ind.	0	0	0	0	0
		Restoration function - MINE Ind.	0	0	0	0	0
		Restoration function - CNST Ind.	2	0	0	0	0
		Restoration function - TRDE Ind.	4	0	0	0	0
		Restoration function - FIRE Ind.	2	0	0	0	0
		Restoration function - SERV Ind.	4	0	0	0	0
		Restoration function - GOVT Ind.	4	0	0	0	0
		Restoration function - MISC Ind.	4	0	0	0	0
		Rebuilding expenditures - buildings	70	30	0	0	0
5-10%	Major	Restoration function - AG Ind.	1	0	0	0	0
		Restoration function - MINE Ind.	1	0	0	0	0
		Restoration function - CNST Ind.	4	0	0	0	0
		Restoration function - TRDE Ind.	8	2	0	0	0
		Restoration function - FIRE Ind.	4	0	0	0	0
		Restoration function - SERV Ind.	8	2	0	0	0
		Restoration function - GOVT Ind.	8	2	0	0	0
		Restoration function - MISC Ind.	8	2	0	0	0
		Rebuilding expenditures - buildings	60	30	10	0	0
>10%	Catastrophic	Restoration function - AG Ind.	2	0	0	0	0
		Restoration function - MINE Ind.	2	0	0	0	0
		Restoration function - CNST Ind.	10	5	0	0	0
		Restoration function - TRDE Ind.	20	10	5	0	0
		Restoration function - FIRE Ind.	10	5	0	0	0
		Restoration function - SERV Ind.	20	10	5	0	0
		Restoration function - GOVT Ind.	20	10	5	0	0
		Restoration function - MISC Ind.	20	10	5	0	0
		Rebuilding expenditures - buildings	50	30	15	5	0

16.5.3 Advanced Data and Models Analysis

For this level of analysis, it is presumed that an economist with experience in the economics of natural hazards will be conducting the study.

16.5.3.1 Extending the Indirect Loss Module

The Indirect Loss Module above holds great potential for further development. Some of the alterations that could be incorporated are:

1. Expand the number of industries to better reflect building classes and individual lifelines.

2. Investigate the implications of how shortages and surpluses are addressed. The current Module follows a particular sequence for alleviating bottlenecks; it is possible that this sequence may influence the final results. As currently programmed, the algorithm attempts to resolve shortfalls by looking first to regional excess capacities. In some instances it may be more realistic to expect local producers to look to imports as a source of replacement. There is no obvious *a priori* way of knowing which alternative will be chosen. The particular sequence currently imbedded in the program will tend to maximize production at the local level and therefore minimize the indirect losses associated with an earthquake.

   A more appealing method would be to randomize the priority in which different avenues of ameliorating bottlenecks are chosen. Under this regime, the entire modeling process would be imbedded in a larger iterative loop that could explore a full range of options. By so doing, the robustness of the solution set can be assessed.

   Alternatively, survey research might be conducted which would ascertain how producers might actually respond to an earthquake. The model could then be modified to reflect this information.

3. Make parameter values sector specific. Currently, the methodology is designed so that the supply and demand options (imports, exports, capacity, and inventory adjustments) are identical across sectors. The next logical step would be to make these adjustments sector dependent. This would allow the analyst to better tailor the model to the circumstances of a particular location. For instance, if industry A required the output of industry B, and no substitutes or imports were permitted, a matrix of import probabilities would assign 0% at the intersection of these two industries.

   Additionally, such matrices would allow for consideration of instances where different industries have dissimilar responses to changes in the same input. If industry A requires a large amount of input C, while industry B requires a smaller amount, industry B would be more likely to pay a premium to import input C.

Although this notion seems daunting, it might be possible to incorporate the parameter matrix idea without making the modeling process totally infeasible. For example, one might begin by assigning a scalar, say 10%, to the entire matrix of import probabilities. Then, entire industries could be modified by inputting vectors of new values to those industries. Finally, key intersections for the local economy could be located and specific parameters applied to those intersections. Therefore, at its simplest level, the parameter matrix concept is no more complex than what is currently programmed into the Indirect Loss Module.

4. Approximate price effects. A common complaint leveled against I/O models is that they do not incorporate prices. While this is true, a couple of points need to be made in reference to this particular Loss Module. Significant relative price changes have not been observed after disaster. This may be due in part to special circumstances emerging during the post-disaster period, where price “gouging" is frowned upon, or made illegal (as in Los Angeles after the Northridge earthquake).

However, if concerns about price effects remain, it should be possible to modify the Module accordingly. As the system is currently configured, there are fixed constraints on output, imports, etc. In a supply and demand framework, these could be thought of as a series of discontinuous supply curves which are horizontal until the quantity constraint is reached, at which point they turn perfectly vertical. Enhancement of this system with a function that reduces output as new input sources are tapped would mimic a price-sensitive supply function. However, it must be pointed out that parameterization of such functions is an extremely difficult task. This is one of the problems that Computable General Equilibrium models also face.

5. Extend the model to asses indirect loss/gain incurred by surrounding regions and the national economy. As it now stands, the model is best suited to analysis of the immediately impacted region. However, as pointed out early in the Chapter, regional consequences may be quite different than that measured at the national level. Figure 16.19 indicates how the module could be extended to account for these broader economic linkages. Direct damages and subsequent indirect loss is transmitted to other regions via changes in the import-export relationships. The national economy is impacted in that external aid has to be financed, either at the expense of canceled federal projects, or increased tax liability. In either case demands elsewhere will suffer.

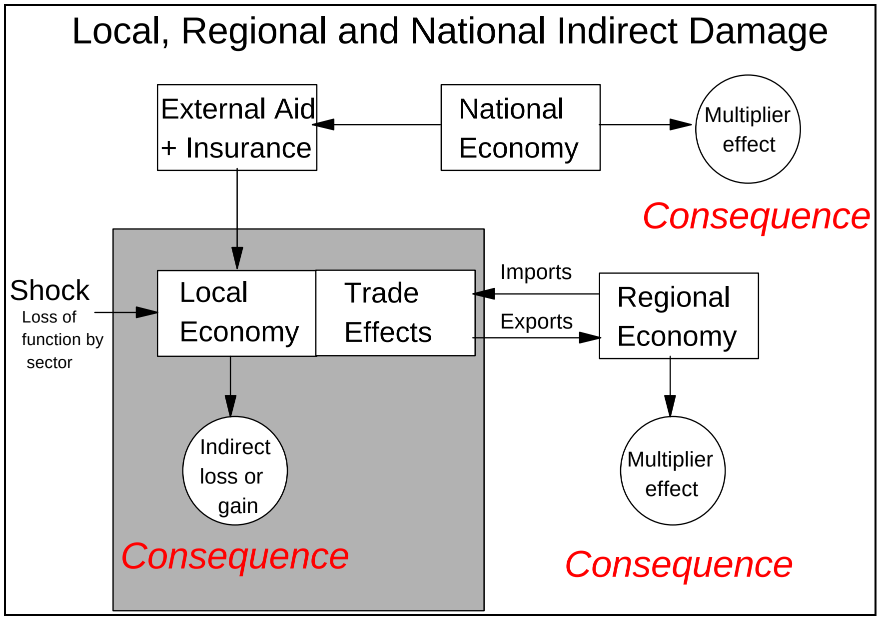

Figure 16.6 Extending the Model to Include Larger Regional and National Losses

16.5.3.2 Alternative Modeling Techniques

It is possible for an economist to use other modeling strategies in conjunction with this loss estimation methodology. For instance, if the region being studied already utilizes a working Computable General Equilibrium model, it could be used to estimate indirect economic loss. Linear Programming methods are also potentially useful. Finally, though not recommended, it is possible to simply feed the direct loss information through a standard set of I-O multipliers (see the discussions in Sections 16.2 and 16.3 above).[10]

[10] See, for example, Shoven and Whaley (1992) for general discussion of CGE systems, and Brookshire and McKee (1992) and Boisvert (1995) for applications to earthquakes.

Linear programming offers a simpler alternative to the CGE approach (Cochrane, 1975; Rose et al., 1997). Again, interindustry trade flows form the basis of the model. As in the previous two methods, the A matrix guides the reallocation of production; the output of each sector is comprised of a fixed proportion of other sector outputs. However, unlike the previous methods, an optimizing routine is utilized to search for that production combination that minimizes the extent to which regional income is impacted by the event.

The results derived from I-O, LP and CGE models are likely to vary. Linear programming is likely to provide the most optimistic projection of loss and the Indirect Loss Module the most pessimistic. The reason for this conclusion rests on the high degree of flexibility assumed (in both the CGE and linear programming) in shifting resource use. It is unlikely that production could be redirected without concern for contractual arrangements, or without considering household preferences. The optimization alternative typically ignores both, though this problem can be mitigated somewhat by the inclusion of explicit constraints (see, for example, Rose and Benavides, 1997).

