Chapter 15
Direct Economic Losses

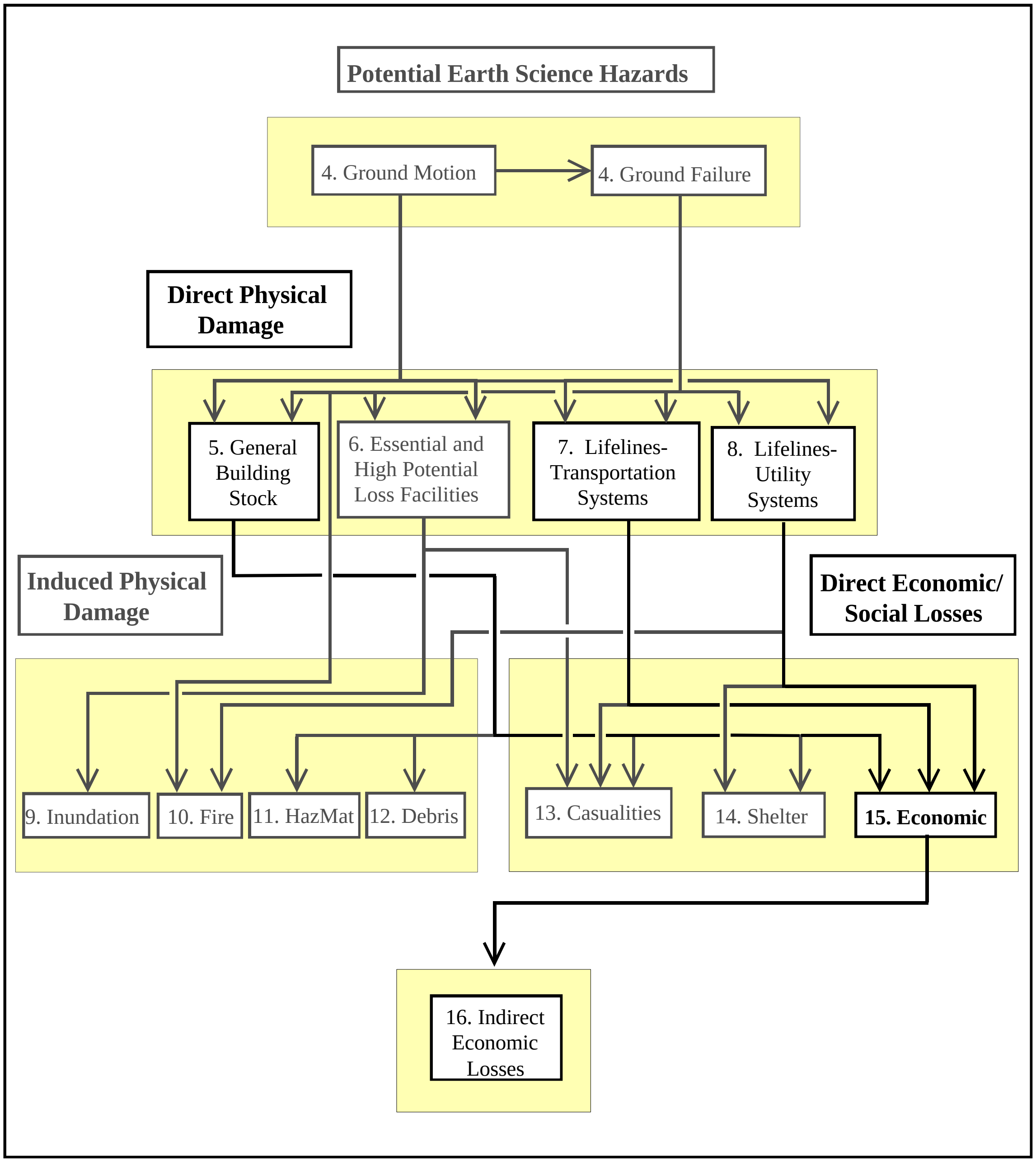
15.1 Introduction

This chapter describes the conversion of damage state information, developed in previous modules, into estimates of dollar loss. In the past, loss estimation studies have generally limited the consideration of loss to estimates of the repair and replacement costs of the building stock.

The methodology provides estimates of the structural and nonstructural repair costs caused by building damage and the associated loss of building contents and business inventory. Building damage can also cause additional losses by restricting the building’s ability to function properly. To account for this, business interruption and rental income losses are estimated. These losses are calculated from the building damage estimates by use of methods described later. The methodology highlighting the Direct Economic Loss component is shown in Flowchart 15.1.

This expression of losses provides an estimate of the costs of building repair and replacement that is a frequently required output of a loss estimation study. The additional estimates of consequential losses give an indication of the immediate impact of such building damage on the community: the financial consequences to the community's businesses due to businesses interruption, the financial resources that will be needed to make good the damage, and an indication of job and housing losses.

In strict economic terms, buildings, inventories, and public facilities represent capital investments that produce income, and the value of the building and inventory will be the capitalized value of the income produced by the investment that created the building or inventory. Hence, if we estimate the dollar value of the buildings damaged or destroyed, and add the income lost from the absence of the functioning facilities we may be overestimating the indirect economic loss (Chapter 16). However, for the assessment of direct economic loss, the losses can be estimated and evaluated independently.



Flowchart 15.1: Direct Economic Losses Relationship to other Components of the Earthquake Loss Estimation Methodology

Since a significant use for loss estimation studies is expected to be that of providing input into future benefit-cost studies used to evaluate mitigation strategies and budgets, the list of these consequential losses is similar to that developed for the FEMA benefit-cost procedure described in FEMA publications 227 and 228, and 255 and 256. This procedure is, however, limited to conventional real-estate parameters similar to those used in evaluating the feasibility of a development project and does not attempt to evaluate the full range of socio/economic impacts that might follow specific mitigation strategies.

Thus, for this loss estimation methodology, even though the derivation of these consequential losses represents a considerable expansion of the normal consideration of building damage/loss, this module is still limited in its consideration of economic loss to those losses that can be directly derived from building and infrastructure damage, and that lend themselves to ready conversion from damage to dollars. The real socio/economic picture is much more complex: economic impacts may have major societal effects on individuals or discrete population groups, and there may be social impacts that ultimately manifest themselves in economic consequences. In many cases the linkages are hard to trace with accuracy and the effects, while easy to discern, are difficult to quantify because definite systematic data is lacking.

For example, the closing of the Oakland/San Francisco Bay Bridge for 30 days following the Loma Prieta earthquake of 1989 required approximately a quarter of a million daily users of the bridge to rearrange their travel patterns. Many individual commuters were forced to take a significantly longer and more costly route to their destinations. At the same time, other commuters changed to use of the BART rail system or bus services, which also altered their family expenditure patterns. More lengthy trips for business service travelers and material suppliers resulted in varying degrees of loss of productivity. Businesses directly related to normal operation of the bridge, such as gas stations and automobile repair shops on the approach routes to the bridge suffered losses.

Repairs to the bridge represented a direct cost to the state budget. At the same time, the revenues from bridge tolls were nonexistent. However, some businesses gained from closure: some gas stations had improved business, and revenues to other bridges, the BART system, and bus companies increased.

Increased commuting time resulted in loss of leisure and family time, and shifts in the customer and sales patterns of many small businesses resulted in an increase in normal business worries.

If this 30-day loss of function had, instead, been a period of years (as is the case for elements of the Bay Area Freeway system) the socio/economic impacts would have been profound and long lasting throughout the Bay region.

This example suggests the range of inter-related consequential impacts stemming from damage to a single structure: but these impacts were accompanied by a host of other impacts to individuals, businesses, institutions and communities that serve further to increase the complexity of post-earthquake effects. As understanding is gained of these interactions, and data collection becomes richer and more systematic, quantification of the consequential losses of earthquake damage can become broader and more accurate.

Given the complexity of the problem and the present paucity of data, the methodology focuses on a few key issues that are of critical importance to government and the community, that can be quantified with reasonable assurance, and that provide a picture of the cost consequences of building and infrastructure damage that are understandable and would be of major concern to a municipality or region. In addition, application of the methodology will provide information that would be useful in a more detailed study of a particular economic or social sector, such as impact on housing stock or on a significant local industry. Finally, the structure of the methodology should be of assistance in future data gathering efforts.

While the links between this module and the previous modules dealing with damage are very direct and the derivations are very transparent, the links between this module and that of Chapter 16, Indirect Economic Losses, are less so. While some of the estimates derived in this module, such as income loss by sector, building repair costs, and the loss of contents and inventories, may be imported directly into the Indirect Loss Module, some interpretation of the direct economic loss estimates would be necessary for a more detailed indirect economic loss study. It would be necessary, for example, to translate the repair and replacement times and costs derived in this module to monthly reconstruction investment estimates for use in a longer-term indirect loss estimate.

15.1.1 Scope

This chapter provides descriptions of the methodologies, the derivation of default data, and explanatory tables for a number of direct economic loss items, derived from estimates of building and lifeline damage. For building related items, methods for calculating the following dollar losses are provided:

- Building Repair and Replacement Costs
- Building Contents Losses
- Building Inventory Losses

To enable time dependent losses to be calculated, default values are provided for:

- Building Recovery Time and Loss of Function (business interruption) time

Procedures for calculating the following time dependent losses are provided:

- Relocation Expenses
- Loss of Proprietors' Income
- Rental Income Losses

For each lifeline, information is provided on replacement values and assumed numerical damage ratios corresponding to damage states. Chapters 7 and 8 provide restoration curves corresponding to lifeline damage states. With this information the cost of damage to lifelines and the elapsed time for their restoration could be calculated; however, no attempt is made to estimate losses due to interruption of customer service, alternative supply services, and the like.

The following lifelines are covered:

Transportation Systems
- Highway Systems
- Railroads
- Light Rail Systems
- Bus Systems
- Port Systems
- Ferry Services
- Airport Systems

Utility Systems:
- Potable Water
- Waste Water
- Oil
- Natural Gas
- Electric Power
- Communication

Dollar losses due to fire and inundation are not explicitly addressed. However, the methodology enables the area of inundation to be estimated and related to the quantity of building stock in the affected census tracts. This, in turn, can be converted into a dollar value.

In a similar manner, a value for building losses from fire can be estimated by relating the area of fire spread to the volume of construction and the construction cost. In both cases, the nature of damage states (which would vary from those of ground shaking damage) are not developed and estimates of dollar loss from these causes should be regarded as very broad estimates. In addition, since the concern is for earthquake-induced fire or inundation, the possibility of double counting of damage is present. More specific studies should be undertaken if the user believes that either fire or inundation might represent a serious risk.

Since the methodology goes no further than indicating sources of hazardous materials, no methodology is provided for estimating losses due to the release of such materials. Again, if the possibility of serious losses from this cause is a matter of concern, specific studies should be undertaken.

15.1.2 Form of Direct Economic Loss Estimates

Direct economic loss estimates are provided in 1994 dollars. In some instances, as in the cost of building replacement, a procedure is provided for the conversion of default dollar values to those prevalent at the time of the loss estimation study. In other instances, user provided information, such as local rental costs, would be provided in current dollar values.

15.1.3 Input Requirements

In general, input data for direct economic losses consists of building damage estimates from the direct physical damage module. The damage estimates are in the form of probabilities of being in each damage state, for each structural type or occupancy class. The building classification system is as discussed in Chapter 3. Damage states are discussed in detail in Chapter 5. Damage state probabilities are provided from the direct physical damage module for both structural and non-structural damage. These damage state probabilities are then converted to monetary losses using inventory information and economic data. For Default Data Analysis values, the buildings are classified into three broad occupancy/use-related categories: residential, commercial/institutional, and industrial. These categories are used to determine the non-structural element make-up of the buildings and the nature and value of their contents. For User-Supplied Data and Advanced Data and Models Analyses, a 28-category occupancy classification (See Table 15.1) is defined that provides for a more refined economic loss analysis. Building replacement cost data is provided for this classification level.

The types of economic data that the user will be expected to supply include repair and replacement costs, contents value for different occupancies, annual gross sales by occupancy, relocation expenses and income by occupancy. While default values are provided for these data, the user may wish to provide more accurate local values or update default values to current dollars.

Direct economic losses for transportation and lifeline systems are limited to the cost of repairing damage to the lifeline system. Default values are provided for replacement values of lifeline components as a guide. It is expected that in a User-Supplied Data Analysis, the user will input replacement values based on knowledge of lifeline values in the region.

Table 15.1: Building Occupancy Classes

No.	Label	Occupancy Class	Description
		Residential	
1	RES1	Single Family Dwelling	Detached House
2	RES2	Mobile Home	Mobile Home
3	RES3	Multi Family Dwelling	Apartment/Condominium
4	RES4	Temporary Lodging	Hotel/Motel
5	RES5	Institutional Dormitory	Group Housing (military, college), Jails
6	RES6	Nursing Home	
		Commercial	
7	COM1	Retail Trade	Store
8	COM2	Wholesale Trade	Warehouse
9	COM3	Personal and Repair Services	Service Station/Shop
10	COM4	Professional/Technical Services	Offices
11	COM5	Banks/Financial Institutions	
12	COM6	Hospital	
13	COM7	Medical Office/Clinic	Offices
14	COM8	Entertainment & Recreation	Restaurants/Bars
15	COM9	Theaters	Theaters
16	COM10	Parking	Garages
		Industrial	
17	IND1	Heavy	Factory
18	IND2	Light	Factory
19	IND3	Food/Drugs/Chemicals	Factory
20	IND4	Metals/Minerals Processing	Factory
21	IND5	High Technology	Factory
22	IND6	Construction	Office
		Agriculture	
23	AGR	Agriculture	
		Religion/Non-Profit	
24	REL	Church	
		Government	
25	GOV1	General Services	Office
26	GOV2	Emergency Response	Police/Fire Station
		Education	
27	ED1	Schools	
28	ED2	Colleges/Universities	Does not include group housing

15.2 Description of Methodology: Buildings

This section describes the estimation of building-related direct economic losses.

15.2.1 Building Repair and Replacement Costs

To establish dollar loss estimates, the damage state probabilities must be converted to dollar loss equivalents. Losses will be due to both structural and non-structural damage. For a given occupancy and damage state, building repair and replacement costs are estimated as the product of the floor area of each building type within the given occupancy, the probability of the building type being in the given damage state, and repair costs of the building type per square foot for the given damage state, summed over all building types within the occupancy.

It can be argued that the true cost of buildings damaged or destroyed is their loss of market value, reflecting the age of the building, depreciation, and the like. Replacement value is a frequently requested output of a loss estimation study, because it gives an immediately understandable picture of the community building losses, and disaster assistance is currently granted on the basis of replacement value. In fact, market value is by no means constant in relation to replacement value. For example, typical estimates of market value include the value of the lot: in locations of high land cost, market value may greatly exceed replacement value (which excludes lot value). Moreover, building age does not necessarily result in a linear loss of market value: after a certain age some buildings begin to acquire additional value by virtue of architectural style and craftsmanship and true replacement cost might greatly exceed market value.

These issues may need to be considered in a detailed evaluation of the direct economic losses where particular building inventories or economic aspects of the damage are being evaluated. Full discussion of these and other related issues may be found in Howe and Cochrane, 1993.