16.6 Example Solutions

The following examples are provided to both illustrate how a typical indirect loss analysis is performed, and to show the wide range of results possible. Indirect loss patterns (produced from thousands of monte carlo simulations) are then analyzed to derive several general principles relating direct and indirect losses. The resultant patterns and assessments are provided to assist the user in interpreting their own results. First, a simple one-sector supply shock is analyzed to clarify how the model works. The Colorado State Hazards Assessment Laboratory version of the Indirect Loss Module was utilized to perform these analyses. This was done in order to isolate and analyze particular damage patterns. This will create slight discrepancies between **HAZUS** model output and what is reported by the CSU model.

16.6.1 Simple One-Sector Supply Shock - No Excess Capacity

Table 16.20 shows the final solution for the example discussed above in Section 16.5.1.2, i.e., a 30 percent decline in the functionality of the transportation sector. In this experiment no adjustments were permitted (all percentages are zero except for the supply shock). Table 16.19 shows the initial conditions (output, income and employment) and the adjusted capacities. The mobility of the construction industry shows up as excess capacity. Because reconstruction spending in the example is assumed zero, the capacity goes unutilized. Table 16.20 (right hand side) shows the resultant impact on output, income and employment. The overall percent reduction in these three categories is computed from regional outputs, incomes and employments with and without the event.

In this example of a highly constrained economy, the 30 percent shock to transportation, produces 1.07, 1.46, and a 1.06 percent change in *direct* output, income and employment, respectively. Because of the constraints assumed, total losses (direct and indirect) are approximately 30 times the direct loss (nearly 30 percent).

16.6.2 The Northridge Earthquake

The following scenarios illustrate the sensitivity of indirect loss to the amounts of outside assistance provided and the degree to which the lifelines (particularly transportation) are disrupted. Four scenarios are presented along with the inputs required to run the Indirect Loss Module. Scenario A looks at the twin effects of $26 billion of reconstruction spending, financed internally (i.e., no external aid), and temporary disruption to the transportation system. Scenario B removes reconstruction spending. Scenario C removes the transportation constraint, but eliminates rebuilding. Scenario D removes the transportation constraint, while the $26 billion of rebuilding expenditures is assumed to be financed by a combination of insurance moneys and federal aid.

Table 16.21 shows the IMPLAN transactions matrix for Los Angeles county. Tables 16.23 and 16.24 summarize the inputs used. The results provided in Tables 16.22, 16.25, 16.27 and 16.31 point out several important issues. First, Scenario D comes closest to capturing what did occur. A relatively small proportion of the rebuilding costs were financed internally. As a result, the negative effects of the disruption to transportation were masked by the stimulative effect of rebuilding. The 7.83% net increase in incomes earned in the county are surprisingly close to the observed rise in Los Angeles County taxable sales (7.35%).

Table 16.18 Initial Transactions Matrix

Initial Shock	**0.00**	**0.00**	**0.00**	**0.00**	**30.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**Total**
Total Change	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**Change**
	Ag	**Mine**	**Cnst**	**Mfg**	**Trns**	**Trde**	**FIRE**	**Serv**	**Govt**	**Misc**	**HH**	
Ag	730	0.1	24.6	503.8	2.3	35.1	141.1	34	1.9	0	145.5	0.00%
Mine	1.1	11.6	6.1	12.7	4.2	0.8	0.2	1.6	2.1	0	20.7	0.00%
Cnst	87.5	6	13.8	295.4	248.4	48.1	403.8	313.4	172.6	0	0	0.00%
Mfg	71.6	8.4	384.6	4,791	51.9	178.8	37.3	424.1	7.8	0	1,565	0.00%
Trns	218.3	20.4	261.2	1,468.2	456.7	200.1	126.7	361.3	76.2	0	1,624	0.00%
Trde	99.8	4.1	461.8	994.1	44.2	78.7	27.2	214	12.8	0	8,477	0.00%
FIRE	195.3	24.5	85.4	279.4	91.5	228.4	1,132	702.1	13	0	10,005	0.00%
Serv	93.4	12.7	552.5	789.5	171.3	294.6	300.6	1,032.1	19.3	0	10,147	0.00%
Govt	28.6	6	22.8	313.5	36.8	78.3	71.3	169.7	29	0	582	0.00%
Misc	0	0	0	0	0	0	0	0	0	0	0	0.00%
HH	1,879	195	3,704	12,729	2,266.3	7,305	2,108	9,724	6,567	0	0	0.00%
											Sum	0.00%

Table 16.19 Original Conditions and Adjustments

	Original Conditions			Additional Demands			Additional Supplies		
Sector	Output	HH Payments	Employ.	Inventory Buildup Capability	Export Capability	Desired New Final Demand	Potential Output Increase	Potential Imports	Potential Inventory Drawdown
Ag	5,964	1,879	106,253	0	0	0	0	0	0
Mine	1,092	195	4,739	0	0	0	0	0	0
Cnst	10,984	3,704	144,407	0	0	0	10,040	0	0
Mfg	52,811	12,729	378,400	0	0	0	0	0	0
Trns	7,169	2,266	72,169	0	0	0	0	0	0
Trde	13,484	7,306	451,276	0	0	0	0	0	0
FIRE	15,791	2,108	124,514	0	0	0	0	0	0
Serv	19,065	9,724	492,969	0	0	0	0	0	0
Govt	7,550	6,567	266,107	0	0	0	0	0	0
Misc	0	0	0	0	0	0	0	0	0
HH									
Totals	66,312	46,478	2,040,834						

Table 16.20 Final Conditions

		Post- Event Spending				Final Losses			
Sector	Net Change Next Round	Hhld Spending	Exports	Post-Event Final Output	Final Output Direct Loss Only	Post-Event Hhld Payments	Hhld Payments Direct Loss Only	Post-Event Employ.	Employ. Direct Loss Only
Ag	29.98%	102	1,284	4,176	5,964	1,316	1,879	74,398	106,253
Mine	29.98%	15	285	765	1,092	137	195	3,318	4,739
Cnst	29.98%	0	252	7,691	10,984	2,594	3,704	101,113	144,407
Mfg	29.98%	1,096	12,565	36,978	52,811	8,914	12,729	264,955	378,400
Trns	30.00%	1,137	617	5,018	5,018	1,586	1,586	50,518	50,518
Trde	29.98%	5,936	801	9,442	13,484	5,116	7,306	315,982	451,276
FIRE	29.98%	7,005	865	11,057	15,791	1,476	2,108	87,184	124,514
Serv	29.98%	7,105	1,608	13,349	19,065	6,809	9,724	345,175	492,969
Govt	29.98%	408	97	5,287	7,550	4,599	6,567	186,327	266,107
Misc	0.00%	0	0	0	0	0	0	0	0
HH									
Totals		22,802	18,375	140,194	198,072	32,544	45,798	1,428,970	2,019,183
Total % Change	29.98%	-29.98%	-29.98%	-29.98%	-1.07%	-29.98%	-1.46%	-29.98%	-1.06%

Second, the effects of transportation bottlenecks alone can only be observed by stripping away rebuilding expenditures, Scenario B. Here we can see that income would have fallen, not risen. The disaster would have caused another $10 billion in indirect losses. Third, outside assistance is an important element in the recovery process. The effects of internal financing are shown in

Scenario A. Here, an additional $1.5 billion in income losses would have been observed had the victims been forced to borrow to rebuild.

These scenarios underscore the importance of rebuilding on the impacted region's post-disaster economic performance. This is particularly true when insurance and federal assistance is made available. Another important lesson learned from these experiments is that case studies of indirect loss can produce misleading results. Clearly Northridge and Los Angeles County did not benefit from disruptions to its transportation network. Yet, an analysis of post-disaster spending and incomes (taxable sales reported after the earthquake) tends to indicate such had occurred. As just shown the Indirect Loss Module is capable of separating the stimulative effects of rebuilding from the "true" indirect losses produced as a result of forward and backward linked damages.