For structural damage, losses are calculated as follows:

$$CS_{ds,i} = CI^* \sum_{j=1}^{36} FA_{i,j} {}^* PMBTSTR_{ds,j} {}^* RCS_{ds,i,j} \tag{15-1}$$

$$CS_i = \sum_{ds=2}^{5} CS_{ds,i} \tag{15-2}$$

where:

$CS_{ds,i}$	cost of structural damage (repair and replacement costs) for damage state ds and occupancy i
CS_i	cost of structural damage (repair and replacement costs) for occupancy i
CI	regional cost index multiplier described in Section 15.2.1.2
$FA_{i,j}$	floor area of model building type j in occupancy group i (in square feet), based on the total floor area of occupancy i and the

	distribution of floor area between model building types described in Chapter 3
$PMBTSTR_{ds,j}$	probability of model building type j being in structural damage state ds, see Chapter 5
$RCS_{ds,i,j}$	structural repair and replacement costs (per square foot) for occupancy i and model building type j in damage state ds, Tables 15.2a through 15.2d

The structural repair cost per square foot for structural damage for each damage state, occupancy, and structural system type is shown in Tables 15.2a through 15.2d. The repair costs for model building types within a structural system type are all the same (e.g. model building types S2L, S2M, and S2H all have the same repair costs listed under structural system type heading S2 in Tables 15.2a through 15.2d). Note that damage state "none" (ds = 1) does not contribute to the calculation of the cost of structural damage and thus the summation in Equation 15-2 is from ds = 2 to ds = 5.

A similar calculation is performed for non-structural damage. Non-structural damage is broken down into acceleration sensitive damage (damage to ceilings, equipment that is an integral part of the facility such as mechanical and electrical equipment, piping and elevators) and drift sensitive damage (partitions, exterior walls, ornamentation and glass). Non-structural damage does not include the damage to contents such as furniture and computers that is accounted for in Section 15.2.2. Non-structural damage costs are calculated as follows:

$$CNSA_{ds,i} = CI*FA_i*PONSA_{ds,i}*RCA_{ds,} \quad (15\text{-}3)$$

$$CNSA_i = \sum_{ds=2}^{5} CNSA_{ds,i} \quad (15\text{-}4)$$

$$CNSD_{ds,i} = CI*FA_i*PONSD_{ds,i}*RCD_{ds,i} \quad (15\text{-}5)$$

$$CNSD_i = \sum_{ds=2}^{5} CNSD_{ds,i} \quad (15\text{-}6)$$

where:

$CNSA_{ds,i}$	cost of acceleration-sensitive non-structural damage (repair and replacement costs) for damage state ds and occupancy i
$CNSA_i$	cost of acceleration-sensitive non-structural damage (repair and replacement costs) for occupancy i
$CNSD_{ds,i}$	cost of drift-sensitive non-structural damage (repair and replacement costs) for damage state ds and occupancy i
$CNSD_i$	cost of drift-sensitive non-structural damage (repair and replacement costs) for occupancy i
CI	regional cost index multiplier described in Section 15.2.1.2

FA_i	floor area of occupancy group i (in square feet)
$PONSA_{ds,i}$	probability of occupancy i being in non-structural acceleration sensitive damage state ds, see Chapter 5
$PONSD_{ds,i}$	probability of occupancy i being in non-structural drift sensitive damage state ds, see Chapter 5
$RCA_{ds,i}$	acceleration sensitive non-structural repair and replacement costs (per square foot) for occupancy i in damage state ds (Table 15-3)
$RCD_{ds,i}$	drift sensitive non-structural repair and replacement costs (per square foot) for occupancy i in damage state ds (Table 15-4)

The cost per square foot for non-structural damage for each damage state are shown in Tables 15.3 and 15.4 for acceleration and drift sensitive non-structural components, respectively.

To determine the total cost of non-structural damage for occupancy class i (CNS_i), Equations 15-4 and 15-6 must be summed.

$$CNS_i = CNSA_i + CNSD_i \qquad (15\text{-}7)$$

The total cost of building damage (CBD_i) for occupancy class i is the sum of the structural and non-structural damage.

$$CBD_i = CS_i + CNS_i \qquad (15\text{-}8)$$

Finally, to determine the total cost of building damage (CBD), Equation 15-8 must be summed over all occupancy classes.

$$CBD = \sum_i CBD_i \qquad (15\text{-}9)$$

15.2.1.1 Default Values for Building Repair Costs

Tables 15.2a through 15.2d show the default values for the repair costs related to the 28 occupancy classifications. These values must be adjusted to reflect different building costs related to location. These adjustment factors are discussed in Section 15.2.1.2. The relative percentage of total building cost allocated to structural and non-structural components is derived from the *Means* component breakdowns for each model building. See Tables 15C.1 and 15C.2 of Appendix 15C.

Tables 15.3 and 15.4 show the default values for the costs of repair of acceleration-sensitive and drift sensitive components. Acceleration sensitive non-structural components include hung ceilings, mechanical and electrical equipment, and elevators. Drift sensitive components include partitions, exterior wall panels, and glazing. Based on the component breakdown provided in *Means* the relative percentages of drift and acceleration sensitive components, (aggregated and numbers rounded off) are estimated as follows:

Occupancy	Acceleration sensitive components	Drift sensitive components
Single Family residential	35%	65%
Other residential	50%	50%
Commercial	60%	40%
Industrial	85%	15%
Agriculture	85%	15%
Religion	60%	40%
Government	60%	40%
Education	35%	65%

The cost of damage is expressed as a percentage of the complete damage state. The assumed relationship between damage states and repair/replacement costs, for both structural and non-structural components, is as follows:

Slight damage:	2% of complete
Moderate damage:	10% of complete
Extensive damage:	50% of complete

These values are consistent with and in the range of the damage definitions and corresponding damage ratios presented in *ATC-13 Earthquake Damage Evaluation Data for California*. For specific building inventories, at an Advanced Data and Models Analysis, more precise estimates of structural/non-structural quantity and cost relationships could be obtained by the user.

Table 15.2a: Structural Repair Costs for Complete Damage (Dollars Per Square Foot)

	Structural System Type															
Occupancy	W1	W2	S1	S2	S3	S4	S5	C1	C2	C3	PC1	PC2	RM1	RM2	URM	MH
RES1	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	*
RES2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	11
RES3	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	*
RES4	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
RES5	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
RES6	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
COM1	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
COM2	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
COM3	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
COM4	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
COM5	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
COM6	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
COM7	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
COM8	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
COM9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
COM10	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
IND1	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
IND2	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
IND3	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
IND4	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
IND5	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
IND6	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
AGR1	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
REL1	17	17	17	17	17	17	17	17	17	17	0	17	17	17	17	17
GOV1	12	12	12	12	12	12	12	12	12	12	0	12	12	12	12	12
GOV2	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
EDU1	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
EDU2	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11

Table 15.2b: Structural Repair Costs for Extensive Damage (Dollars Per Square Foot)

	Structural System Type															
Occupancy	W1	W2	S1	S2	S3	S4	S5	C1	C2	C3	PC1	PC2	RM1	RM2	URM	MH
RES1	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	4.5	4.5	*
RES2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	3.3
RES3	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	3.3	3.3	*
RES4	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	3.3	3.3	3.3
RES5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	4.5	4.5	4.5
RES6	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	4.2	4.2	4.2
COM1	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	4.5	4.5	4.5
COM2	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	3.3	3.3	3.3
COM3	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	3.3	3.3	3.3
COM4	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	4.2	4.2	4.2
COM5	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	4.8	4.8	4.8
COM6	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	5.1	5.1	5.1
COM7	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	3.9	3.9	3.9
COM8	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	3.0	3.0	3.0
COM9	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	2.7	2.7	2.7
COM10	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	4.2	4.2	4.2
IND1	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	2.4	2.4	2.4
IND2	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	2.4	2.4	2.4
IND3	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	2.4	2.4	2.4
IND4	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	2.4	2.4	2.4
IND5	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	2.4	2.4	2.4
IND6	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	2.4	2.4	2.4
AGR1	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	1.8	1.8	1.8
REL1	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	0.0	8.5	8.5	5.1	5.1	5.1
GOV1	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	0.0	6.0	6.0	3.6	3.6	3.6
GOV2	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	5.1	5.1	5.1
EDU1	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	4.2	4.2	4.2
EDU2	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	3.3	3.3	3.3

Table 15.2c: Structural Repair Costs for Moderate Damage (Dollars Per Square Foot)

	Structural System Type															
Occupancy	W1	W2	S1	S2	S3	S4	S5	C1	C2	C3	PC1	PC2	RM1	RM2	URM	MH
RES1	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	*
RES2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	1.1
RES3	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	*
RES4	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
RES5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
RES6	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
COM1	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
COM2	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
COM3	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
COM4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
COM5	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
COM6	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
COM7	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
COM8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
COM9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
COM10	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
IND1	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
IND2	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
IND3	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
IND4	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
IND5	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
IND6	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
AGR1	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
REL1	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	*	1.7	1.7	1.7	1.7	1.7
GOV1	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	*	1.2	1.2	1.2	1.2	1.2
GOV2	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
EDU1	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
EDU2	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1

Table 15.2d: Structural Repair Costs for Slight Damage (Dollars Per Square Foot)

	Structural System Type															
Occupancy	W1	W2	S1	S2	S3	S4	S5	C1	C2	C3	PC1	PC2	RM1	RM2	URM	MH
RES1	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	*
RES2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.2
RES3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	*
RES4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
RES5	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
RES6	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
COM1	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
COM2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
COM3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
COM4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
COM5	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
COM6	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
COM7	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
COM8	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
COM9	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
COM10	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
IND1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
IND2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
IND3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
IND4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
IND5	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
IND6	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
AGR1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
REL1	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	*	0.3	0.3	0.3	0.3	0.3
GOV1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	*	0.2	0.2	0.2	0.2	0.2
GOV2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
EDU1	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
EDU2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Table 15.3: Acceleration Sensitive Non-structural Repair Costs (Dollars Per Square Foot)

No.	Label	Occupancy Class	Acceleration Sensitive Non-structural Damage State			
			Slight	Moderate	Extensive	Complete
		Residential				
1	RES1	Single Family Dwelling	0.3	1.7	5.1	17
2	RES2	Mobile Home	0.3	1.7	5.1	17
3	RES3	Multi Family Dwelling	0.7	3.5	10.5	35
4	RES4	Temporary Lodging	0.7	3.5	10.5	35
5	RES5	Institutional Dormitory	0.7	3.3	9.9	33
6	RES6	Nursing Home	0.6	3.1	9.3	31
		Commercial				
7	COM1	Retail Trade	0.4	2.2	6.6	22
8	COM2	Wholesale Trade	0.3	1.4	4.2	14
9	COM3	Personal and Repair Services	0.7	3.4	10.2	34
10	COM4	Professional/Technical/ Business Services	0.7	3.5	10.5	35
11	COM5	Banks/Financial Institutions	1.2	6.0	18.0	60
12	COM6	Hospital	1.2	6.2	18.6	62
13	COM7	Medical Office/Clinic	0.9	4.6	13.8	46
14	COM8	Entertainment & Recreation	1.1	5.5	16.5	55
15	COM9	Theaters	0.8	3.9	11.7	39
16	COM10	Parking	0.1	0.5	1.5	5
		Industrial				
17	IND1	Heavy	0.7	3.7	11.1	37
18	IND2	Light	0.7	3.7	11.1	37
19	IND3	Food/Drugs/Chemicals	0.7	3.7	11.1	37
20	IND4	Metals/Minerals Processing	0.7	3.7	11.1	37
21	IND5	High Technology	0.7	3.7	11.1	37
22	IND6	Construction	0.7	3.7	11.1	37
		Agriculture				
23	AGR1	Agriculture	0.1	0.6	1.8	6
		Religion/Non-Profit				
24	REL1	Church/Membership Organization	0.8	4.1	12.3	41
		Government				
25	GOV1	General Services	0.7	3.3	9.9	33
26	GOV2	Emergency Response	1.1	5.6	16.8	56
		Education				
27	EDU1	Schools/Libraries	0.5	2.4	7.2	24
28	EDU2	Colleges/Universities	0.6	2.9	8.7	29

Table 15.4: Drift Sensitive Non-structural Repair Costs (Dollars Per Square Foot)

No.	Label	Occupancy Class	Drift Sensitive Non-structural Damage State			
			Slight	Moderate	Extensive	Complete
		Residential				
1	RES1	Single Family Dwelling	0.6	3.2	16.0	32.0
2	RES2	Mobile Home	0.3	1.7	8.5	17.0
3	RES3	Multi Family Dwelling	0.7	3.4	17.0	34.0
4	RES4	Temporary Lodging	0.7	3.5	17.5	35.0
5	RES5	Institutional Dormitory	0.6	3.2	16.0	32.0
6	RES6	Nursing Home	0.6	3.1	15.5	31.0
		Commercial				
7	COM1	Retail Trade	0.3	1.4	7.0	14.0
8	COM2	Wholesale Trade	0.2	0.9	4.5	9.0
9	COM3	Personal and Repair Services	0.5	2.3	11.5	23.0
10	COM4	Professional/Technical/ Business Services	0.5	2.4	12.0	24.0
11	COM5	Banks/Financial Institutions	0.8	4.0	20.0	40.0
12	COM6	Hospital	0.8	4.2	21.0	42.0
13	COM7	Medical Office/Clinic	0.6	3.1	15.5	31.0
14	COM8	Entertainment & Recreation	0.7	3.6	18.0	36.0
15	COM9	Theaters	0.5	2.6	13.0	26.0
16	COM10	Parking	0.1	0.4	2.0	4.0
		Industrial				
17	IND1	Heavy	0.1	0.6	3.0	6.0
18	IND2	Light	0.1	0.6	3.0	6.0
19	IND3	Food/Drugs/Chemicals	0.1	0.6	3.0	6.0
20	IND4	Metals/Minerals Processing	0.1	0.6	3.0	6.0
21	IND5	High Technology	0.1	0.6	3.0	6.0
22	IND6	Construction	0.1	0.6	3.0	6.0
		Agriculture				
23	AGR1	Agriculture	*	0.1	0.5	1
		Religion/Non-Profit				
24	REL1	Church/Membership Organization	0.6	2.8	14	28
		Government				
25	GOV1	General Services	0.4	2.2	11	22
26	GOV2	Emergency Response	0.8	3.8	19	38
		Education				
27	EDU1	Schools/Libraries	0.7	3.6	18	36
28	EDU2	Colleges/Universities	1.2	6.0	30	60

Note that the costs in Table 15.2a and in the last column of Tables 15.3 and 15.4 correspond to replacement costs, since the complete damage state implies that the structure must be replaced. The replacement value of the structure is the sum of the structural and non-structural components. Thus to determine total replacement cost per square foot for a particular occupancy, one must sum values from Tables 15.2a, 15.3 and 15.4 as follows:

$$RC_i = CI*[RCA_{5,i} + RCD_{5,i} + RCS_{5,i}] \quad (15\text{-}10)$$

$$RCS_{5,i} = \sum_{j=1}^{36} RCMBT_{5,i,j}*FA_{i,j}/FA_i$$

where:

RC_i	replacement costs (per square foot) for occupancy i
CI	regional cost index multiplier described in Section 15.2.1.2
$RCA_{5,i}$	acceleration sensitive non-structural repair (per square foot) for occupancy i in damage state 5
$RCD_{5,i}$	drift sensitive non-structural repair (per square foot) for occupancy i in damage state 5
$RCS_{5,i}$	structural repair costs (per square foot) for occupancy i in damage state 5
$RCMBT_{5,i,j}$	structural replacement cost for model building type j in occupancy i in damage state 5
$FA_{i,j}$	floor area of model building type j in occupancy group i (in square feet), see Equation 15-1
FA_i	floor area of occupancy group i (in square feet)

The replacement costs (damage state = complete) shown in Tables 15.2a, 15.3, and 15.4 are derived from Means Square Foot Costs 1994, for Residential, Commercial, Industrial, and Institutional buildings. The Means publication is a nationally accepted reference on building construction costs, which is published annually. This publication provides cost information for a number of low-rise residential model buildings, and for 70 other residential, commercial, institutional and industrial buildings. These are presented in a format that shows typical costs for each model building, showing variations by size of building, type of building structure, and building enclosure. One of these variations is chosen as "typical" for this model, and a breakdown is provided that shows the cost and percentages of each building system or component. From this breakdown it is possible to determine the relative value of structural and non-structural components for each model building. In addition, for each model building, the spread of costs from the database is provided.

For example, the model building representing a 5-10 story office building is an 8-story building with 100,000 square feet of floor area. The typical square foot cost is

$67.80/square foot, based on a steel frame structure with precast concrete panel exterior. The cost related to building area varies from $73.90/square foot for a 50,000 square foot building to $66.15/square foot for a building of 130,000 square feet. Depending on the exterior cladding, the cost varies from $67.80/square foot to $74.85/square foot. A range of completed project costs from $41.15 to $116.85 per square foot have been reported for this type of structure depending on design alternatives, owners requirements, and geographical location.

The Means typical costs omit site work costs, but include 15% contractors overhead and profit, and a cost for the architect's fee that varies from 6 % to 11 % of construction cost according to occupancy type. In addition, an **additional 15% has been added** to the Means costs to reflect cost of financing, decision-making delays and additional construction services such as repair and/or demolition. Finally, in view of the generic nature of this analysis, the Means square foot costs have been rounded to the nearest dollar.

For the loss estimation methodology, selected Means models have been chosen from the 70 plus models that represent the 28 occupancy types. The wide range of costs shown, even for a single model, emphasize the importance of understanding that the dollar values shown should only be used to represent costs of large aggregations of building types. If costs for single buildings or small groups (such as a college campus) are desired for more detailed loss analysis, then local building specific cost estimates should be used.

The Means model buildings are classified by occupancy. It is clear from the cost breakdowns that cost variations relate much more to occupancy than to material or structural system type.

Since Means is published annually, fluctuations in typical building cost can be tracked and the user can insert the most up-to-date Means typical building cost into the default database. This procedure is outlined in Section 15.2.1.3.

15.2.1.2 Default Values for Regional Cost Variation

Construction costs vary significantly from one location to another. In order to account for this, the methodology provides default values for multipliers to be applied to the typical costs provided in Tables 15.2 through 15.4, which are based on National averages for materials and installation. These multipliers are shown in the Means Square Foot Cost publication as *Historical Cost Indices.* Means provides indices for a number of cities in each state (some of the smaller states have one or two cities only). This information, along with expert opinion, was used to develop default regional cost modifiers for each state in the United States. Since certain counties in each state can vary drastically from the statewide average (e.g. California = 116.9 versus San Francisco = 132.7), county exceptions are provided for a limited number of counties. The default values for regional cost variation are presented in Appendix 15A, Table 15A.1.

In calculating losses, values in Tables 15.2a through 15.4 are multiplied by the local index/100. For example, for buildings located in Boston (see Table 15A.1), values in Tables 15.2a through 15.4 are multiplied by 1.256.

15.2.1.3 Procedure for Updating Building Cost Estimates

The typical costs shown in Tables 15.2 through 15.4 are for 1994. The historical cost indices provided in the Means publication can also be used to adjust costs (generally upwards) to the year in which the loss estimate is being implemented. (It will be necessary for the user to obtain access to the Means publication for the year of implementation.)

Means provides cost indices, for the 200 representative cities, for the last 54 years (i.e. 1994 to 1940). These are updated each year, so the difference in index for a given city relative to 1994 can be ascertained from the list and the user can adjust the default value, if the difference is judged to be significant.

15.2.2 Building Contents Losses

Building contents are defined as furniture, equipment that is not integral with the structure, computers and other supplies. Contents do not include inventory or non-structural components (see Section 15.2.1) such as lighting, ceilings, mechanical and electrical equipment and other fixtures. It is assumed that most contents damage, such as overturned cabinets and equipment or equipment sliding off tables and counters, is a function of building accelerations. Therefore, acceleration sensitive non-structural damage is considered to be a good indicator of contents damage. That is, if there is no acceleration sensitive non-structural damage, it is unlikely that there will be contents damage. The cost of contents damage is calculated as follows:

$$CCD_i = CI*CV_i*\sum_{ds=2}^{5} CD_{ds,i}*RC_{ds,i} \qquad (15\text{-}11)$$

$$RC_{ds,i} = \sum_{j=1}^{36} PMBTNSA_{ds,j}*FA_{i,j}*(RCA_{5,i}+RCD_{5,i}+RCMBT_{5,i,j})$$

where:

CCD_i	cost of contents damage for occupancy i
CI	regional cost index multiplier described in Section 15.2.1.2
CV_i	contents value for occupancy i (expressed as percent of replacement value, see Table 15.5)
$CD_{ds,i}$	percent contents damage for occupancy i in damage state ds (from Table 15.6)
$RC_{ds,i}$	replacement costs (dollars) for occupancy i in damage state ds

$PMBTNSA_{ds,j}$	the probability of model building type j being in non-structural acceleration sensitive damage state ds, see Chapter 5
$FA_{i,j}$	floor area of model building type j in occupancy group i (in square feet), see Equation 15-1
$RCA_{5,i}$	acceleration sensitive non-structural repair (per square foot) for occupancy i in damage state 5, Table 15.3
$RCD_{5,i}$	drift sensitive non-structural repair (per square foot) for occupancy i in damage state 5, Table 15.4
$RCMBT_{5,i,j}$	structural repair cost (per square foot) for model building type j in occupancy 5 in damage state 5, Table 15.2a

Table 15.5 provides default contents values for each occupancy as a percentage of the replacement value of the facility. This table is based on values found in Table 4.11 of ATC-13 [ATC, 1985]. The contents damage percentages in Table 15.6 assume that at complete damage state some percentage of contents, set at 15%, can be retrieved. At the present time, contents damage percentages in Table 15.6 are the same for all occupancies.

Table 15.5: Contents Value as Percentage of Building Replacement Value (from Table 4.11 of ATC-13, 1985)

No.	Label	Occupancy Class	Contents Value (%)
		Residential	
1	RES1	Single Family Dwelling	50
2	RES2	Mobile Home	50
3	RES3	Multi Family Dwelling	50
4	RES4	Temporary Lodging	50
5	RES5	Institutional Dormitory	50
6	RES6	Nursing Home	50
		Commercial	
7	COM1	Retail Trade	100
8	COM2	Wholesale Trade	100
9	COM3	Personal and Repair Services	100
10	COM4	Professional/Technical/ Business Services	100
11	COM5	Banks	100
12	COM6	Hospital	150
13	COM7	Medical Office/Clinic	150
14	COM8	Entertainment & Recreation	100
15	COM9	Theaters	100
16	COM10	Parking	50
		Industrial	
17	IND1	Heavy	150
18	IND2	Light	150
19	IND3	Food/Drugs/Chemicals	150
20	IND4	Metals/Minerals Processing	150
21	IND5	High Technology	150
22	IND6	Construction	100
		Agriculture	
23	AGR1	Agriculture	100
		Religion/Non/Profit	
24	REL1	Church/Membership Organization	100
		Government	
25	GOV1	General Services	100
26	GOV2	Emergency Response	150
		Education	
27	EDU1	Schools/Libraries	100
28	EDU2	Colleges/Universities	150

Table 15.6: Percent Contents Damage

No.	Label	Occupancy Class	Acceleration Sensitive Non-structural Damage State			
			Slight	Moderate	Extensive	Complete*
		Residential				
1	RES1	Single Family Dwelling	1	5	25	50
2	RES2	Mobile Home	1	5	25	50
3	RES3	Multi Family Dwelling	1	5	25	50
4	RES4	Temporary Lodging	1	5	25	50
5	RES5	Institutional Dormitory	1	5	25	50
6	RES6	Nursing Home	1	5	25	50
		Commercial				
7	COM1	Retail Trade	1	5	25	50
8	COM2	Wholesale Trade	1	5	25	50
9	COM3	Personal and Repair Services	1	5	25	50
10	COM4	Professional/Technical/ Business Services	1	5	25	50
11	COM5	Banks/Financial Institutions	1	5	25	50
12	COM6	Hospital	1	5	25	50
13	COM7	Medical Office/Clinic	1	5	25	50
14	COM8	Entertainment & Recreation	1	5	25	50
15	COM9	Theaters	1	5	25	50
16	COM10	Parking	1	5	25	50
		Industrial				
17	IND1	Heavy	1	5	25	50
18	IND2	Light	1	5	25	50
19	IND3	Food/Drugs/Chemicals	1	5	25	50
20	IND4	Metals/Minerals Processing	1	5	25	50
21	IND5	High Technology	1	5	25	50
22	IND6	Construction	1	5	25	50
		Agriculture				
23	AGR1	Agriculture	1	5	25	50
		Religion/Non-Profit				
24	REL1	Church/Membership Organization	1	5	25	50
		Government				
25	GOV1	General Services	1	5	25	50
26	GOV2	Emergency Response	1	5	25	50
		Education				
27	EDU1	Schools/Libraries	1	5	25	50
28	EDU2	Colleges/Universities	1	5	25	50

*At complete damage state, it is assumed that some salvage of contents will take place.

15.2.3 Business Inventory Losses

Business inventories vary considerably with occupancy. For example, the value of inventory for a high tech manufacturing facility would be very different from that of a retail store. Thus, it is assumed for this model that business inventory for each occupancy class is based on annual sales. Since losses to business inventory most likely occur from stacks of inventory falling over, objects falling off shelves, or from water damage when piping breaks, it is assumed, as it was with building contents, that acceleration sensitive non-structural damage is a good indicator of losses to business inventory. Business inventory losses then become the product of the total inventory value (floor area times the percent of gross sales or production per square foot) of buildings of a given occupancy in a given acceleration-sensitive damage state, the percent loss to the inventory and the probability of given damage states. The business inventory losses are given by the following expressions.

$$INV_i = FA_i * SALES_i * BI_i * \sum_{ds=2}^{5} PONSA_{ds,i} * INVD_{ds,i} \qquad (15\text{-}12)$$

$$INV = INV_7 + INV_8 + \sum_{i=17}^{23} INV_i \qquad (15\text{-}13)$$

where:

INV_i	value of inventory losses for occupancy i
INV	total value of inventory losses
FA_i	floor area of occupancy group i (in square feet)
$SALES_i$	annual gross sales or production (per square foot) for occupancy i (see Table 15.7)
BI_i	business inventory as a percentage of annual gross sales for occupancy i (i = 7, 8, 17-23, see Table 15.8)
$PONSA_{ds,i}$	probability of occupancy i being in non-structural acceleration sensitive damage state ds, see Chapter 5
$INVD_{ds,i}$	percent inventory damage for occupancy i in damage state ds (from Table 15.9)

Statistics representing national or state economic sectors may not adequately reflect the regional situation. Therefore, estimates of annual gross sales or the value of production for any one of the 28 economic sectors can vary widely depending on the type of firms that are located in the region. It is important to review and adjust any data to insure that the regional economy is correctly portrayed. Annual sales or production per square foot of building can be estimated by dividing the output-employment ratio (sector output/sector employment) by the average floor space occupied by employee. Current data to derive the regional (county or standard metropolitan statistical area), sector output-employment ratio is usually available from either the state or the U.S. Department of Commerce's Bureau of Economic Analysis [(202) 482-1986]. The annual sales per square foot for the agriculture category are for greenhouses. The average sector floor space occupied per employee is based on values found in ATC-13, table 4.7 (pages 94-97). Judgment was used in estimating of business inventory as a percent of gross annual sales.

Table 15.7: Annual Gross Sales or Production (Dollars per Square Foot)

No.	Label	Occupancy Class	1990 Output/ Employment*	Sq. ft. floor Space/Employee**	Annual Sales ($/ft^2)
		Commercial			
7	COM1	Retail Trade	$24,979	825	30
8	COM2	Wholesale Trade	$38,338	900	43
		Industrial			
17	IND1	Heavy	$220,212	550	400
18	IND2	Light	$74,930	590	127
19	IND3	Food/Drugs/Chemicals	$210,943	540	391
20	IND4	Metals/Minerals Processing	$268,385	730	368
21	IND5	High Technology	$73,517	300	245
22	IND6	Construction	$107,739	250	431
		Agriculture			
23	AGR1	Agriculture	$20,771	250	83

* Typical sector values.
** ATC-13, Table 4.7, pages 94-97 (ATC, 1985).

Table 15.8: Business Inventory (% of Gross Annual Sales)

No.	Label	Occupancy Class	Business Inventory (%)
		Commercial	
7	COM1	Retail Trade	13
8	COM2	Wholesale Trade	10
		Industrial	
17	IND1	Heavy	5
18	IND2	Light	4
19	IND3	Food/Drugs/Chemicals	5
20	IND4	Metals/Minerals Processing	3
21	IND5	High Technology	4
22	IND6	Construction	2
		Agriculture	
23	AGR1	Agriculture	8

Table 15.9: Percent Business Inventory Damage

No.	Label	Occupancy Class	Acceleration Sensitive Non-structural Damage State			
			Slight	Moderate	Extensive	Complete*
		Commercial				
7	COM1	Retail Trade	1	5	25	50
8	COM2	Wholesale Trade	1	5	25	50
		Industrial				
17	IND1	Heavy	1	5	25	50
18	IND2	Light	1	5	25	50
19	IND3	Food/Drugs/Chemicals	1	5	25	50
20	IND4	Metals/Minerals Processing	1	5	25	50
21	IND5	High Technology	1	5	25	50
22	IND6	Construction	1	5	25	50
		Agriculture				
23	AGR1	Agriculture	1	5	25	50

*At complete damage state, it is assumed that some salvage of inventory will take place.

15.2.4 Building Repair Time/Loss of Function

The damage state descriptions provide a basis for establishing loss of function and repair time. A distinction should be made between loss of function and repair time. Here loss of function is the time that a facility is not capable of conducting business. This, in general, will be shorter than repair time because business will rent alternative space while repairs and construction are being completed. The time to repair a damaged building can be divided into two parts: construction and clean-up time, and time to obtain financing, permits and complete design. For the lower damage states, the construction time will be close to the real repair time. At the higher damage levels, a number of additional tasks must be undertaken that typically will considerably increase the actual repair time. These tasks, which may vary considerably in scope and time between individual projects, include:

- Decision-making (related to business of institutional constraints, plans, financial status, etc.)
- Negotiation with FEMA (for public and non-profit), SBA etc.
- Negotiation with insurance company, if insured
- Obtain financing
- Contract negotiation with design firms(s)
- Detailed inspections and recommendations
- Preparation of contract documents
- Obtain building and other permits
- Bid/negotiate construction contract
- Start-up and occupancy activities after construction completion

Building repair and clean-up times are presented in Table 15.10. These times represent estimates of the median time for actual cleanup and repair, or construction. These estimates are extended in Table 15.11 to account for delays in decision-making, financing, inspection etc., as outlined above, and represent estimates of the median time for recovery of building functions.