Table 16.21 Los Angeles County Transactions Matrix

	Ag	**Mine**	**Cnst**	**Mfg**	**Trns**	**Trde**	**FIRE**	**Serv**	**Govt**	**Misc**	**HH**
Ag	26	0	28	173	2	13	213	46	5	0	49
Mine	2	1	13	66	44	16	2	22	53	0	119
Cnst	14	10	24	353	482	167	1162	694	603	0	0
Mfg	121	25	1942	13201	1363	1707	378	3415	285	0	12219
Trns	50	38	929	4069	2381	1724	920	2741	1078	0	6677
Trde	43	6	1609	2662	207	511	140	904	103	0	21900
FIRE	60	189	301	1080	653	1519	7279	4210	134	0	28696
Serv	122	37	2839	4933	1916	4636	3177	14326	275	0	31357
Govt	17	25	96	1195	200	651	389	1213	255	0	2514
Misc	0	0	0	0	0	0	0	0	0	0	0
HH	660	424	8846	30473	8601	25129	10985	51410	17318	0	0
TypeII sum	1115	754	16627	58204	15850	36072	24645	78981	20111	0	103530
TypeII FP	431	4936	7708	62601	10039	13605	32460	13019	1838	0	57838
Imports	403	1201	6920	42925	3400	3284	1744	6543	669	0	0
Ind Out	1546	5690	24335	120805	25888	49677	57105	92000	21948	0	161368

Table 16.22 Results – Scenario A Constrained Transportation Sector Reconstruction

Direct Output Loss	($15,508)	-2.77%
Indirect Output Loss	$8,286	1.48%
Total Loss (Direct+Indirect)	($7,222)	-1.29%
Direct Income Loss	($3,710)	-2.41%
Indirect Income Loss	$1,552	1.01%
Total Loss Income (Direct+Indirect)	($2,158)	-1.40%
Direct Employment Loss	(122,015)	-2.39%
Indirect Employment Loss	24,013	0.47%
Total Employment Loss (Direct+Indirect)	(98,002)	-1.92%

Table 16.23 Scenario A; Damage and User Inputs

Economic Sector	Percent Damage
Agriculture	0.00%
Mining	0.00%
Construction	0.00%
Manufacturing	3.80%
Transportation	10.00%
Trade	3.50%
Finance, Insurance and Real Estate	2.00%
Service	0.86%
Government	0.87%
Misc.	0.00%

Assumptions	Value
Rate of Unemployment	8.00%
Excess Capacity in Transportation	0.00%
Earthquake Construction Spending	$26 billion

Table 16.24 Restoration and Reconstruction Spending after Northridge

SECTOR	Months after the Northridge Earthquake										
	1	**2**	**3**	**6**	**9**	**12**	**24**	**36**	**48**	**60**	**120**
Agriculture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Construction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Manufacturing	3.80	3.19	2.58	1.98	1.37	0.76	0.15	0.00	0.00	0.00	0.00
Transportation	10.00	8.40	6.80	5.20	3.60	2.00	0.40	0.00	0.00	0.00	0.00
Trade	3.50	2.94	2.38	1.82	1.26	0.70	0.14	0.00	0.00	0.00	0.00
FIRE	2.00	1.68	1.36	1.04	0.72	0.40	0.08	0.00	0.00	0.00	0.00
Service	0.86	0.72	0.58	0.45	0.31	0.17	0.03	0.00	0.00	0.00	0.00
Government	0.87	0.73	0.59	0.45	0.31	0.17	0.03	0.00	0.00	0.00	0.00
Misc.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Spending/Mn	Months after the Northridge Earthquake										
	1	**2**	**3**	**6**	**9**	**12**	**24**	**36**	**48**	**60**	**120**
$ Billons	0.10	0.30	0.60	0.70	0.70	0.60	0.30	0.12	0.00	0.00	0.00

**Table 16.25 Results – Scenario B
Constrained Transportation Sector
No Reconstruction**

Direct Output Loss	($15,508)	-2.77%
Indirect Output Loss	($33,685)	-6.01%
Total Loss (Direct+Indirect)	($49,193)	-8.78%
Direct Income Loss	($3,710)	-2.41%
Indirect Income Loss	($9,692)	-6.30%
Total Loss Income (Direct+Indirect)	($13,403)	-8.71%
Direct Employment Loss	(122,015)	-2.39%
Indirect Employment Loss	(318,930)	-6.24%
Total Employment Loss (Direct+Indirect)	(440,945)	-8.63%

Table 16.26 Scenario B, User Inputs

Assumptions	Value
Rate of Unemployment	8.0%
Excess Capacity in Transportation	0.00%
Earthquake Construction Spending	$0 billion

**Table 16.27 Results – Scenario C
Unconstrained Transportation Sector
No Reconstruction**

Direct Output Loss	($15,508)	-2.77%
Indirect Output Loss	$2,648	0.47%
Total Loss (Direct+Indirect)	($12,860)	-2.29%
Direct Income Loss	($3,710)	-2.41%
Indirect Income Loss	$640	0.42%
Total Loss Income (Direct+Indirect)	($3,070)	-2.00%
Direct Employment Loss	(122,015)	-2.39%
Indirect Employment Loss	21,250	0.42%
Total Employment Loss (Direct+Indirect)	(100,765)	-1.97%

Table 16.28 Scenario C, User Inputs

Assumptions	Value
Rate of Unemployment	8.00%
Excess Capacity in Transportation	no constraint
Earthquake Construction Spending	$0 billion

Table 16.29 Results – Scenario D
Unconstrained Transportation Sector
Reconstruction, No Indebtedness

Direct Output Loss	($9,754)	-2.12%
Indirect Output Loss	$37,061	8.05%
Total Loss (Direct+Indirect)	$27,307	5.93%
Direct Income Loss	($2,850)	-1.85%
Indirect Income Loss	$12,046	7.83%
Total Loss Income (Direct+Indirect)	$9,196	5.98%
Direct Employment Loss	(99,044)	-1.94%
Indirect Employment Loss	370,072	7.24%
Total Employment Loss (Direct+Indirect)	271,028	5.31%

Table 16.30 Scenario D, User Inputs

Assumptions	Value
Rate of Unemployment	8.00%
Excess Capacity in Transportation	no constraint
Earthquake Construction Spending	$26 billion

16.6.3 The Sensitivity of Indirect Loss to Capacity, Damage and Reconstruction

Our analysis to date suggests that there may not be a simple relationship between direct and indirect losses. Much depends upon the pattern of damage, which sectors sustain the greatest disruption, and their relative importance in the economy. In addition, the demand stimulus inherent in the rebuilding process would lessen indirect loss, possibly producing gains in instances where large amounts of excess capacity exist. The sensitivity of indirect loss to random patterns of damage and rebuilding was determined through a series of experiments that are presented in summary form below. Four major classes of experiments were conducted; they are identified and explained in Table 16.31.

Table 16.31 Monte Carlo Experiments

Experiment	Explanation
Damage Pattern	1. Random damage pattern drawn from a uniform probability distribution (all sectors). 2. Random damage pattern drawn from a skewed probability distribution (all sectors). 3. Random pattern of damage to the lifelines sector, no damage to all other sectors.
Outside Assistance	4. Random amounts of rebuilding. 5. Rebuilding in proportion to direct losses
Economic Structure	Different transactions matrices were utilized to evaluate the extent to which economic structure impacted indirect loss when the economy was fully constrained
Internal and External Capacity	The effects of eliminating supplemental imports and exports and varying internal capacity.

Indirect and direct losses were recorded for twenty thousand experiments[11]. The joint density function of direct and indirect loss, along with the probability density function of indirect loss were then plotted to derive relationships capable of being generalized. See Figure 16.7. The joint density function is displayed on the higher of the two horizontal plains. Regions of indirect gain and loss are identified. The lower of the two planes is a contour map (projection) of the joint probability of indirect and direct loss. The back projection is the indirect loss probability density function.

The results of the experiments are plotted in Figures 16.8 through 16.17. As shown, either regional indirect loss or gain can be observed. Which occurs depends upon the combination of the damage pattern, preexisting economic conditions and the amount of outside assistance received. Several of the maps have ready explanations. The map shown in Figure 16.8 is based on two assumptions: 1) the existence of sufficient (to avoid shortages) excess capacity and 2) rebuilding expenditures are proportionate to direct loss. The first assumption eliminates all constraints and, therefore, indirect losses are eliminated as well. By linking reconstruction spending to direct loss, indirect gain (the effect of the construction multiplier) is made proportionate to direct loss. It will be shown below that the slope implied by the contour is a function of the construction multiplier.

It appears from these experiments that reconstruction spending exerts a powerful influence on indirect loss. Figure 16.9 shows the results of an experiment where internal capacity was varied randomly from zero to 30 percent, the shocks were drawn randomly from a uniform probability distribution, and reconstruction spending was random. As shown, indirect losses were recorded for fewer than 10 percent of the cases. Figure 16.10

[6]Damage to each of 10 economic sectors was determined by generating a random number between zero and one for the uniform distribution and cubing the random number to arrive at a skewed distribution.

shows the effect of eliminating reconstruction expenditures. As expected, the gains shown in Figure 16.8 disappear.