Table 15.10: Building Cleanup and Repair Time (Construction) (Time in Days)

No.	Label	Occupancy Class	Construction Time				
			Structural Damage State				
			None	Slight	Moderate	Extensive	Complete
		Residential					
1	RES1	Single Family Dwelling	0	2	30	90	180
2	RES2	Mobile Home	0	2	10	30	60
3	RES3	Multi Family Dwelling	0	5	30	120	240
4	RES4	Temporary Lodging	0	5	30	120	240
5	RES5	Institutional Dormitory	0	5	30	120	240
6	RES6	Nursing Home	0	5	30	120	240
		Commercial					
7	COM1	Retail Trade	0	5	30	90	180
8	COM2	Wholesale Trade	0	5	30	90	180
9	COM3	Personal and Repair Services	0	5	30	90	180
10	COM4	Professional/Technical/ Business Services	0	5	30	120	240
11	COM5	Banks/Financial Institutions	0	5	30	90	180
12	COM6	Hospital	0	10	45	180	360
13	COM7	Medical Office/Clinic	0	10	45	180	240
14	COM8	Entertainment & Recreation	0	5	30	90	180
15	COM9	Theaters	0	5	30	120	240
16	COM10	Parking	0	2	20	80	160
		Industrial					
17	IND1	Heavy	0	10	30	120	240
18	IND2	Light	0	10	30	120	240
19	IND3	Food/Drugs/Chemicals	0	10	30	120	240
20	IND4	Metals/Minerals Processing	0	10	30	120	240
21	IND5	High Technology	0	20	45	180	360
22	IND6	Construction	0	5	20	80	160
		Agriculture					
23	AGR1	Agriculture	0	2	10	30	60
		Religion/Non-Profit					
24	REL1	Church/Membership Organization	0	10	30	120	240
		Government					
25	GOV1	General Services	0	10	30	120	240
26	GOV2	Emergency Response	0	5	20	90	180
		Education					
27	EDU1	Schools/Libraries	0	10	30	120	240
28	EDU2	Colleges/Universities	0	10	45	180	360

Table 15.11: Building Recovery Time
(Time in Days)

No.	Label	Occupancy Class	Recovery Time				
			Structural Damage State				
			None	**Slight**	**Moderate**	**Extensive**	**Complete**
		Residential					
1	RES1	Single Family Dwelling	0	5	120	360	720
2	RES2	Mobile Home	0	5	20	120	240
3	RES3	Multi Family Dwelling	0	10	120	480	960
4	RES4	Temporary Lodging	0	10	90	360	480
5	RES5	Institutional Dormitory	0	10	90	360	480
6	RES6	Nursing Home	0	10	120	480	960
		Commercial					
7	COM1	Retail Trade	0	10	90	270	360
8	COM2	Wholesale Trade	0	10	90	270	360
9	COM3	Personal and Repair Services	0	10	90	270	360
10	COM4	Professional/Technical/ Business Services	0	20	90	360	480
11	COM5	Banks/Financial Institutions	0	20	90	180	360
12	COM6	Hospital	0	20	135	540	720
13	COM7	Medical Office/Clinic	0	20	135	270	540
14	COM8	Entertainment & Recreation	0	20	90	180	360
15	COM9	Theaters	0	20	90	180	360
16	COM10	Parking	0	5	60	180	360
		Industrial					
17	IND1	Heavy	0	10	90	240	360
18	IND2	Light	0	10	90	240	360
19	IND3	Food/Drugs/Chemicals	0	10	90	240	360
20	IND4	Metals/Minerals Processing	0	10	90	240	360
21	IND5	High Technology	0	20	135	360	540
22	IND6	Construction	0	10	60	160	320
		Agriculture					
23	AGR1	Agriculture	0	2	20	60	120
		Religion/Non-Profit					
24	REL1	Church/Membership Organization	0	5	120	480	960
		Government					
25	GOV1	General Services	0	10	90	360	480
26	GOV2	Emergency Response	0	10	60	270	360
		Education					
27	EDU1	Schools/Libraries	0	10	90	360	480
28	EDU2	Colleges/Universities	0	10	120	480	960

Repair times differ for similar damage states depending on building occupancy: thus simpler and smaller buildings will take less time to repair than more complex, heavily serviced or larger buildings. It has also been noted that large well-financed corporations can sometimes accelerate the repair time compared to normal construction procedures.

However, establishment of a more realistic repair time does not translate directly into business or service interruption. For some businesses, building repair time is largely irrelevant, because these businesses can rent alternative space or use spare industrial/commercial capacity elsewhere. These factors are reflected in Table 15.12, which provides multipliers to be applied to the values in Table 15.11 to arrive at estimates of business interruption for economic purposes. The factors in Tables 15.10, 15.11, and 15.12 are judgmentally derived, using ATC-13, Table 9.11 as a starting point.

The times resulting from the application of the Table 15.12 multipliers to the times shown in Table 15.11 represent median values for the probability of business or service interruption. For none and slight damage the time loss is assumed to be short, with cleanup by staff, but work can resume while slight repairs are done. For most commercial and industrial businesses that suffer moderate or extensive damage, the business interruption time is shown as short on the assumption that these concerns will find alternate ways of continuing their activities. The values in Table15.12 also reflect the fact that a proportion of business will suffer longer outages or even fail completely. Church and Membership Organizations generally quickly find temporary accommodation, and government offices also resume operating almost at once. It is assumed that hospitals and medical offices can continue operating, perhaps with some temporary rearrangement and departmental relocation if necessary, after moderate damage, but with extensive damage their loss of function time is also assumed to be equal to the total time for repair.

For other businesses and facilities, the interruption time is assumed to be equal to, or approaching, the total time for repair. This applies to residential, entertainment, theaters, parking, and religious facilities whose revenue or continued service, is dependent on the existence and continued operation of the facility.

The modifiers from Table 15.12 are multiplied by extended building construction times as follows:

$$LOF_{ds} = BCT_{ds} * MOD_{ds} \tag{15-14}$$

where:

LOF_{ds}	loss of function for damage state ds
BCT_{ds}	building construction and clean up time for damage state ds (See Table 15.11)
MOD_{ds}	construction time modifiers for damage state ds (See Table 15.12)

The median value applies to a large inventory of facilities. Thus, at moderate damage, some marginal businesses may close, while others will open after a day's cleanup. Even with extensive damage, some businesses will accelerate repair, while a number will also close or be demolished. For example, one might reasonably assume that a URM building that suffers moderate damage is more likely to be demolished than a newer building that suffers moderate, or even, extensive damage. If the URM building is an historic structure its likelihood of survival and repair will probably increase. There will also be a small number of extreme cases: the slightly damaged building that becomes derelict, or the extensively damaged building that continues to function for years, with temporary shoring, until an expensive repair is financed and executed.

Table 15.12: Building and Service Interruption Time Multipliers

No.	Label	Occupancy Class	Construction Time Structural Damage State				
			None	Slight	Moderate	Extensive	Complete
		Residential					
1	RES1	Single Family Dwelling	0	0	0.5	1	1
2	RES2	Mobile Home	0	0	0.5	1	1
3	RES3	Multi Family Dwelling	0	0	0.5	1	1
4	RES4	Temporary Lodging	0	0	0.5	1	1
5	RES5	Institutional Dormitory	0	0	0.5	1	1
6	RES6	Nursing Home	0	0	0.5	1	1
		Commercial					
7	COM1	Retail Trade	0.5	0.1	0.1	0.3	0.4
8	COM2	Wholesale Trade	0.5	0.1	0.2	0.3	0.4
9	COM3	Personal and Repair Services	0.5	0.1	0.2	0.3	0.4
10	COM4	Professional/Technical/ Business Services	0.5	0.1	0.1	0.2	0.3
11	COM5	Banks/Financial Institutions	0.5	0.1	0.05	0.03	0.03
12	COM6	Hospital	0.5	0.1	0.5	0.5	0.5
13	COM7	Medical Office/Clinic	0.5	0.1	0.5	0.5	0.5
14	COM8	Entertainment & Recreation	0.5	0.1	1	1	1
15	COM9	Theaters	0.5	0.1	1	1	1
16	COM10	Parking	0.1	0.1	1	1	1
		Industrial					
17	IND1	Heavy	0.5	0.5	1	1	1
18	IND2	Light	0.5	0.1	0.2	0.3	0.4
19	IND3	Food/Drugs/Chemicals	0.5	0.2	0.2	0.3	0.4
20	IND4	Metals/Minerals Processing	0.5	0.2	0.2	0.3	0.4
21	IND5	High Technology	0.5	0.2	0.2	0.3	0.4
22	IND6	Construction	0.5	0.1	0.2	0.3	0.4
		Agriculture					
23	AGR1	Agriculture	0	0	0.05	0.1	0.2
		Religion/Non-Profit					
24	REL1	Church/Membership Organization	1	0.2	0.05	0.03	0.03
		Government					
25	GOV1	General Services	0.5	0.1	0.02	0.03	0.03
26	GOV2	Emergency Response	0.5	0.1	0.02	0.03	0.03
		Education					
27	EDU1	Schools/Libraries	0.5	0.1	0.02	0.05	0.05
28	EDU2	Colleges/Universities	0.5	0.1	0.02	0.03	0.03

Further discussion of the problem of estimating business interruption times is contained in Appendix B to this chapter.

An analogous situation exists for transportation and utility lifelines. For example, in many instances loss of portions of a freeway network can be offset by use of alternative surface streets. Occasionally, a bridge may represent the only means of access to a community. In this case, the downtime is directly significant and the economic losses may greatly exceed the cost of bridge replacement. The relationships between lifeline loss of function and loss of customer service is not direct because of the possibility of redundancy, alternative routings, and the fact that lifeline interruption is a routine occurrence for utility companies and common procedures are available to deal with it.

15.2.5 Relocation Expenses

Relocation costs may be incurred when the level of building damage is such that the building or portions of the building are unusable while repairs are being made. While relocation costs may include a number of expenses, in this model, only the following components are considered: **disruption costs** that include the cost of shifting and transferring, and the **rental** of temporary space. It should be noted that the burden of relocation expenses are not expected to be borne by the renter. Instead it is assumed that the building owners will incur the expense of moving their tenants to a new location. It should also be noted that a renter who has been displaced from a property due to earthquake damage would cease to pay rent to the owner of the damaged property and only pay rent to the new landlord. Therefore, the renter has no new rental expenses. It is assumed that the owner of the damaged property will pay the disruption costs for his renter. If the damaged property is owner occupied, then the owner will have to pay for disruption costs in addition to the cost of rent while he is repairing his building.

It is assumed in this model that it is unlikely that an occupant will relocate if a building is in the damage states none or slight. The exceptions are some government or emergency response services that need to be operational immediately after an earthquake. However these are considered to contribute very little to the total relocation expenses for a region and are ignored. Finally, it is assumed that entertainment, theaters, parking facilities and heavy industry (occupancy classes 14 to 17) will not relocate to new facilities. Instead they will resume operation when their facilities have been repaired or replaced. Relocation expenses are then a function of the floor area, the rental costs per day per square foot, a disruption cost, the expected days of loss of function for each damage state, the type of occupancy and the damage state itself. These are given by the following expression.

$$REL_i = FA_i * \begin{bmatrix} (1 - \%OO_i) * \sum_{ds=3}^{5} (POSTR_{ds,i} * DC_i) + \\ \%OO_i * \sum_{ds=3}^{5} (POSTR_{ds,i} * (DC_i + RENT_i * RT_{ds}) * \end{bmatrix} \quad (15\text{-}15)$$

where:

REL_i relocation costs for occupancy class i (i = 1-13 and 18-28)

FA_i	floor area of occupancy class i (in square feet)
$POSTR_{ds,i}$	probability of occupancy class i being in structural damage state ds, see Chapter 5
DC_i	disruption costs for occupancy i (\$/ft^2, See Table 15.13)
RT_{ds}	recovery time for damage state ds (See Table 15.11)
%OO	percent owner occupied for occupancy i (See Table 15.14)
$RENT_i$	rental cost (\$/ft^2/day) for occupancy i (See Table 15.13)

The default values for rental costs and disruption costs are typical 1994 values. However, actual values will vary from region to region; local numbers should be substituted for the default values for Default and User-Supplied Data Analyses. Regional numbers are commonly available from Chambers of Commerce or state and/or local regional economic development agencies.

Table 15.13: Rental Costs and Disruption Costs

No.	Label	Occupancy Class	Rental Cost ($/ft²/month)	Rental Cost ($/ft²/day)	Disruption Costs ($/ft²)
		Residential			
1	RES1	Single Family Dwelling	0.50	0.02	0.60
2	RES2	Mobile Home	0.35	0.01	0.60
3	RES3	Multi Family Dwelling	0.45	0.02	0.60
4	RES4	Temporary Lodging	1.50	0.05	0.60
5	RES5	Institutional Dormitory	0.30	0.01	0.60
6	RES6	Nursing Home	0.55	0.02	0.60
		Commercial			
7	COM1	Retail Trade	0.85	0.03	0.80
8	COM2	Wholesale Trade	0.35	0.01	0.70
9	COM3	Personal and Repair Services	1.00	0.03	0.70
10	COM4	Professional/Technical/ Business Services	1.00	0.03	0.70
11	COM5	Banks	1.25	0.04	0.70
12	COM6	Hospital	1.00	0.03	1.00
13	COM7	Medical Office/Clinic	1.00	0.03	1.00
14	COM8	Entertainment & Recreation	1.25	0.04	N/A
15	COM9	Theaters	1.25	0.04	N/A
16	COM10	Parking	0.25	0.01	N/A
		Industrial			
17	IND1	Heavy	0.15	0.01	N/A
18	IND2	Light	0.20	0.01	0.70
19	IND3	Food/Drugs/Chemicals	0.20	0.01	0.70
20	IND4	Metals/Minerals Processing	0.15	0.01	0.70
21	IND5	High Technology	0.25	0.01	0.70
22	IND6	Construction	0.10	0.00	0.70
		Agriculture			
23	AGR1	Agriculture	0.50	0.02	0.50
		Religion/Non/Profit			
24	REL1	Church/Membership Organization	0.75	0.03	0.70
		Government			
25	GOV1	General Services	1.00	0.03	0.70
26	GOV2	Emergency Response	1.00	0.03	0.70
		Education			
27	EDU1	Schools/Libraries	0.75	0.03	0.70
28	EDU2	Colleges/Universities	1.00	0.03	0.70

Table 15.14: Percent Owner Occupied

No.	Label	Occupancy Class	Percent Owner Occupied
		Residential	
1	RES1	Single Family Dwelling	75
2	RES2	Mobile Home	85
3	RES3	Multi Family Dwelling	35
4	RES4	Temporary Lodging	0
5	RES5	Institutional Dormitory	0
6	RES6	Nursing Home	0
		Commercial	
7	COM1	Retail Trade	55
8	COM2	Wholesale Trade	55
9	COM3	Personal and Repair Services	55
10	COM4	Professional/Technical/ Business Services	55
11	COM5	Banks	75
12	COM6	Hospital	95
13	COM7	Medical Office/Clinic	65
14	COM8	Entertainment & Recreation	55
15	COM9	Theaters	45
16	COM10	Parking	25
		Industrial	
17	IND1	Heavy	75
18	IND2	Light	75
19	IND3	Food/Drugs/Chemicals	75
20	IND4	Metals/Minerals Processing	75
21	IND5	High Technology	55
22	IND6	Construction	85
		Agriculture	
23	AGR1	Agriculture	95
		Religion/Non/Profit	
24	REL1	Church/Membership Organization	90
		Government	
25	GOV1	General Services	70
26	GOV2	Emergency Response	95
		Education	
27	EDU1	Schools/Libraries	95
28	EDU2	Colleges/Universities	90

15.2.6 Loss of Income

Business activity generates several types of income. First is income associated with capital, or property ownership. Business generates profits, and a portion of this is paid out to individuals (as well as to pension funds and other businesses) as dividends, while another portion, retained earnings, is plowed back into the enterprise. Businesses also make interest payments to banks and bondholders for loans. They pay rental income on property and make royalty payments for the use of tangible assets. Those in business for themselves, or in partnerships, generate a category called proprietary income, one portion of which reflects their profits and the other that reflects an imputed salary (e.g., the case of lawyers or dentists). Finally, the biggest category of income generated/paid is associated with labor. In most urban regions of the U.S., wage and salary income comprises more than 75% of total personal income payments.

It is possible to link income payments to various physical damage measures including sales, property values, and square footage. The latter approach is used here. Income losses occur when building damage disrupts economic activity. Income losses are the product of floor area, income realized per square foot and the expected days of loss of function for each damage state. Proprietor's income losses are expressed as follows:

$$YLOS_i = (1\text{-}RF_i)*FA_i*INC_i*\sum_{ds=1}^{5} POSTR_{ds,i} * LOF_{ds} \qquad (15\text{-}16)$$

where:

$YLOS_i$	income losses for occupancy class i
FA_i	floor area of occupancy class i (in square feet)
INCi	income per day (per square foot) for occupancy class i (Table 15.15)
$POSTR_{ds,i}$	probability of occupancy i being in structural damage state ds, see Chapter 5
LOF_{ds}	loss of function time for damage state ds (see Equation 15-14)
RF_i	recapture factor for occupancy class i (see Section 15.2.6.1)

National estimates of sectoral income were obtained from the IMPLAN System, which in turn is based on U.S. Department of Commerce Bureau of Analysis data. The income data used was a three-year average to dampen cyclical variations especially prevalent for profit-related income. Income per square foot of floor space can then be derived by dividing income by the floor space occupied by a specific sector. As with losses and costs discussed above, income will vary considerably depending on regional economic conditions. Therefore, default values need to be adjusted for local conditions. Default values for floor space were derived from information in Table 4.7 of ATC-13.

15.2.6.1 Recapture Factors

The business-related losses from earthquakes can be recouped to some extent by working overtime after the event. For example, a factory that is closed for six weeks due to directly-caused structural damage or indirectly-caused shortage of supplies may work extra shifts in the weeks or months following its reopening. It is necessary that there be a demand for its output (including inventory buildup), but this is likely to be the case as undamaged firms try to overcome input shortages, other firms that were temporarily closed try to make-up their lost production as well, and firms outside the region press for resumption of export sales to them.

Obviously, this ability to "recapture" production will differ across industries. It will be high for those that produce durable output and lower for those that produce perishables or "spot" products (examples of the latter being utility sales to residential customers, hotel services, entertainment). Even some durable manufacturing enterprises would seem to have severe recapture limits because they already work three shifts per day; however, work on weekends, excess capacity, and temporary production facilities all can be used to make up lost sales.

The following table presents a set of recapture factors for the economic sectors used in the direct loss module. They are deemed appropriate for business disruptions lasting up to three months. As lost production becomes larger, it is increasingly difficult to recapture it for both demand-side and supply-side reasons. Recapture factors should be adjusted downward for such longer disruptions. A linear "decay" function is suggested, but only for that portion of production lost after the first three months. An end point of one year (i.e., no portion of lost sales beyond one year can be recaptured) would be appropriate.

Table of Recapture Factors

Occupancy	Wage Recapture (%)	Employment Recapture (%)	Income Recapture (%)	Output Recapture (%)
RES1	0	0	0	0
RES2	0	0	0	0
RES3	0	0	0	0
RES4	0.60	0.60	0.60	0.60
RES5	0.60	0.60	0.60	0.60
RES6	0.60	0.60	0.60	0.60
COM1	0.87	0.87	0.87	0.87
COM2	0.87	0.87	0.87	0.87
COM3	0.51	0.51	0.51	0.51
COM4	0.90	0.90	0.90	0.90
COM5	0.90	0.90	0.90	0.90
COM6	0.60	0.60	0.60	0.60
COM7	0.60	0.60	0.60	0.60
COM8	0.60	0.60	0.60	0.60
COM9	0.60	0.60	0.60	0.60
COM10	0.60	0.60	0.60	0.60
IND1	0.98	0.98	0.98	0.98
IND2	0.98	0.98	0.98	0.98
IND3	0.98	0.98	0.98	0.98
IND4	0.98	0.98	0.98	0.98
IND5	0.98	0.98	0.98	0.98
IND6	0.95	0.95	0.95	0.95
AGR1	0.75	0.75	0.75	0.75
REL1	0.60	0.60	0.60	0.60
GOV1	0.80	0.80	0.80	0.80
GOV2	0	0	0	0
EDU1	0.60	0.60	0.60	0.60
EDU2	0.60	0.60	0.60	0.60

15.2.7 Rental Income Losses

Rental income losses are the product of floor area, rental rates per sq. ft. and the expected days of loss of function for each damage state. Rental income losses include residential, commercial and industrial properties. It is assumed that a renter will pay full rent if the property is in the damage state none or slight. Thus rental income losses are calculated only for damage states 3, 4 and 5. It should be noted that rental income is based upon the percentage of floor area in occupancy i that is being rented (1 - $\%OO_i$).

$$RY_i = (1-\%OO_i) * FA_i * RENT_i * \sum_{ds=3}^{5} POSTR_{ds,i} * RT_{ds} \qquad (15\text{-}17)$$

where:

RY_i	rental income losses for occupancy i
$\%OO_i$	percent owner occupied for occupancy i (See Table 15.14)
FA_i	floor area of occupancy group i (in square feet)
$RENT_i$	rental cost ($\$/ft^2/day$) for occupancy i (See Table 15.13)
$POSTR_{ds,I}$	probability of occupancy i being in structural damage state ds, see Chapter 5
RT_{ds}	recovery time for damage state ds (See Table 15.11)

Rental rates vary widely with region and depend on local economic conditions including vacancy rate, the desirability of the neighborhood, and the desirability of the buildings. Regional and city rental rates are published annually by various real estate information services. The percentage rates given for owner occupancy are judgmentally based. For a given study region, census data will provide a more accurate measure for residential numbers.

15.2.8 Annualized Economic Loss to the General Building Stock

Using the approach described in this chapter, a methodology was developed to compute the expected annualized loss to the general building stock. Annualized economic loss is defined as the expected value of loss in any one year, and is developed by aggregating the losses and their exceedance probabilities. The annualized loss is equivalent to the area under a probabilistic loss curve such as the one shown in Figure 15.1. This integration combines the loss for each return period with its probability of exceedance.

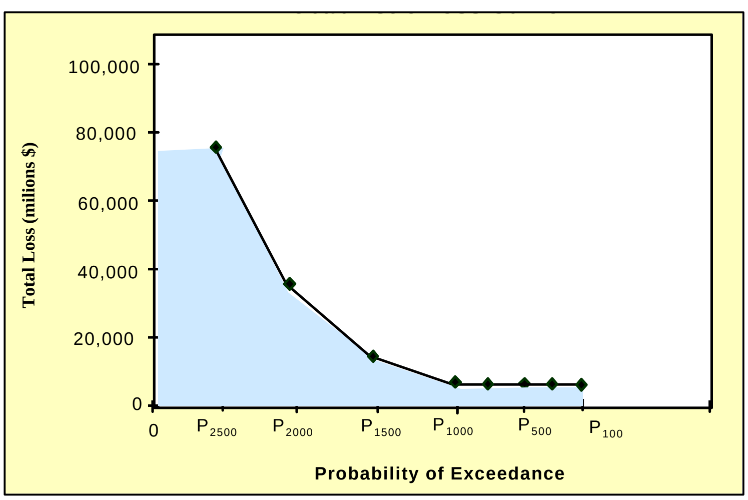


Figure 15-1: Probabilistic Loss Curve

The Methodology generates eight loss-probability pairs for the general building stock using the eight USGS probabilistic ground shaking return periods included with **HAZUS™**. A best-fit curve approach is used to generate a loss curve from the eight loss-probability pairs. Two different curve-fitting approaches are used; log-linear and exponential. The exponential relationship was found to generally provide a better fit for states with higher seismicity, while the log-linear approach was found to work better for states with lower seismicity. In **HAZUS^{TM}**, both relationships are used for each set of eight loss-probability pairs and the curve with the better fit is used as the basis for the annualized loss computation. Once the loss curve has been developed, the expected annual loss is computed by calculating the area under the curve.

15.2.9 Guidance for Estimate Using Advanced Data and Models Analysis

The methodological framework shown for the Default and User-Supplied Data Analyses will still apply for this type of analysis. However, depending on the type of analysis required, much more detailed inventory and cost information can be obtained from consultants. In the area of cost, professional building cost consultants maintain detailed records of costs and trends, and have knowledge of local building practices that might affect a loss estimate. Inventory improvement might include substantial "windshield" surveys that can greatly augment the accuracy of building type and occupancy information. It should be noted that while the windshield survey has limitations in procuring detailed information on structural types it is effective in procuring the kind of size and occupancy information necessary for the generic cost estimating proposed in this methodology.

Certain kinds of Advanced Data and Models Analysis estimates, for example one focused on the implications of hospital or specific industry losses, would require individual building cost estimates (together with similar individual building damage estimates) that might result in costs considerably different than the typical aggregated costs provided as part of the default database provided with this methodology.

Table 15.15: Proprietor's Income

No	Label	Occupancy Class	Income		Wages per Square Foot per Day	Employees per Square Foot	Output per Square Foot per Day
			per Square Foot per Year	per Square Foot per Day			
		Residential					
1	RES1	Single Family Dwelling	0.000	0.000	0.000	0.000	0.000
2	RES2	Mobile Home	0.000	0.000	0.000	0.000	0.000
3	RES3	Multi Family Dwelling	0.000	0.000	0.000	0.000	0.000
4	RES4	Temporary Lodging	26.415	0.072	0.170	0.003	0.379
5	RES5	Institutional Dormitory	0.000	0.000	0.000	0.000	0.000
6	RES6	Nursing Home	44.025	0.121	0.284	0.005	0.632
		Commercial					
7	COM1	Retail Trade	16.299	0.045	0.156	0.004	0.330
8	COM2	Wholesale Trade	26.731	0.073	0.192	0.002	0.429
9	COM3	Personal and Repair Services	35.220	0.096	0.227	0.004	0.506
10	COM4	Professional/Technical/ Business Services	277.520	0.760	0.270	0.004	0.739
11	COM5	Banks	316.683	0.868	0.440	0.006	2.399
12	COM6	Hospital	44.025	0.121	0.284	0.005	0.632
13	COM7	Medical Office/Clinic	88.050	0.241	0.568	0.010	1.264
14	COM8	Entertainment & Recreation	161.474	0.442	0.352	0.007	0.797
15	COM9	Theaters	52.830	0.145	0.341	0.006	0.759
16	COM10	Parking	0.000	0.000	0.000	0.000	0.000
		Industrial					
17	IND1	Heavy	66.808	0.183	0.303	0.003	1.281
18	IND2	Light	66.808	0.183	0.303	0.003	1.281
19	IND3	Food/Drugs/Chemicals	89.077	0.244	0.405	0.004	1.708
20	IND4	Metals/Minerals Processing	202.395	0.555	0.313	0.003	1.355
21	IND5	High Technology	133.616	0.366	0.607	0.006	2.561
22	IND6	Construction	65.133	0.178	0.328	0.005	1.269
		Agriculture					
23	AGR1	Agriculture	61.810	0.169	0.067	0.004	0.632
		Religion/Non/Profit					
24	REL1	Church/Membership Organization	35.220	0.096	0.227	0.004	1.264
		Government					
25	GOV1	General Services	28.925	0.079	2.180	0.025	0.506
26	GOV2	Emergency Response	0.000	0.000	3.314	0.038	0.581
		Education					
27	EDU1	Schools/Libraries	44.025	0.121	0.284	0.005	2.449
28	EDU2	Colleges/Universities	88.050	0.241	0.568	0.010	3.722

15.3 Description of Methodology: Lifelines

This section describes the methodologies used to estimate lifeline related direct economic losses. Direct physical damage to transportation and utility lifelines was discussed in Chapters 7 and 8, respectively. Estimation of direct economic losses for the extended network lifelines such as highways, railroads, water supply, and power supply, depends on the inventory data providing the location of all nodes and links, and the models relating ground motions to damage.

Direct economic losses are computed based on (1) probabilities of being in a certain damage state ($P[D_S \geq ds_i]$), (2) the replacement value of the component, and (3) damage ratios (DR_i) for each damage state, ds_i. Economic losses are evaluated by multiplying the compounded damage ratio (DR_C) by the replacement value. The compounded damage ratio is computed as the probabilistic combination of damage ratios as follows.

$$DR_c = \sum_{i=2}^{5} DR_i \text{ x } P[ds_i] \qquad (15\text{-}18)$$

where $P[ds_i]$ is the probability of being in damage state i, and 1, 2, 3, 4 and 5 are associated with damage states none, slight, moderate, extensive and complete. No losses are associated with damage state 1, therefore, the summation is from i = 2 to 5.

The probability of being in or exceeding a certain damage state ($P[D_S > ds_i$ | PGA, PGV or PGD]), for each component, were presented in Chapter 7 and Chapter 8. The probabilities of being in a particular damage state are as follows:

$$P[D_s = ds_1|\text{PGA or PGD}] = 1 - P[D_s \geq ds_2 \mid \text{PGA or PGD}] = \mathbf{P_1} \qquad (15\text{-}19)$$

$$P[D_s = ds_2|\text{PGA or PGD}] = P[D_s \geq ds_2 \mid \text{PGA or PGD}] - P[D_s \geq ds_3 \mid \text{PGA or PGD}] = \mathbf{P_2} \qquad (15\text{-}20)$$

$$P[D_s = ds_3|\text{PGA or PGD}] = P[D_s \geq ds_3 \mid \text{PGA or PGD}] - P[D_s \geq ds_4 \mid \text{PGA or PGD}] = \mathbf{P_3} \qquad (15\text{-}21)$$

$$P[D_s = ds_4|\text{PGA or PGD}] = P[D_s \geq ds_4 \mid \text{PGA or PGD}] - P[D_s \geq ds_5 \mid \text{PGA or PGD}] = \mathbf{P_4} \qquad (15\text{-}22)$$

$$P[D_s = ds_5|\text{PGA or PGD}] = P[D_s \geq ds_5 \mid \text{PGA or PGD}] = \mathbf{P_5} \qquad (15\text{-}23)$$

The estimates of replacement values of all lifeline system components are given in Tables 15.16 and 15.17. Table 15.16 provides the replacement values for the components of the transportation system, while Table 15.17 provides the replacement values for the utility system components. Most of the replacement value data comes from ATC-13 and ATC-25. These values are rough estimates and should only be used as a guide. It is expected that that user will input replacement values based on specific knowledge of the lifeline components in the study area. In cases where a range is given in Tables 15.16 and 15.17, the default value is set equal to the midpoint of the range.