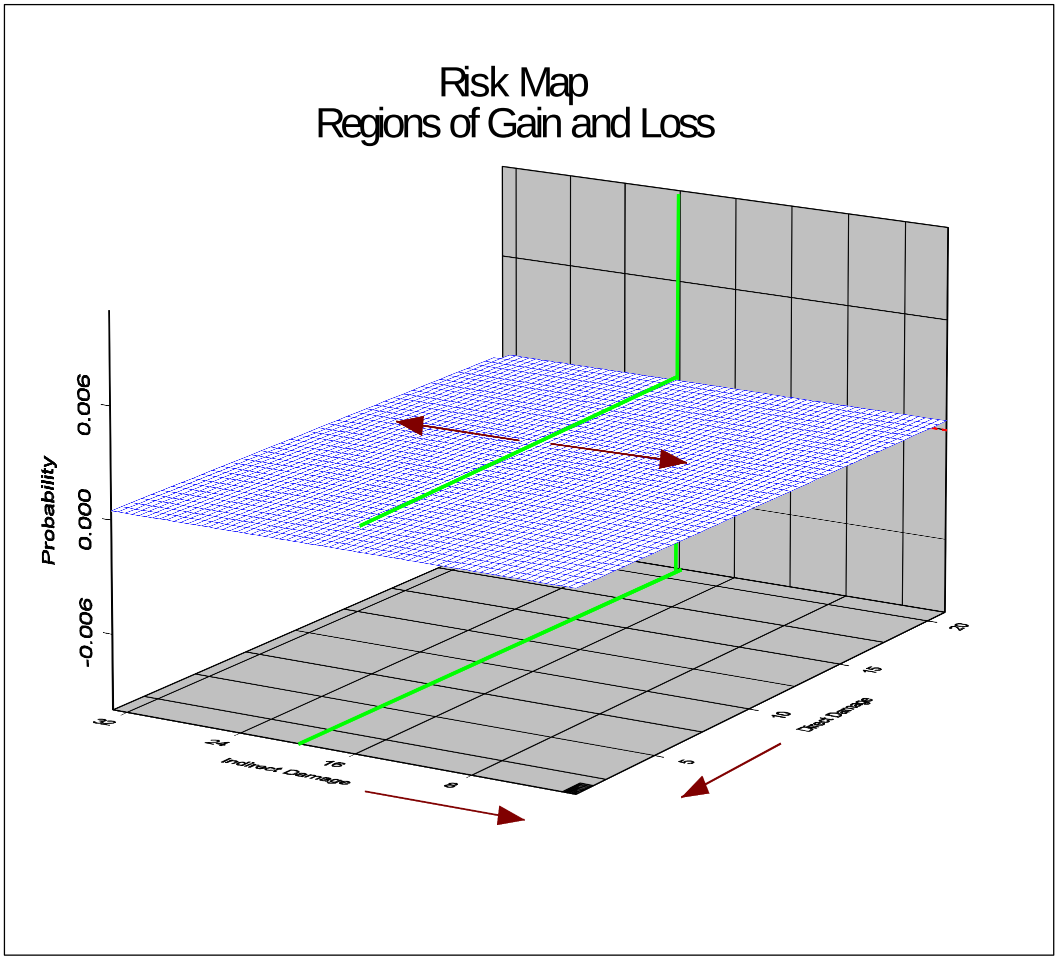

Figure 16.7 Risk Map - Direct vs. Indirect

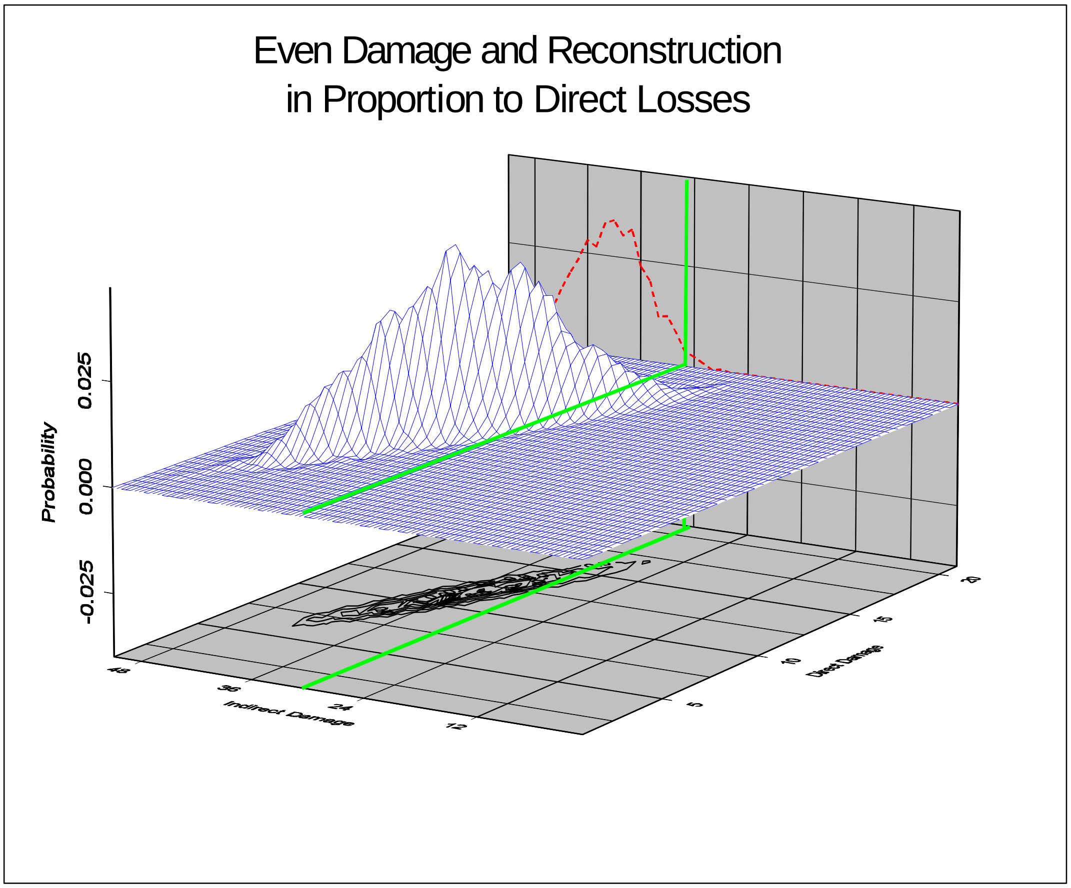

Figure 16.8 Risk Map - No Constraints

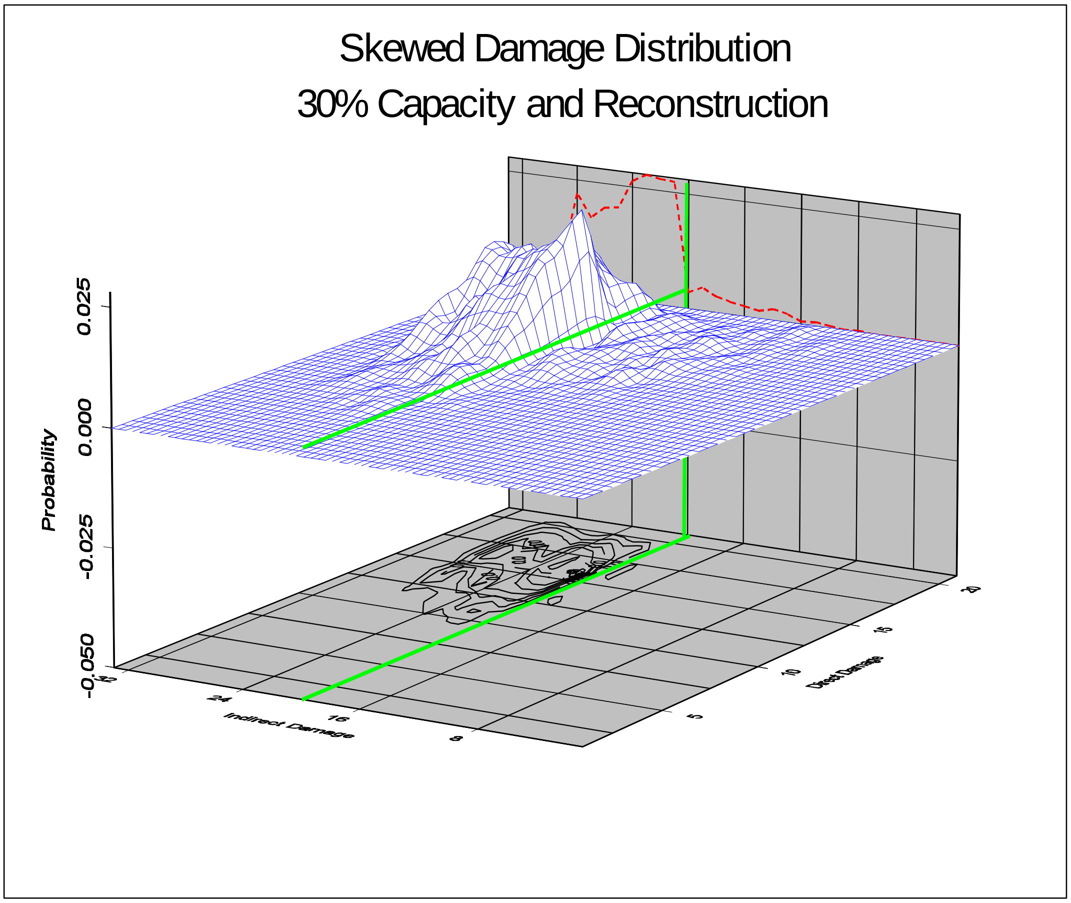

Figure 16.9 Risk Map - Random Capacity

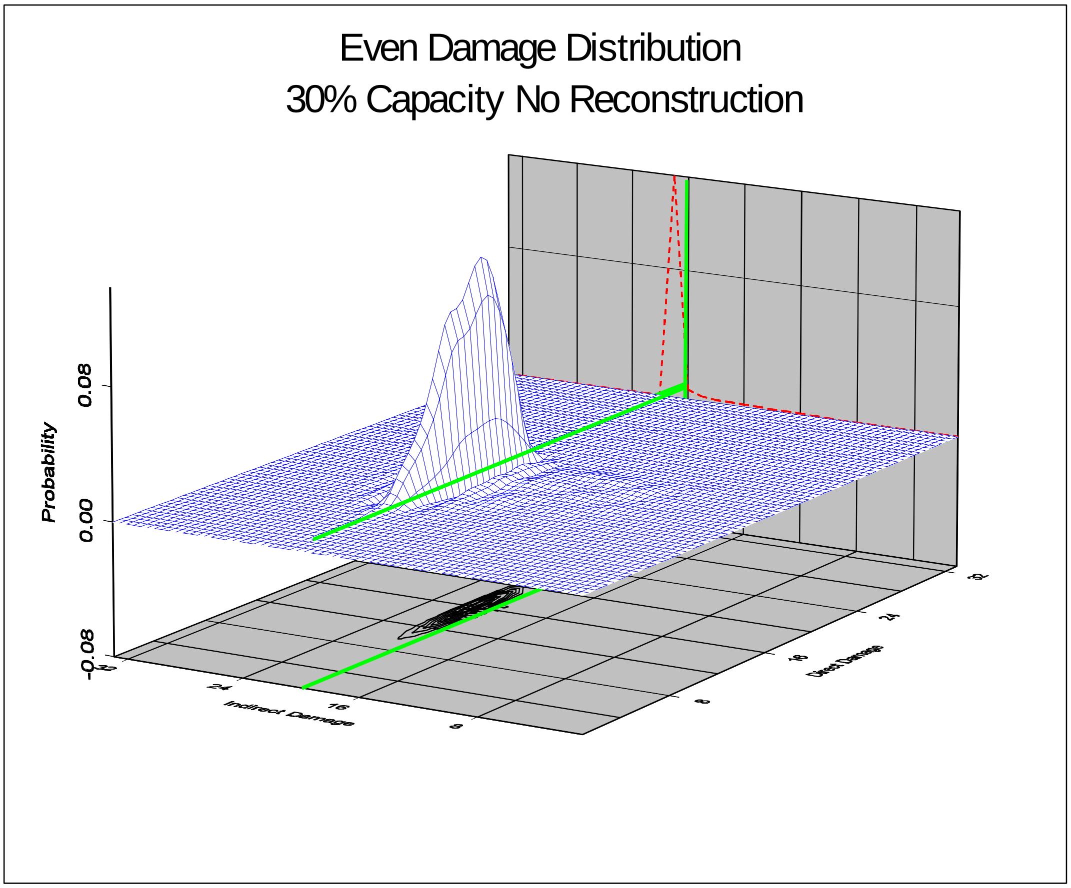

Figure 16.10 Risk Map - No Rebuilding In contrast, Figure 16.11 shows that when the economy is constrained (internally and externally) indirect losses can be quite high and indirect gains are impossible. The shape of this result map can be explained. The outline of the contour map provided in Figure 16.11 and several regions of the solution set are identified in Figure 16.12. The triangular shape of the map follows directly from the way in which the economy responds to damages. Point B, the uppermost level of indirect loss, results from a maximum shock to the smallest sector. Even though B proved to be improbable, other combinations of low direct loss and relatively high indirect loss were observed. The Line segment D-C shows the effect of a uniform[12] damage patterns. An even pattern of damages produce no indirect loss since the