Table 15.16: Default Replacement Values of Transportation System Components

System	Replacement Value (thous. $)	Label	Component Classification
Highway	10,000	HRD1	Major Roads (value based on one km length, 4 lanes)
	5,000	HRD2	Urban Streets (value based on one km length, 2 lanes)
	20,000	HWB1/HWB2	Major Bridges
	5,000	HWB8, 9, 10, 11, 15, 16, 20, 21, 22, 23, 26, 27	Continuous Bridges
	1,000	HWB3, 4, 5, 6, 7, 12, 13, 14, 17, 18, 19, 24, 25, 28	Other Bridges
	20,000	HTU1	Highway Bored/Drilled Tunnel (value based on liner)
	20,000	HTU2	Highway Cut and Cover Tunnel (value based on liner)
Rail	1,500	RTR1	Rail Track (value based on one km length)
	5,000	RBR1	Rail Bridge - Seismically Designed
	5,000	RBR2	Rail Bridge - Conventionally Designed
	10,000	RTU1	Rail Bored/Drilled Tunnel (value based on liner)
	10,000	RTU2	Rail Cut and Cover Tunnel (value based on liner)
	2,000	RST1	Rail Urban Station (C2L)
	2,000	RST2	Rail Urban Station (S2L)
	2,000	RST3	Rail Urban Station (S1L)
	2,000	RST4	Rail Urban Station (S5L)
	2,000	RST5	Rail Urban Station (PC1)
	2,000	RST6	Rail Urban Station (C3L)
	2,000	RST7	Rail Urban Station (W1L)
	3,000	RFF1	Rail Fuel Facility w/ Anchored Tanks, w/ BU Power
	3,000	RFF2	Rail Fuel Facility w/ Anchored Tanks, wo/ BU Power
	3,000	RFF3	Rail Fuel Facility w/ Unanchored Tanks, w/ BU Power
	3,000	RFF4	Rail Fuel Facility w/ Unanchored Tanks, wo/ BU Power
	3,000	RFF5	Rail Fuel Facility w/ Buried Tanks
	3,000	RDF1	Rail Dispatch Facility w/ Anchored Sub-Comp., w/ BU Power
	3,000	RDF2	Rail Dispatch Facility w/ Anchored Sub-Comp., wo/ BU Power
	3,000	RDF3	Rail Dispatch Facility w/ Unanchored Sub-Comp., w/ BU Power
	3,000	RDF4	Rail Dispatch Facility w/ Unanchored. Sub-Comp., w/0 BU Power
	2,800	RMF1	Rail Maintenance Facility (C2L)
	2,800	RMF2	Rail Maintenance Facility (S2L)
	2,800	RMF3	Rail Maintenance Facility (S1L)
	2,800	RMF4	Rail Maintenance Facility (S5L)
	2,800	RMF5	Rail Maintenance Facility (PC1)
	2,800	RMF6	Rail Maintenance Facility (C3L)
	2,800	RMF7	Rail Maintenance Facility (W1)

Table 15.16: Default Replacement Values of Transportation System Components (con't)

System	Replacement Value (thous $)	Label	Component Classification
Light Rail	1,500	LTR1	Light Rail Track
	5,000	LBR1	Light Rail Bridge - Seismically Designed/Retrofitted
	5,000	LBR2	Light Rail Bridge - Conventionally Designed
	10,000	LTU1	Light Rail Bored/Drilled Tunnel (value based on liner)
	10,000	LTU2	Light Rail Cut and Cover Tunnel (value based on liner)
	2,000	LDC1	Light Rail DC Substation w/ Anchored Sub-Components
	2,000	LDC2	Light Rail DC Substation w/ Unanchored Sub-Comp.
	3,000	LDF1	Lt Rail Dispatch Fac w/ Anchored Sub-Comp., w/ BU Power
	3,000	LDF2	Lt Rail Dispatch Fac w/ Anchored Sub-Comp., wo/ BU Power
	3,000	LDF3	Lt Rail Dispatch Fac w/ Unanchored Sub-Comp., w/ BU Power
	3,000	LDF4	Lt Rail Dispatch Fac w/ Unanchored Sub-Comp., wo/ BU Power
	2,600	LMF1	Light Rail Maintenance Facility (C2L)
	2,600	LMF2	Light Rail Maintenance Facility (S2L)
	2,600	LMF3	Light Rail Maintenance Facility (S1L)
	2,600	LMF4	Light Rail Maintenance Facility (S5L)
	2,600	LMF5	Light Rail Maintenance Facility (PC1)
	2,600	LMF6	Light Rail Maintenance Facility (C3L)
	2,600	LMF7	Light Rail Maintenance Facility (W1)
Bus	1,000	BPT1	Bus Urban Station (C2L)
	1,000	BPT2	Bus Urban Station (S2L)
	1,000	BPT3	Bus Urban Station (S1L)
	1,000	BPT4	Bus Urban Station (S5L)
	1,000	BPT5	Bus Urban Station (PC1)
	1,000	BPT6	Bus Urban Station (C3L)
	1,000	BPT7	Bus Urban Station (W1)
	150	BFF1	Bus Fuel Facility w/ Anchored Tanks, w/ BU Power
	150	BFF2	Bus Fuel Facility w/ Anchored Tanks, wo/ BU Power
	150	BFF3	Bus Fuel Facility w/ Unanchored Tanks, w/ BU Power
	150	BFF4	Bus Fuel Facility w/ Unanchored Tanks, wo/ BU Power
	150	BFF5	Bus Fuel Facility w/ Buried Tanks
	400	BDF1	Bus Dispatch Fac. w/ Anchored. Sub-Comp., w/ BU Power
	400	BDF2	Bus Dispatch Fac. w/ Anchored. Sub-Comp., wo/ BU Power
	400	BDF3	Bus Dispatch Fac. w/ Unanchored. Sub-Comp., w/ BU Power
	400	BDF4	Bus Dispatch Fac. w/ Unanchored. Sub-Comp., wo/ BU Power
	1,300	BMF1	Bus Maintenance Facility (C2L)
	1,300	BMF2	Bus Maintenance Facility (S2L)
	1,300	BMF3	Bus Maintenance Facility (S1L)
	1,300	BMF4	Bus Maintenance Facility (S5L)
	1,300	BMF5	Bus Maintenance Facility (PC1)
	1,300	BMF6	Bus Maintenance Facility (C3L)
	1,300	BMF7	Bus Maintenance Facility (W1)

Table 15.16: Default Replacement Values of Transportation System Components (con't)

System	Replacement Value (thous $)	Label	Component Classification
Port	1,500	PWS1	Port Waterfront Structures
	2,000	PEQ1	Anchored Port Handling Equipment
	2,000	PEQ2	Unanchored Port Handling Equipment
	1,200	PWH1	Port Warehouses (C2L)
	1,200	PWH2	Port Warehouses (S2L)
	1,200	PWH3	Port Warehouses (S1L)
	1,200	PWH4	Port Warehouses (S5L)
	1,200	PWH5	Port Warehouses (PC1)
	1,200	PWH6	Port Warehouses (C3L)
	1,200	PWH7	Port Warehouses (W1)
	2,000	PFF1	Port Fuel Facility w/ Anchored Tanks, w/ BU Power
	2,000	PFF2	Port Fuel Facility w/ Anchored Tanks, wo/ BU Power
	2,000	PFF3	Port Fuel Facility w/ Unanchored Tanks, w/ BU Power
	2,000	PFF4	Port Fuel Facility w/ Unanchored Tanks, wo/ BU Power
	2,000	PFF5	Port Fuel Facility w/ Buried Tanks
Ferry	1,500	FWS1	Ferry Waterfront Structures (Value for 7,500 ft^2 facility)
	1,000	FPT1	Ferry Passenger Terminals (C2L)
	1,000	FPT2	Ferry Passenger Terminals (S2L)
	1,000	FPT3	Ferry Passenger Terminals (S1L)
	1,000	FPT4	Ferry Passenger Terminals (S5L)
	1,000	FPT5	Ferry Passenger Terminals (PC1)
	1,000	FPT6	Ferry Passenger Terminals (C3L)
	1,000	FPT7	Ferry Passenger Terminals (W1)
	400	FFF1	Ferry Fuel Facility w/ Anchored Tanks, w/ BU Power
	400	FFF2	Ferry Fuel Facility w/ Anchored Tanks, wo/ BU Power
	400	FFF3	Ferry Fuel Facility w/ Unanchored Tanks, w/ BU Power
	400	FFF4	Ferry Fuel Facility w/ Unanchored Tanks, wo/ BU Power
	400	FFF5	Ferry Fuel Facility w/ Buried Tanks
	200	FDF1	Ferry Dispatch Fac. w/ Anchored. Sub-Comp., w/ BU Power
	200	FDF2	Ferry Dispatch Fac. w/ Anchored. Sub-Comp., wo/ BU Power
	200	FDF3	Ferry Dispatch Fac. w/ Unanchored. Sub-Comp., w/ BU Power
	200	FDF4	Ferry Dispatch Fac. w/ Unanchored. Sub-Comp., wo/ BU Power
	520	FMF1	Ferry Maintenance Facility (C2L)
	520	FMF2	Ferry Maintenance Facility (S2L)
	520	FMF3	Ferry Maintenance Facility (S1L)
	520	FMF4	Ferry Maintenance Facility (S5L)
	520	FMF5	Ferry Maintenance Facility (PC1)
	520	FMF6	Ferry Maintenance Facility (C3L)
	520	FMF7	Ferry Maintenance Facility (W1)

Table 15.16: Default Replacement Values of Transportation System Components (con't)

System	Replacement Value (thous $)	Label	Component Classification
Airport	5,000	ACT1	Airport Control Towers (C2L)
	5,000	ACT2	Airport Control Towers (S2L)
	5,000	ACT3	Airport Control Towers (S1L)
	5,000	ACT4	Airport Control Towers (S5L)
	5,000	ACT5	Airport Control Towers (PC1)
	5,000	ACT6	Airport Control Towers (C3L)
	5,000	ACT7	Airport Control Towers (W1)
	28,000	ARW1	Airport Runways
	8,000	ATB1	Airport Terminal Buildings (C2L)
	8,000	ATB2	Airport Terminal Buildings (S2L)
	8,000	ATB3	Airport Terminal Buildings (S1L)
	8,000	ATB4	Airport Terminal Buildings (S5L)
	8,000	ATB5	Airport Terminal Buildings (PC1)
	8,000	ATB6	Airport Terminal Buildings (C3L)
	8,000	ATB7	Airport Terminal Buildings (W1)
	1,400	APS1	Airport Parking Structures (C2L)
	1,400	APS2	Airport Parking Structures (S2L)
	1,400	APS3	Airport Parking Structures (S1L)
	1,400	APS4	Airport Parking Structures (S5L)
	1,400	APS5	Airport Parking Structures (PC1)
	1,400	APS65	Airport Parking Structures (C3L)
	5,000	AFF1	Airport Fuel Facility w/ Anchored Tanks, w/ BU Power
	5,000	AFF2	Airport Fuel Facility w/ Anchored Tanks, wo/ BU Power
	5,000	AFF3	Airport Fuel Facility w/ Unanchored Tanks, w/ BU Power
	5,000	AFF4	Airport Fuel Facility w/ Unanchored Tanks, wo/ BU Power
	5,000	AFF5	Airport Fuel Facility w/ Buried Tanks
	3,200	AMF1	Airport Maintenance & Hanger Facility
	8,000	ATBU1	Airport - General
	2,000	AFH1	Heliport
	500	AFO1	Seaport / Stolport / Gliderport / Seaplane

Table 15.17: Default Replacement Values of Utility System Components

System	Replacement Value (thous $)	Label	Component Classification
Potable Water	1	PWP1	Brittle Pipe (per break)
	1	PWP2	Ductile Pipe (per break)
	30,000	PWT1	Small WTP with Anchored Components < 50 MGD
	30,000	PWT2	Small WTP with Unanchored Components <50 MGD
	100,000	PWT3	Medium WTP with Anchored Components 50-200 MGD
	100,000	PWT4	Medium WTP with Unanchored Components 50-200 MGD
	360,000	PWT5	Large WTP with Anchored Components >200 MGD
	360,000	PWT6	Large WTP with Unanchored Components >200 MGD
	400	PWE1	Wells
	1,500	PST1	On Ground Anchored Concrete Tank
	1,500	PST2	On Ground Unanchored Concrete Tank
	800	PST3	On Ground Anchored Steel Tank
	800	PST4	On Ground Unanchored Steel Tank
	800	PST5	Above Ground Anchored Steel Tank
	800	PST6	Above Ground Unanchored Steel Tank
	30	PST7	On Ground Wood Tank
	150	PPP1	Small Pumping Plant with Anchored Equipment <10 MGD
	150	PPP2	Small Pumping Plant with Unanchored Equipment <10 MGD
	525	PPP3	Medium/Large Pumping Plant with Anchored Equipment >10 MGD
	525	PPP4	Med./Large Pumping Plant with Unanchored Equipment >10 MGD
Waste Water	1	WWP1	Brittle Pipe (per break)
	1	WWP2	Ductile Pipe (per break)
	60,000	WWT1	Small WWTP with Anchored Components <50 MGD
	60,000	WWT2	Small WWTP with Unanchored Components <50 MGD
	200,000	WWT3	Medium WWTP with Anchored Components 50-200 MGD
	200,000	WWT4	Medium WWTP with Unanchored Components 50-200 MGD
	720,000	WWT5	Large WWTP with Anchored Components >200 MGD
	720,000	WWT6	Large WWTP with Unanchored Components >200 MGD
	300	WLS1	Small Lift Stations with Anchored Components <10 MGD
	300	WLS2	Small Lift Stations with Unanchored Components <10 MGD
	1,050	WLS3	Medium/Large Lift Stations with Anchored Components >10 MGD
	1,050	WLS4	Med./Large Lift Stations with Unanchored Components >10 MGD
Oil	1	OIP1	Welded Steel Pipe with Gas Welded Joints (per break)
	1	OIP2	Welded Steel Pipe with Arc Welded Joints (per break)
	175,000	ORF1	Small Refinery with Anchored Equipment <100,000 bl/day
	175,000	ORF2	Small Refinery with Unanchored Equipment <100,000 bl/day
	750,000	ORF3	Medium/Large Refinery with Anchored Equipment >100,000 bl/day
	750,000	ORF4	Medium/Large Refinery with Unanchored Equipment >100,000 bl/day
	1,000	OPP1	Pumping Plant with Anchored Equipment
	1,000	OPP2	Pumping Plant with Unanchored Equipment
	2,000	OTF1	Tank Farms with Anchored Tanks
	2,000	OTF2	Tank Farms with Unanchored Tanks

Table 15.17: Default Replacement Values of Utility System Components (con't)

System	Replacement Value (thous $)	Label	Component Classification
Natural Gas	1	NGP1	Welded Steel Pipe with Gas Welded Joints (per break)
	1	NGP2	Welded Steel Pipe with Arc Welded Joints (per break)
	1,000	NGC1	Compressor Stations with Anchored Components
	1,000	NGC2	Compressor Stations with Unanchored Components
Electric Power Systems	10,000	ESS1	Low voltage (115 KV) substation, anchored comp.
	10,000	ESS2	Low voltage (115 KV) substation, unanchored comp.
	20,000	ESS3	Medium Voltage (230 KV) substation, anchored comp.
	20,000	ESS4	Medium Voltage (230 KV) substation, unanchored. comp.
	50,000	ESS5	High Voltage (500 KV) substation, anchored comp.
	50,000	ESS6	High Voltage (500 KV) substation, unanchored comp.
	3	EDC1	Distribution Circuits with seismically designed components
	3	EDC2	Distribution Circuits with standard components
	100,000	EPP1	Small Power Plants with Anchored Comp < 100 MW
	100,000	EPP2	Small Power Plants with Unanchored Comp <100 MW
	500,000	EPP3	Medium/Large Power Plants with Anchored Comp >100 MW
	500,000	EPP4	Medium/Large Power Plants with Unanchored Comp >100 MW
Commu-nication Systems	5,000	CCO1	Central Office with Anchored Components, w/BU Power
	5,000	CCO2	Central Office with Anchored Components, w/o BU Power
	5,000	CCO3	Central Office with Unanchored Components, w/BU Power
	5,000	CCO4	Central Office with Unanchored Components, w/o BU Power
	2,000	CBR1	Radio Broadcasting Station
	2,000	CBT1	TV Broadcasting Station
	2,000	CBW1	Weather Broadcasting Station
	2,000	CBO1	Other Communication Facility

15.3.1 Transportation Systems

This section describes the methodologies used to estimate direct economic losses related to transportation system damage. Transportation systems include highway, railway, light rail, bus, port, ferry, and airport systems. Damage models for each of these systems was discussed in detail in Chapter 7.

15.3.1.1 Highway Systems

In this subsection, damage ratios are presented for the following highway system components: roadways; bridges; tunnels. Damage ratios for bridges are expressed as a fraction of the component (bridge) replacement cost. Damage ratios for roadways are expressed as a fraction of the roadway replacement cost per unit length. Damage ratios for highway tunnels are expressed as a fraction of the liner replacement cost per unit length. The damage ratios for roadways, tunnels, and bridges are presented in Table 15.18.

Table 15.18: Damage Ratios for Highway System Components

Classification	Damage State	Best Estimate Damage Ratio	Range of Damage Ratios
Roadways	slight	0.05	0.01 to 0.15
	moderate	0.20	0.15 to 0.4
	extensive/ complete	0.70	0.4 to 1.0
Tunnel's Lining	slight	0.01	0.01 to 0.15
	moderate	0.30	0.15 to 0.4
	extensive	0.70	0.4 to 0.8
	complete	1.00	0.8 to 1.0
Bridges	slight	0.03	0.01 to 0.03
	moderate	0.08	0.02 to 0.15
	extensive	0.25	0.10 to 0.40
	complete	1.00*	0.30 to 1.00

* If the number of spans is greater than two, then the best estimate damage ratio for complete damage is [2/(number of spans)]

15.3.1.2 Railway Systems

In this subsection, damage ratios are presented for the following railway system components: tracks/roadbeds; bridges; tunnels; facilities. Damage ratios associated with bridges and facilities are expressed as a fraction of the component replacement cost. Damage ratios for tracks are expressed as a fraction of the replacement cost per length. Damage ratios for railway tunnels are expressed as a fraction of the liner replacement cost per unit length.

The damage ratios for railway bridges, fuel facilities, dispatch facilities, and urban stations and maintenance facilities, are presented in Table 15.19. The damage ratios for railway tracks and tunnels are the same as for urban roads and tunnels for the highway systems presented in Section 15.3.1.1. The damage ratios for bridges are computed in the same manner as for highway bridges. For a given damage state, the damage ratios for fuel and dispatch facilities are evaluated as the sum of the damage ratios of all the subcomponents multiplied by their respective percentages of the total component (fuel or dispatch facility) value. The subcomponents information is presented in Table 15D.1 of Appendix 15D.

Table 15.19: Damage Ratios for Railway System Components

Classification	Damage State	Best Estimate Damage Ratio	Range of Damage Ratios
Bridges	slight moderate extensive complete	0.12 0.19 0.40 1.00	0.01 to 0.15 0.15 to 0.4 0.4 to 0.8 0.8 to 1.0
Fuel Facilities	slight moderate extensive complete	0.15 0.39 0.80 1.00	0.01 to 0.15 0.15 to 0.4 0.4 to 0.8 0.8 to 1.0
Dispatch Facilities	slight moderate extensive complete	0.04 0.4 0.8 1.00	0.01 to 0.15 0.15 to 0.4 0.4 to 0.8 0.8 to 1.0
Urban Stations and Maintenance Facilities	slight moderate extensive complete	0.10 0.40 0.80 1.00	0.01 to 0.15 0.15 to 0.4 0.4 to 0.8 0.8 to 1.0

15.3.1.3 Light Rail Systems

In this subsection, damage ratios are presented for the following light rail system components: tracks/roadbeds; bridges; tunnels; facilities. Damage ratios for bridges and facilities are expressed as a fraction of the component replacement cost. Damage ratios for tracks are expressed as a fraction of the replacement value per unit length. Damage ratios for light rail tunnels are expressed as a fraction of the linear replacement cost.

The damage ratios for DC substations are presented in Table 15.20. The damage ratios for light rail tracks and tunnels are the same as for urban roads and tunnels for highway systems presented in Section 15.3.1.1. The damage ratios for dispatch facilities and bridges are the same as those for railway systems presented in Section 15.3.1.2. The damage ratios for the subcomponents of DC substations are estimated as the sum of the damage ratios of all the subcomponents multiplied by their respective percentages of the total substation value. The subcomponent information for the DC substations are presented in Table 15D.2 of Appendix 15D.

Table 15.20: Damage Ratios for DC Substations

Classification	Damage State	Best Estimate Damage Ratio	Range of Damage Ratios
DC Substations	slight moderate extensive complete	0.04 0.4 0.8 1.00	0.01 to 0.15 0.15 to 0.4 0.4 to 0.8 0.8 to 1.0

15.3.1.4 Bus Systems

In this subsection, damage ratios are presented for the following bus system components: urban stations; maintenance, fuel, and dispatch facilities. Damage ratios for these components are expressed as a fraction of the component replacement cost.

The damage ratios for bus system components are presented in Table 15.21. The damage ratios for urban stations and maintenance facilities are the same as those for railway systems presented in Section 15.3.1.2. The damage ratios for fuel and dispatch facilities are evaluated as the sum of the damage ratios of all the subcomponents multiplied by their respective percentages of the total component (fuel or dispatch facility) value. The subcomponent information is presented in Table 15D.3 of Appendix 15D.

Table 15.21: Damage Ratios for Bus System Components

Classification	Damage State	Best Estimate Damage Ratio	Range of Damage Ratios
Fuel Facilities	slight moderate extensive complete	0.15 0.39 0.8 1.00	0.01 to 0.15 0.15 to 0.4 0.4 to 0.8 0.8 to 1.0
Dispatch Facilities	slight moderate extensive complete	0.06 0.4 0.8 1.00	0.01 to 0.15 0.15 to 0.4 0.4 to 0.8 0.8 to 1.0

15.3.1.5 Port Systems

In this subsection, damage ratios are presented for the following port system components: waterfront structures (e.g., wharves, piers and sea-walls); cranes and cargo handling equipment; fuel facilities; warehouses. Damage ratios for these components are expressed as a fraction of the component replacement cost.

The damage ratios for port system components are presented in Table 15.22. The damage ratios for fuel facilities are evaluated as the sum of the damage ratios of all the subcomponents multiplied by their respective percentages of the total component (fuel facility) value. The subcomponent information is presented in Table 15D.4 of Appendix 15D.

Table 15.22: Damage Ratios for Port System Components

Classification	Damage State	Best Estimate Damage Ratio	Range of Damage Ratios
Waterfront Structures	slight moderate extensive complete	0.10 0.40 0.80 1.00	0.01 to 0.15 0.15 to 0.4 0.4 to 0.8 0.8 to 1.0
Cranes/Cargo Handling Equipment	slight moderate extensive/ complete	0.05 0.25 0.75	0.01 to 0.15 0.15 to 0.4 0.4 to 1.0
Warehouses	slight moderate extensive complete	0.10 0.40 0.80 1.00	0.01 to 0.15 0.15 to 0.4 0.4 to 0.8 0.8 to 1.0
Fuel Facilities	slight moderate extensive complete	0.16 0.39 0.8 1.00	0.01 to 0.15 0.15 to 0.4 0.4 to 0.8 0.8 to 1.0

15.3.1.6 Ferry Systems

In this subsection, damage ratios are presented for the following ferry system components: waterfront structures (e.g., wharf's piers and sea-walls); fuel, maintenance, and dispatch facilities; passenger terminals. Damage ratios for ferry system components are expressed as a fraction of the component replacement cost.

The damage ratios for ferry system components are presented in Table 15.23. The damage ratios for waterfront structures are the same as those for port systems. The damage ratios for maintenance and dispatch facilities are the same as those for railway systems. The damage ratios for passenger terminals are the same as those for urban stations in railway systems. The damage ratios for fuel facilities are evaluated as the sum of the damage ratios of all the subcomponents multiplied by their respective percentages of the total component (fuel facility) value. The subcomponent information is presented in Table 15D.4 of Appendix 15D.

Table 15.23: Damage Ratios for Ferry System Component

Classification	Damage State	Best Estimate Damage Ratio	Range of Damage Ratios
Fuel Facilities	slight moderate extensive complete	0.15 0.37 0.8 1.00	0.01 to 0.15 0.15 to 0.4 0.4 to 0.8 0.8 to 1.0

15.3.1.7 Airport Systems

In this subsection, damage ratios are presented for the following airport system components: runways; control towers; fuel facilities; terminal buildings; maintenance and hangar facilities; parking structures. Damage ratios for the airport system components are expressed as a fraction of the component replacement cost.

The damage ratios for airport system components are presented in Table 15.24. The damage ratios for fuel facilities are evaluated as the sum of the damage ratios of all the subcomponents multiplied by their respective percentages of the total component (fuel facility) value. The subcomponent information is presented in Table 15D.4 of Appendix 15D.

Table 15.24: Damage Ratios for Airport System Components

Classification	Damage State	Best Estimate Damage Ratio	Range of Damage Ratios
Runways	slight moderate extensive complete	0.05 0.05 0.8 1.0	0.01 to 0.4 0.01 to 0.4 0.4 to 0.8 0.8 to 1.0
Control Towers	slight moderate extensive complete	0.10 0.40 0.80 1.00	0.01 to 0.15 0.15 to 0.4 0.4 to 0.8 0.8 to 1.0
Terminal Buildings	slight moderate extensive complete	0.10 0.40 0.80 1.00	0.01 to 0.15 0.15 to 0.4 0.4 to 0.8 0.8 to 1.0

Table 15.24: Damage Ratios for Airport System Components (Continued)

Classification	Damage State	Best Estimate Damage Ratio	Range of Damage Ratios
Parking Structures	slight	0.10	0.01 to 0.15
	moderate	0.40	0.15 to 0.4
	extensive	0.80	0.4 to 0.8
	complete	1.00	0.8 to 1.0
Fuel Facilities	slight	0.14	0.01 to 0.15
	moderate	0.37	0.15 to 0.4
	extensive	0.8	0.4 to 0.8
	complete	1.00	0.8 to 1.0
Maintenance & Hangar Facilities	slight	0.10	0.01 to 0.15
	moderate	0.40	0.15 to 0.4
	extensive	0.80	0.4 to 0.8
	complete	1.00	0.8 to 1.0

15.3.2 Utility Systems

This section describes the methodologies used to estimate direct economic losses related to utility system damage. Utility systems include potable water, waste water, oil, natural gas, electric power, and communication systems. The estimation of the direct economic losses associated with each of these systems is presented in the following sections.

15.3.2.1 Potable Water Systems

In this subsection, damage ratios are presented for the following potable water system components: pipelines; water treatment plants; wells; storage tanks; pumping plants. Damage ratios for these components are expressed as a fraction of the component replacement cost.

The damage ratios for potable water system components are presented in Table 15.25. The damage ratios for water treatment plants, wells, and pumping plants are evaluated as the sum of the damage ratios of all the subcomponents multiplied by their respective percentages of the total component value. The subcomponent information is presented in Table 15D.5 of Appendix 15D.

Table 15.25: Damage Ratios for Potable Water Systems

Classification	Damage State	Best Estimate Damage Ratio	Range of Damage Ratios
Pipelines	leak break	0.10* 0.75*	0.05 to 0.20 0.5 to 1.0
Water Treatment Plants	slight	0.08	0.01 to 0.15
	moderate	0.4	0.15 to 0.4
	extensive	0.77	0.4 to 0.8
	complete	1.00	0.8 to 1.0
Tanks	slight	0.20	0.01 to 0.15
	moderate	0.40	0.15 to 0.4
	extensive	0.8	0.4 to 0.8
	complete	1.00	0.8 to 1.0
Wells and Pumping Plants	slight	0.05	0.01 to 0.15
	moderate	0.38	0.15 to 0.4
	extensive	0.8	0.4 to 0.8
	complete	1.00	0.8 to 1.0

* % of the replacement cost for one 20 ft. pipe segment

15.3.2.2 Waste Water Systems

In this subsection, damage ratios are presented for the following waste water system components: underground sewers and interceptors; waste water treatment plants; lift stations. Damage ratios for these components are expressed as a fraction of the component replacement cost.

The damage ratios for waste water system components are presented in Table 15.26. The damage ratios for lift stations are same as those for pumping plants in potable water systems presented in Section 15.3.2.2. The damage ratios for waste water treatment plants are evaluated as the sum of the damage ratios of all the subcomponents multiplied by their respective percentages of the total component value. The subcomponent information is presented in Table 15D.6 of Appendix 15D.

Table 15.26: Damage Ratios for Waste Water Systems

Classification	Damage State	Best Estimate Damage Ratio	Range of Damage Ratios
Underground Sewers & Interceptors	leak break	0.10 0.75	0.05 to 0.20 0.5 to 1.0
Waste Water Treatment Plants	slight moderate extensive complete	0.10 0.37 0.65 1.00	0.01 to 0.15 0.15 to 0.4 0.4 to 0.8 0.8 to 1.0

15.3.2.3 Oil Systems

In this subsection, damage ratios are presented for the following oil system components: buried pipes; refineries; pumping plants; tank farms. Damage ratios for these components are expressed as a function of the component replacement cost.

The damage ratios for oil system components are presented in Table 15.27. The damage ratios for refineries, pumping plants, and tank farms are evaluated as the sum of the damage ratios of all the subcomponents multiplied by their respective percentages of the total component value. The subcomponent information is presented in Table 15D.7 of Appendix 15D.