economy remains balanced. Only an uneven pattern of damage produces bottleneck effects and indirect losses. The line segment A-C can be interpreted as the indirect loss frontier. At the extreme, when direct loss is total, indirect loss must be zero. Similarly, when direct loss is total for the smallest sector, indirect loss is maximum. Hence, point A would be observed if the size of the smallest sector approached zero. Line segment D-B shows the

[12]Uniform means that each sector suffers an equal ratio of damage.

influence of increased variance in the pattern of loss. The variance is zero at D and maximum at B.

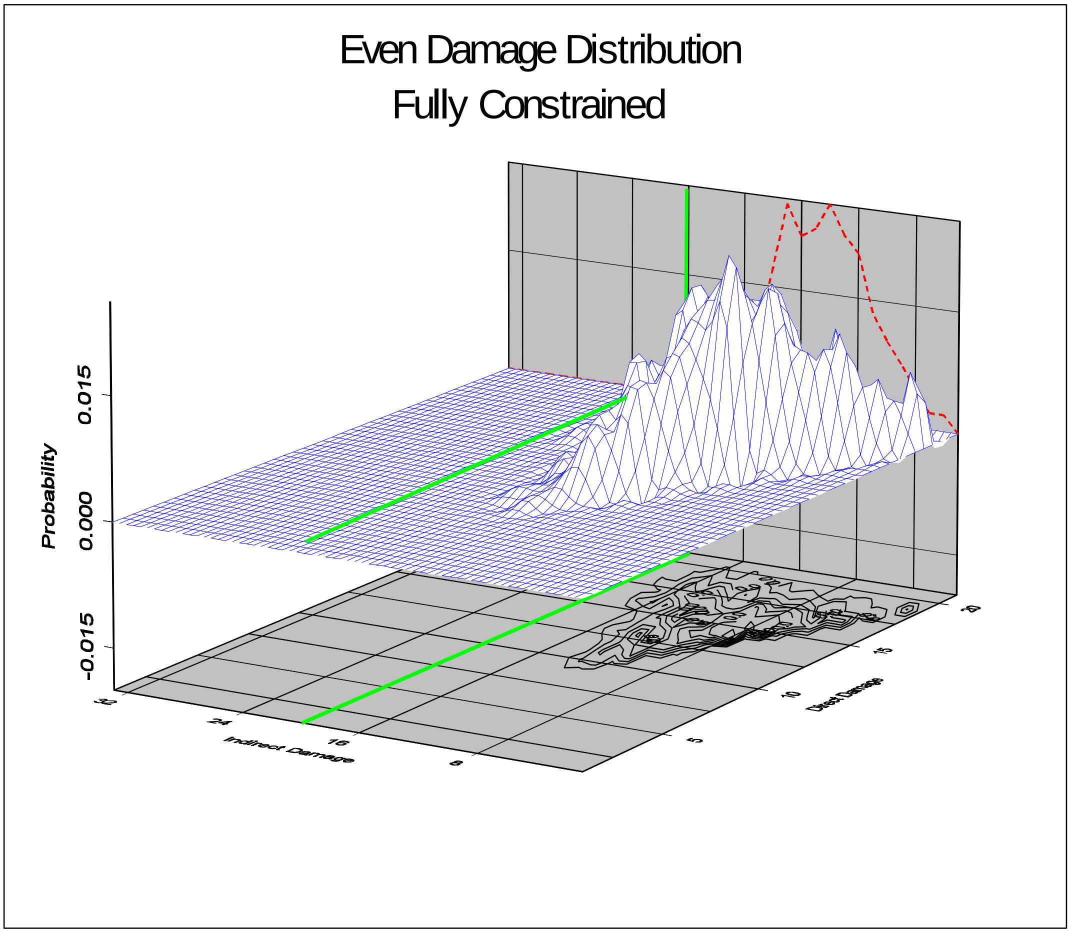

Figure 16.11 Risk Map Fully Constrained

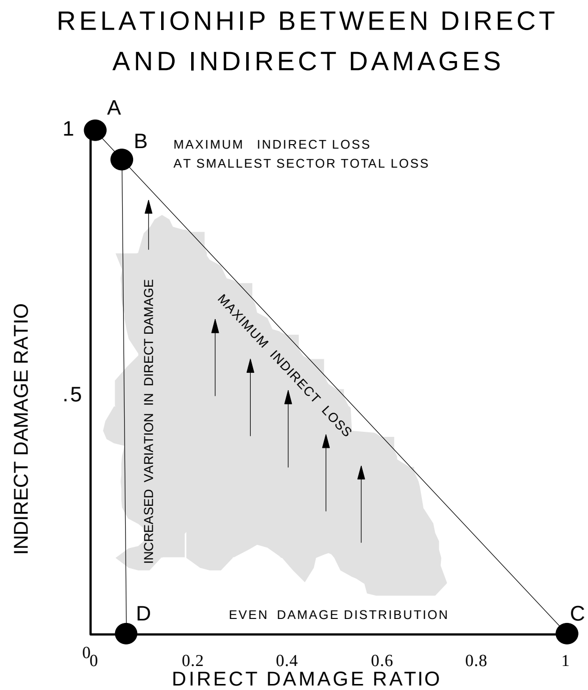

Figure 16.12 Relationship Between Direct and Indirect Damages

Figures 16.13 and 16.14 show the effect of a shock to lifelines (transportation) alone. The only difference between the two experiments is the amount of excess capacity assumed, 30 percent in the former and none in the latter. It is not surprising that this latter scenario produces the potential for sizable indirect losses.

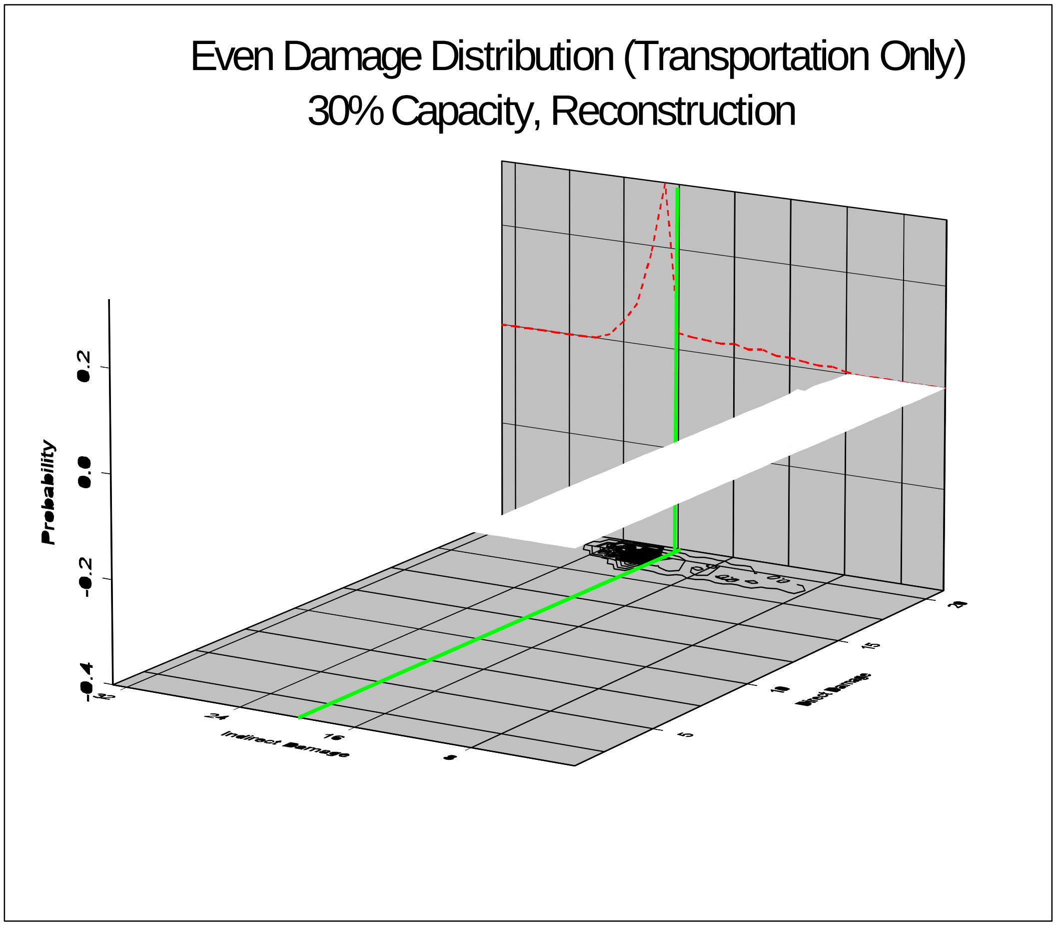

Figure 16.13 Risk Map - Transportation Disruption and Excess Capacity

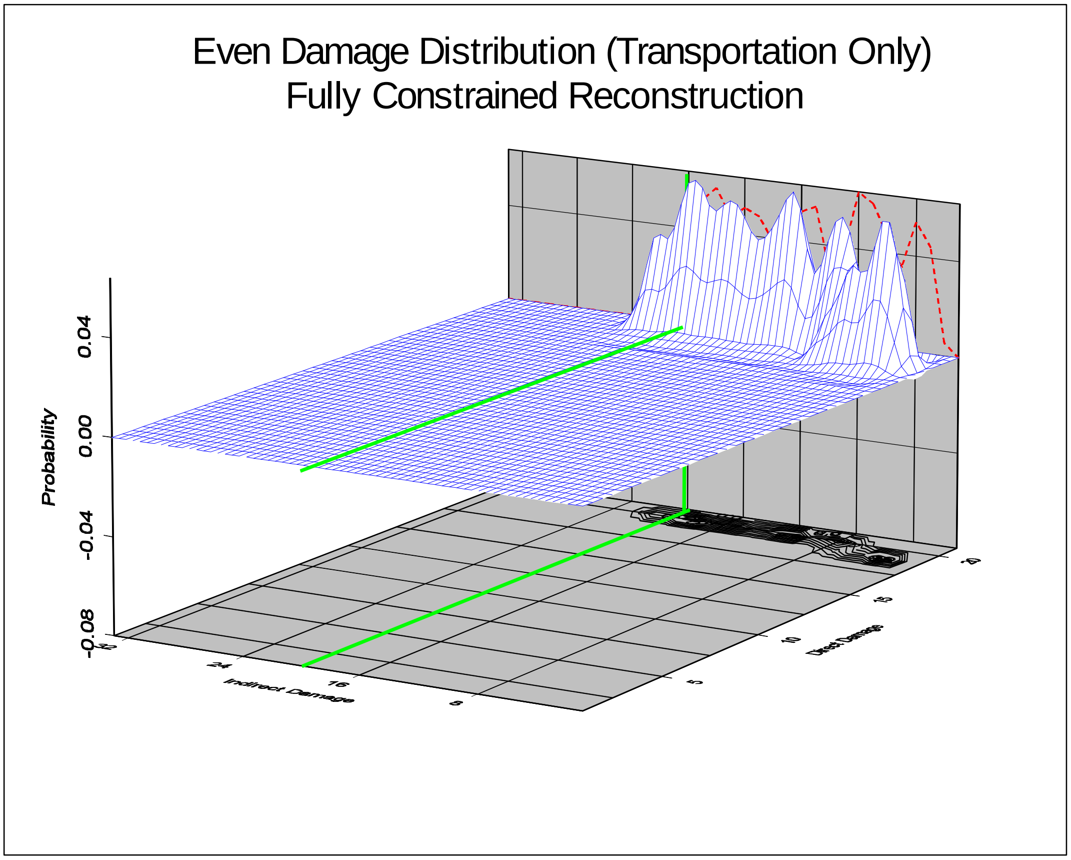

Figure 16.14 Risk Map - Transportation Disruption and No Excess Capacity

Figures 16.15, 16.16 and 16.17 provide a comparison of how economies respond to differing damage patterns, capacities and economic structure. Figure 16.15 summarizes the experiments that varied capacity. Figure 16.16 contrasts the degree of skewness in sectoral damage. As shown, the greater the concentration of damage, the greater the indirect loss as a proportion of total loss. The greater the capacity the greater the chances of indirect gain. Rebuilding expenditures enhances such gains. It is somewhat surprising in Figure 16.17 that economic structure appears to play an insignificant role in determining indirect losses when the economy is fully constrained. All three economies shown appear to produce very similar joint density functions. Clearly, the same conclusion will not apply in the event that internal excess capacity exists. In that case, economic gains are sensitive to economic structure, through a construction multiplier.

It was asserted above that, if unconstrained, this model produces a solution that is equivalent to what conventional input-output techniques yield. This is easily demonstrated by making reconstruction expenditures proportionate to direct loss. A simple linear regression of spending and indirect gain should produce a slope (zero intercept) equal to the construction multiplier. Figure 16.18 shows the result of this experiment. The slopes of the indirect gain functions for Los Angeles and Santa Cruz are

1.397 and 1.145 respectively. The respective IMPLAN construction multipliers for these two counties are 1.431 and 1.141.

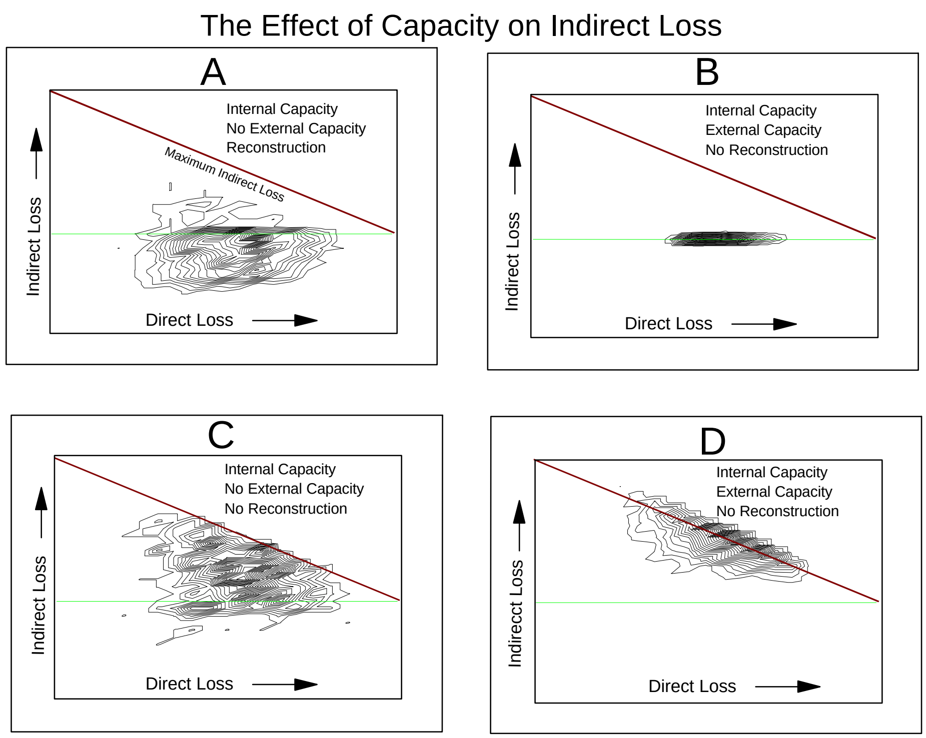

Figure 16.15 Risk Maps—The Effects of Capacity

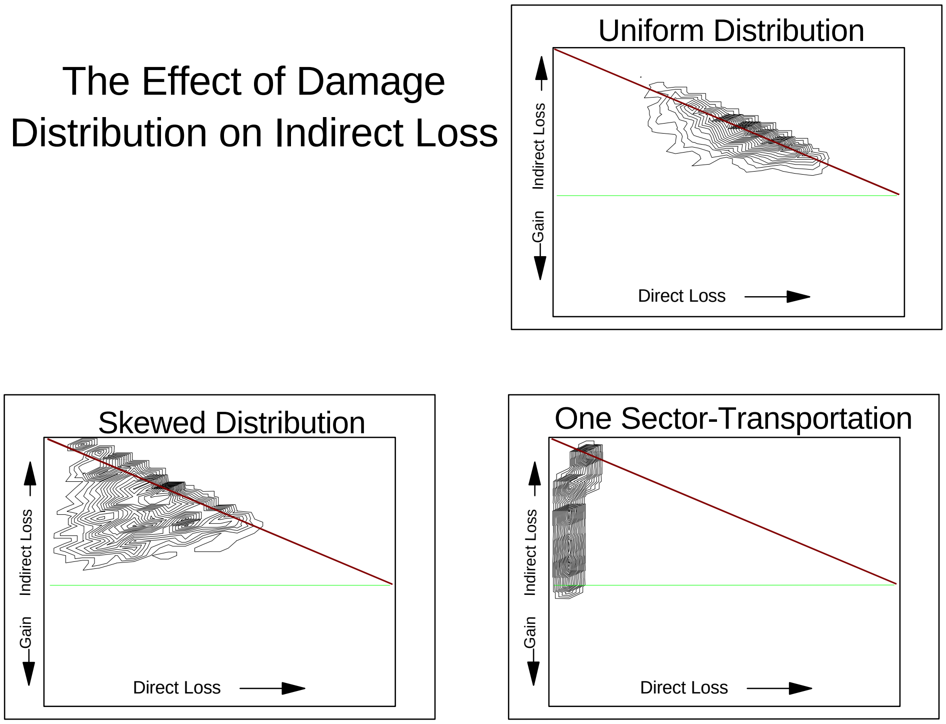

Figure 16.16 Risk Maps – The Effects of Damage Distributions

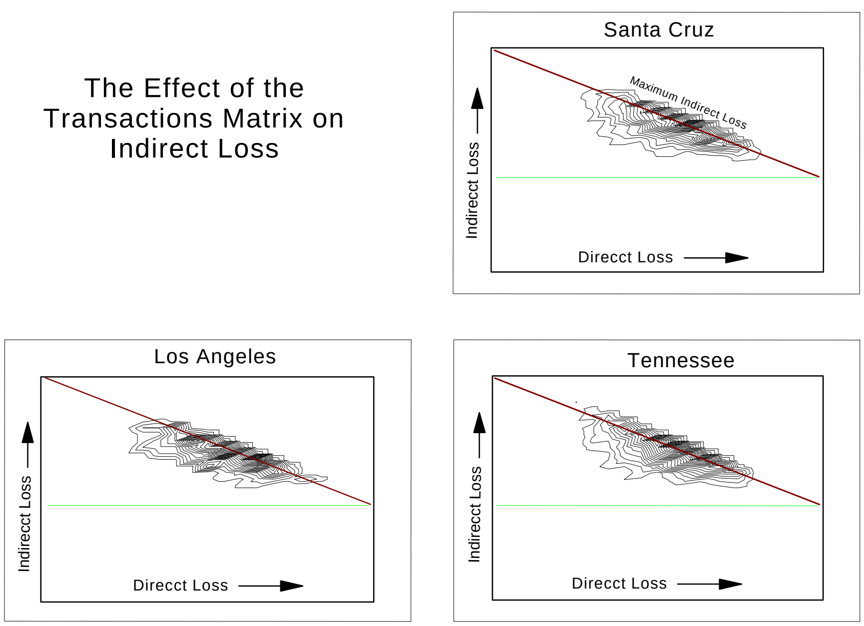

Figure 16.17 Risk Map -- The Effect of the Transactions Matrix When Fully Constrained

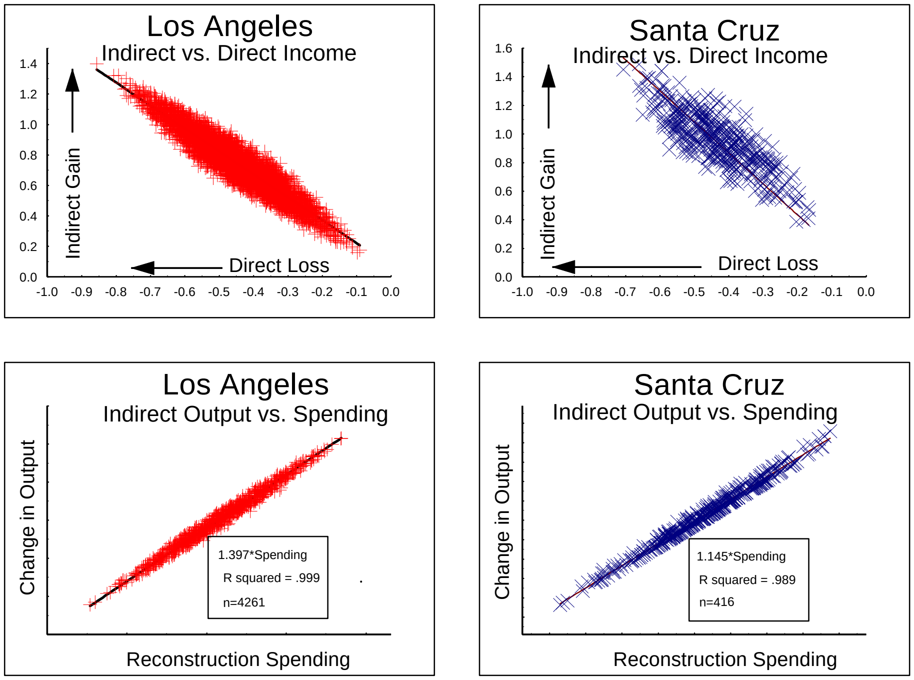

Figure 16.18 Indirect Gains and the Construction Multiplier

16.6.4 Observations About Indirect Loss

The following generalizations can be drawn from the foregoing experiments:

1. Holding capacity and rebuilding fixed, indirect losses are inversely proportional to the size of the sector shocked. For example, in the extreme case of an economy with a dominant sector, the rest of the economy in which indirect effects take place is relatively small.

2. Imports can either reduce or promote indirect loss, dampening losses if used to supply industry with raw and semi-finished ingredients so that production can be resumed, and accentuating losses if imports are used to satisfy unmet household demand, thus displacing local production.

3. Shocks to a fully constrained economy produce indirect losses, but not indirect gains because there is no leeway for the latter (e.g., multiplier effects from construction). In such an economy, the probability of indirect losses exceeding direct damage is approximately 50 percent.

4. The greater the variance in the pattern of damage, the greater the indirect loss due to factors such as “bottleneck” effects.

5. A uniform pattern of loss produces no indirect loss because internal rearrangements of buyers and sellers can be perfectly matched (barring transportation problems and contractual constraints).

6. If the economy is fully constrained, indirect losses are maximum when the economy's smallest sector is totally destroyed (this is the inverse of generalization No. 1).

7. When unconstrained, the economy expands from the construction stimulus as conventional I-O techniques (multipliers) would predict.

8. A dynamic analysis of indirect loss reflects both the forward and backward linked losses and future demand changes resulting from disaster caused indebtedness, both of which are generally long-run dampening effects.

9. When economies are fully constrained, indirect loss appears to be insensitive to economic structure. Different transactions matrices yield <u>marginally different indirect losses,</u> most likely because of similarities of multiplier values or stochastic offsets of multipliers of differing values.

10. From a regional accounting stance reconstruction gains tend to dominate indirect losses when excess capacity exists.

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Appendix 16A

Default Data Analysis
Synthetic Economies

113 state and county IMPLAN tables were analyzed to derive synthetic transactions matrices for the Default Data Analysis model. A frequency histogram of employment (See Tables 16A.2 through 16A.4) revealed that 90 percent of the tables could be classified as Manufacturing/Service, Service/Manufacturing, or Service/Trade. Since nearly two thirds of employment in these tables can be traced to these three sectors, it was decided that this means of classifying economies could be used as a basis for deriving Default Data Analysis interindustry trade flows. Further adjustments were made to reflect the size of the economy. Four size classes were created resulting in the 12 way classification shown below.

Table 16A.1 Classification of Synthetic Economies

Employment		**Type**		
Upper Bound	**Lower Bound**	**Manufacturing/ Service**	**Service/ Manufacturing**	**Service/ Trade**
unlimited	2 million	SUP1	SUP2	SUP3
2 million	.6 million	LAR1	LAR2	LAR3
.6 million	30,000	MID1	MID2	MID3
30,000	0	LOW1	LOW2	LOW3

The particular states and counties which were utilized to create the 12 synthetic tables are shown in Tables 16A.5 through 16A.6.

Table 16A.2 Manufacturing/Service

Sector	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**AVG**
Manufacturing	0	0	0	9	25	10	4	1	0	0	0	37.5%
Government	0	0	14	35	0	0	0	0	0	0	0	21.5%
FIRE	0	3	44	2	0	0	0	0	0	0	0	13.6%
Trade	0	42	7	0	0	0	0	0	0	0	0	7.5%
Service	0	46	3	0	0	0	0	0	0	0	0	6.3%
Construction	0	46	3	0	0	0	0	0	0	0	0	6.3%
Transportation	0	48	1	0	0	0	0	0	0	0	0	6.1%
Agriculture	0	49	0	0	0	0	0	0	0	0	0	0.6%
Mining	0	49	0	0	0	0	0	0	0	0	0	0.6%

Table 16A.3 Service/Manufacturing

Sector	0	10	20	30	40	50	60	70	80	90	100	AVG
Government	0	0	1	20	11	1	0	0	0	0	0	28.6%
Manufacturing	0	0	12	18	2	0	1	0	0	0	0	23.4%
FIRE	0	2	29	2	0	0	0	0	0	0	0	13.9%
Trade	0	27	6	0	0	0	0	0	0	0	0	8.4%
Transportation	0	25	8	0	0	0	0	0	0	0	0	8.3%
Service	0	28	5	0	0	0	0	0	0	0	0	7.8%
Construction	0	28	5	0	0	0	0	0	0	0	0	7.1%
Mining	0	32	1	0	0	0	0	0	0	0	0	2.2%
Agriculture	0	33	0	0	0	0	0	0	0	0	0	0.4%

Table 16A.4 Service/Trade

Sector	0	10	20	30	40	50	60	70	80	90	100	AVG
Government	0	0	0	2	7	6	0	1	0	0	0	37.4%
Service	0	1	8	7	0	0	0	0	0	0	0	18.2%
Transportation	0	10	6	0	0	0	0	0	0	0	0	9.3%
Manufacturing	0	9	7	0	0	0	0	0	0	0	0	9.2%
Construction	0	13	3	0	0	0	0	0	0	0	0	7.8%
FIRE	0	13	3	0	0	0	0	0	0	0	0	7.4%
Trade	0	14	2	0	0	0	0	0	0	0	0	6.0%
Mining	0	13	2	1	0	0	0	0	0	0	0	4.1%
Agriculture	0	16	0	0	0	0	0	0	0	0	0	0.5%

Table 16A.5 Manufacturing/Service Economy

Super			Large		
FIPS	STATE/CNTY.	EMPLOY.	FIPS	STATE/CNTY.	EMPLOY.
39,000	Ohio	5,831,755	53,033	King, WA	1,112,072
26,000	Michigan	4,714,837	9,000	Connecticut	1,989,824
13,000	Georgia	3,673,183	19,000	Iowa	1,635,164
37,000	North Carolina	3,858,712	5,000	Arkansas	1,194,095
18,000	Indiana	3,064,277	28,000	Mississippi	1,186,175
29,000	Missouri	2,986,395	33,000	New Hampshire	655,638
53,000	Washington	2,777,829	6,059	Orange, CA	1,514,438
27,000	Minnesota	2,642,082	41,000	Oregon	1,621,333
47,000	Tennessee	2,733,161	23,000	Maine	709,529
55,000	Wisconsin	2,796,572			
1,000	Alabama	2,028,495			

Mid			Low		
FIPS	STATE/CNTY.	EMPLOY.	FIPS	STATE/CNTY.	EMPLOY.
8,059	Jefferson, CO	224,465	48,257	Kaufman, TX	19,758
53,061	Snohomish, WA	212,107	6,069	San Benito, CA	16,274
41,067	Washington, OR	179,331	55,029	Door, WI	15,682
55,009	Brown, WI	123,090	55,093	Pierce, WI	13,707
41,005	Clackamas, OR	129,712	55,099	Price, WI	8,637
55,087	Outagamie, WI	89,502	8,087	Morgan, CO	12,408
48,121	Denton, TX	88,726	41,015	Curry, OR	8,996
49,057	Weber, UT	77,041	48,285	Lavaca, TX	9,272
55,089	Ozaukee, WI	36,021	55,129	Washburn, WI	6,590
48,139	Ellis, TX	31,798	41,035	Klamath, OR	28,783
41,071	Yamhill, OR	30,416	55,109	St.Croix, WI	23,213
16,000	Idaho	547,056			
50,000	Vermont	345,166			
44,000	Rhode Island	554,121			
10,000	Delaware	414,343			

Table 16A.6 Service/Manufacturing Economy

Super			Large		
FIPS	**STATE/CNTY.**	**EMPLOY.**	**FIPS**	**STATE/CNTY.**	**EMPLOY.**
36,000	New York	9,747,535	19,000	Iowa	1,635,164
6,037	Los Angeles, CA	5,108,213	40,000	Oklahoma	1,614,109
48,000	Texas	8,900,073	4,013	Maricopa, AZ	1,212,392
34,000	New Jersey	4,327,815	22,000	Louisiana	1,969,967
25,000	Massachusetts	3,644,604	5,000	Arkansas	1,194,095
6,000	California	16,532,145	31,000	Nebraska	987,260
13,000	Georgia	3,673,183	54,000	West Virginia	769,662
51,000	Virginia	3,695,334	4,000	Arizona	1,870,344
24,000	Maryland	2,697,448	20,000	Kansas	1,485,215
8,000	Colorado	2,017,818	49,000	Utah	895,454

Mid			Low		
FIPS	**STATE/CNTY.**	**EMPLOY.**	**FIPS**	**STATE/CNTY.**	**EMPLOY.**
35,001	Bernalillo, NM	306,176	35,041	Roosevelt, NM	7,593
53,053	Pierce, WA	263,512			
41,051	Multnomah, OR	441,788			
53,063	Spokane, WA	192,662			
48,085	Collin, TX	103,086			
6,089	Shasta, CA	71,398			
48,485	Wichita, TX	74,491			
49,011	Davis, UT	78,170			
6,071	San Bernardino, CA	529,198			
49,035	Salt Lake, UT	436,832			
6,065	Riverside, CA	434,846			
6,111	Ventura, CA	313,911			

Table 16A.7 Service/Trade Economy

Super			Large		
FIPS	**STATE/CNTY.**	**EMPLOY.**	**FIPS**	**STATE/CNTY.**	**EMPLOY.**
	NONE		11,000	District of Columbia	761,680
			32,000	Nevada	741,574
			15,000	Hawaii	696,759
			35,000	New Mexico	745,539

Mid			Low		
FIPS	**STATE/CNTY.**	**EMPLOY.**	**FIPS**	**STATE/CNTY.**	**EMPLOY.**
30,000	Montana	433,623	48,397	Rockwall, TX	9,140
8,005	Arapahoe, CO	217,208	8,067	La Plata, CO	19,079
4,003	Cochise, AZ	39,611	56,001	Albany, WY	16,959
38,000	North Dakota	377,987	56,041	Uinta, WY	9,948
6,029	Kern, CA	262,422	55,125	Vilas, WI	8,364
56,021	Laramie, WY	44,438	35,061	Valencia, NM	11,787