Table 15.27: Damage Ratios for Oil Systems

Classification	Damage State	Best Estimate Damage Ratio	Range of Damage Ratios
Buried Pipes	leak break	0.10 0.75	0.05 to 0.20 0.5 to 1.0
Refineries	slight moderate extensive complete	0.09 0.23 0.78 1.00	0.01 to 0.15 0.15 to 0.4 0.4 to 0.8 0.8 to 1.0
Pumping Plants	slight moderate extensive complete	0.08 0.4 0.8 1.00	0.01 to 0.15 0.15 to 0.4 0.4 to 0.8 0.8 to 1.0
Tank Farms	slight moderate extensive complete	0.13 0.4 0.8 1.00	0.01 to 0.15 0.15 to 0.4 0.4 to 0.8 0.8 to 1.0

15.3.2.4 Natural Gas Systems

In this subsection, damage ratios are presented for the following gas system components: buried pipes; compressor stations. Damage ratios for these components are expressed as a fraction of the component replacement cost. The damage ratios for buried pipes are the same as those for oil systems. The damage ratios for compressor stations are the same as those for pumping plants in the oil system.

15.3.2.5 Electric Power Systems

In this subsection, damage ratios are presented for the following electric power system components: substations; distribution circuits; generation plants. Damage ratios for these components are expressed as a fraction of the component replacement cost.

The damage ratios for electric power system components are presented in Table 15.28. The damage ratios for substations and generation plants are evaluated as the sum of the damage ratios of all the subcomponents multiplied by their respective percentages of the total component value. The subcomponent information is presented in Table 15D.8 & 15D.9 of Appendix 15D.

Table 15.28: Damage Ratios for Electric Power Systems

Classification	Damage State	Best Estimate Damage Ratio	Range of Damage Ratios
Substations	slight	0.05	0.01 to 0.15
	moderate	0.11	0.15 to 0.4
	extensive	0.55	0.4 to 0.8
	complete	1.00	0.8 to 1.0
Distribution Circuits	slight	0.05	0.01 to 0.15
	moderate	0.15	0.15 to 0.4
	extensive	0.60	0.4 to 0.8
	complete	1.00	0.8 to 1.0
Generation Plants	slight	0.08	0.01 to 0.15
	moderate	0.35	0.15 to 0.4
	extensive	0.72	0.4 to 0.8
	complete	1.00	0.8 to 1.0

15.3.2.6 Communication Systems

In this subsection, damage ratios are presented for communication system central offices. Damage ratios for central offices are expressed as a fraction of the central office replacement cost.

The damage ratios for central offices are presented in Table 15.29. The damage ratios for a central office are evaluated as the sum of the damage ratios of all the subcomponents multiplied by their respective percentages of the total component (central office) value. The subcomponent information is presented in Table 15D.10 of Appendix 15D.

Table 15.29: Damage Ratios for Communication System Component

Classification	Damage State	Best Estimate Damage Ratio	Range of Damage Ratios
Central Office	slight moderate extensive complete	0.09 0.35 0.73 1.00	0.01 to 0.15 0.15 to 0.4 0.4 to 0.8 0.8 to 1.0

15.4. **References**

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Appendix 15A
Default Values for Regional Cost Variations

Construction costs vary significantly from one location to another. In order to account for this, the methodology provides default values for multipliers to be applied to the typical costs provided in Tables 15.2 through 15.4, which are based on national averages for materials and installation. These multipliers are shown in the Means Square Foot Cost publication as *Historical Cost Indices.* Means provides indices for a number of cities in each state (some of the smaller states have one or two cities only). This information, along with expert opinion, was used to develop default regional cost modifiers for each state in the United States. Since certain counties in each state can vary drastically from the state-wide average (e.g., San Francisco), county exceptions are provided for a limited number of counties.

Table 15A.1: State Cost Modifiers with County Exception

State		County Exceptions		Index
#	Name	#	Name	
01	Alabama			83.0
		01097	Mobile (Mobile)	87.5
02	Alaska			134.3
04	Arizona			92.8
		04013	Maricopa (Phoenix)	92.9
05	Arkansas			82.4
		05119	Pulaski (Little Rock)	84.1
06	California			116.9
		06075	San Francisco	132.7
		06037	Los Angeles	118.6
		06073	San Diego	113.6
08	Colorado			95.4
		08031	Denver	94.1
09	Connecticut			110.7
		09003	Hartford	111.2
10	Delaware			104.5
11	District of Colombia			98.9
12	Florida			90.1
		12095	Orange(Orlando)	90.7
13	Georgia			82.4
		13121	Fulton (Atlanta)	87.9
		13215	Muscogee (Columbus)	79.3
15	Hawaii			126.4
16	Idaho			94.1
		16001	Ada (Boise)	94.0
17	Illinois			100.3
		17031	Cook (Chicago)	111.0
		17167	Sangamon (Springfield)	97.0
		17197	Will (Joliet)	109.4
18	Indiana			94.4
		18089	Lake (Gary)	99.5
		18097	Marion (Indianapolis)	96.4
19	Iowa			92.3
		19113	Linn (Cedar Rapids)	92.6
		19153	Polk (Des Moines)	92.4
		19163	Scott (Davenport)	92.2

Table 15A.1: State Cost Modifiers with County Exception (continued)

State		County Exceptions		Index
#	Name	#	Name	
20	Kansas			89.1
		20177	Shawnee (Topeka)	91.8
21	Kentucky			91.8
		21111	Jefferson (Lousiville)	89.1
22	Louisiana			87.9
		22071	Orleans (New Orleans)	88.9
23	Maine			95.1
24	Maryland			95.8
25	Massachusetts			114.2
		25025	Suffolk (Boston)	125.6
26	Michigan			100.3
		26077	Kalamazoo	94.5
		26081	Kent (Grand Rapids)	89.1
		26163	Wayne (Detroit)	108.2
27	Minnesota			101.6
		27053	Hennepin (Minneapolis)	109.4
28	Mississippi			81.3
		28049	Hinds (Jackson)	80.8
29	Missouri			89.9
		29510	St. Louis City (St. Louis)	102.5
		29095	Jackson (Kansas City)	96.8
30	Montana			99.7
		30111	Yellowstone (Billings)	100.2
31	Nebraska			83.5
		31055	Douglas (Omaha)	90.3
32	Nevada			102.0
		32003	Clark (Las Vegas)	104.8
33	New Hampshire			97.8
34	New Jersey			111.5
		34013	Essex (Newark)	111.9
		34017	Hudson (Jersey City)	112.5
35	New Mexico			92.3
36	New York			102.7
		36061	New York (New York)	137.3
		36007	Broome (Binghampton)	98.1
			(Utica)	96.6
37	North Carolina			80.1
		37183	Wake (Raleigh)	80.3

Table 15A.1: State Cost Modifiers with County Exception (continued)

State		County Exceptions		Index
#	Name	#	Name	
38	North Dakota			87.5
39	Ohio			95.1
		39035	Cuyahoga (Cleveland)	104.1
		39153	Summit (Akron)	102.1
		39095	Lucas (Toledo)	100.5
		39023	Clark (Springfield)	89.4
40	Oklahoma			84.9
		40109	Oklahoma (Oklahoma City)	85.6
41	Oregon			109.4
		41051	Multnomah (Portland)	111.2
42	Pennsylvania			100.8
		42101	Philadelphia (Philadelphia)	110.2
		42075	Lebanon (Allentown)	106.3
		42049	Erie (Erie)	97.1
44	Rhode Island			110.5
45	South Carolina			79.4
		45019	Charleston (Charleston)	80.1
46	South Dakota			82.8
		46099	Minnehaha (Sioux Falls)	83.3
47	Tennessee			84.0
		47157	Shelby (Memphis)	88.8
48	Texas			84.6
		48201	Harris (Houston)	92.8
		48113	Dallas (Dallas)	89.4
		48245	Jefferson (Beaumont)	91.5
49	Utah			89.1
		49035	Salt Lake (Salt Lake City)	89.5
50	Vermont			89.3
51	Virginia			83.6
		51087	Henrico (Richmond)	86.4
		51013	Arlington (Alexandria)	93.9
53	Washington			107.6
		53033	King (Seattle)	110.1
54	West Virginia			95.4
		54039	Kanawha (Charleston)	94.3
55	Wisconsin			95.7
		55079	Milwaukee (Milwaukee)	99.4
56	Wyoming			84.3

Appendix 15B
Relationship Between Building Damage and Business Interruption

The subject of business and service interruption due to building damage has been identified for some time as an important contributor to indirect economic losses following earthquakes.

The issue of relating building damage to business interruption, and developing some statistical measures has been little researched, and available information is largely anecdotal. ATC-13 provided extensive coverage of the topic of building repair and loss of function, at the same time noting that:

" ... it is clear that there is a great variation in repair and demolition actions taken in connection with buildings that are moderately or severely damaged. There is also great variation for the loss of function associated with a given degree of damage.... The paucity of data currently available precludes describing loss of function based on statistical data from past events."

ATC-13 provided detailed tables with estimates of loss of function times for all the ATC-13 social classes of buildings (and all lifelines). These tables, which were developed by expert opinion, provided estimates of the time to restore 30%, 60%, and 100% of useability, for each of the six ATC-13 damage states.

Since ATC-13 was published, the information that relates building damage to loss of function continues to be unsystematic and anecdotal. A study of damage and loss of function for 14 industrial and administrative buildings in the Loma Prieta earthquake shows a typical wide spread of conditions and consequences (Phipps, et. al, 1992). Table 16A-1 summarizes some of the information from this study. It is possible that surveys of the recovery after the Northridge earthquake may provide some more systematic information on this issue.

Table 15B.1: Summary of Building Damage Vs Restoration Time: for 14 Industrial/Administrative Low-Rise Buildings, Loma Prieta Earthquake (Time in Days) (from Phipps, et. al., 1992)

#	Structure Type	Damage Percentage	Restoration Time (days)	Description of Damage
1	Tilt-up	2	5	roof-wall connections
2.	Steel	20	180	window wall cracked
3	Steel	2	1	piping, clogs
4	Steel	37	270	floor cracked
5	Steel	33	270	bracing buckled
6	Steel	32	270	bracing buckled
7	Steel	33	270	bracing buckled
8	Steel	NA	360	sprinklers
9	Steel	23	150	buckled bracing
10	Tilt-up	89	540	cracked walls
11	Tilt-up	60	90	failed roof
12	Precast	NA	90	wall-floor connections
13	Steel	42	180	asbestos
14	Steel	NA	21	radioactive contamination

Surveys of available information and experience suggest that the ATC-13 attempt to use expert opinion resulted in more apparent precision in estimating than was justified by the data. In addition, the attempt to provide 30%, 60% and 100% restoration estimates may be relevant for lifelines, but has little meaning for building function. Typical business and service facilities either provide something approaching 100% function in a fairly short time after the earthquake or cease to exist. Considerable improvisation and ingenuity is usually applied by management and staff to ensure rapid restoration .

Thus, this methodology presents a much simplified set of estimates, which it is felt match the current state of knowledge. In doing this, the distinction between the time needed for repair and the often much longer time needed for the whole repair project is recognized by multipliers applied to the extended construction time. In addition, the fact that business function can be to a large extent divorced from the building that housed it is also recognized by these multipliers. The latter situation might vary greatly among different kinds of business and users of the methodology may find it useful to discuss with key businesses in their area the functional consequences of building damage. It is also a reasonable supposition that businesses that have not experienced earthquake damage tend to overestimate its effect on their operation because it is hard for them to imagine emergency improvisation since they lack the experience.

Table 15B-2 shows a correlation between the **HAZUS** damage states and the ATC-13 estimates for functional restoration time: these may be compared with the estimates in

Tables 15.11, 15 .12 and 15.13. The ATC estimates assume that repair time is equivalent to restoration time.

Table 15B.2: ATC-13: Restoration Times Related to HAZUS Occupancies (Time in days) (ATC-13, 1985)

No.	Label	Occupancy Class	Damage State		
			Slight	**Moderate**	**Extensive**
		Residential			
1	RES1	Single Family Dwelling	3	11-72	72-146
2	RES2	Mobile Home	3	11-72	72-146
3	RES3	Multi Family Dwelling	3	11-72	72-146
4	RES4	Temporary Lodging	3	11-72	72-146
5	RES5	Institutional Dormitory	3	11-72	72-146
6	RES6	Nursing Home	3	11-72	72-146
		Commercial			
7	COM1	Retail Trade	20	71-202	202-347
8	COM2	Wholesale Trade	20	71-202	202-347
9	COM3	Personal and Repair Services	20	71-202	202-347
10	COM4	Professional/Technical Services	20	71-202	202-347
11	COM5	Banks/Financial Institutions	20	71-202	202-347
12	COM6	Hospital	56	156-338	338-613
13	COM7	Medical Office/Clinic	56	156-338	338-613
14	COM8	Entertainment & Recreation	20	71-202	202-343
15	COM9	Theaters	20	71-202	202-343
16	COM10	Parking	6	24-76	76-172
		Industrial			
17	IND1	Heavy	23	99-240	240-405
18	IND2	Light	23	99-240	240-405
19	IND3	Food/Drugs/Chemicals	16	72-235	235-380
20	IND4	Metals/Minerals Processing	22	99-248	248-405
21	IND5	High Technology	16	112-258	258-429
22	IND6	Construction	28	68-121	121-257
		Agriculture			
23	AGR	Agriculture	9	26-77	77-154
		Religion/Non-Profit			
24	REL	Church/Membership Organization	17	72-215	215-382
		Government			
25	GOV1	General Services	28	91-196	196-396
26	GOV2	Emergency Response	18	60-134	134-256
		Education			
27	ED1	Schools/Libraries	16	72-183	183-362
28	ED2	Colleges/Universities	16	72-183	183-362

Note: **HAZUS** Damage State
Slight = ATC #3: (CDF 5%)
Moderate: 30%, = between ATC 4-5 (20 - 45%)
Extensive 50%, = between ATC 5-6 (45 - 80%)

Appendix 15C
Derivation of Repair and Replacement Costs

The repair and replacement cost estimates in this document are derived from Means Square Foot Cost 1994, for Residential, Commercial, Industrial and Institutional Buildings

To arrive at these costs, the following procedure was used.

- A model building was selected from Means to represent each of the **HAZUS** NIBS Occupancy Classes. The Means identification number for the buildings chosen is shown in Table 15C.1.

- From the detailed cost and percentage for the selected model buildings the value for "Structure" was derived as follows: Means provides a percentage and value for "Superstructure" Means also provides cost estimate for “Foundations & Substructures”. The “Structural” cost was estimated by adding the “Superstructure” costs and the “Foundations & Substructures” costs together.

- The Nonstructural component value was calculated by the following relationship:

  "Total Building Cost" - ["Superstructure Cost" + "Foundations & Substructures Cost"].

- Means provides a value for Total Building Cost: this is shown as "$Means/sq.ft" in Table 15C.1. This value is multiplied by 1.35 (the last column in Table 15C.1) to account for contractor's overhead and profit, design fees, and for additional post-earthquake costs including cleanup and demolition. Large additions to construction costs resulting from post-earthquake conditions are not assumed.

In Table 15C.2, the total costs for non-structural components shown in Table 15C.1 are allocated to Drift and Acceleration sensitive non-structural components in accord with the percentages noted in Section 15.2.1.1.

Table 15C.1: MEANS/NIBS Correlation and Cost Percentages

Class #	Label	Means ID #	Found./Subs. %	Structure %	Structure $ /sq. ft.	Means $ / sq. ft.	Total $ /sq. ft.
1	RES1	Av[1]	12	23	15	52	66
2	RES2	NA	0	25	11	NA	45
3	RES3	010	5	13	11	62	84
4	RES4	350	3	13	11	65	88
5	RES5	130	4	18	15	62	84
6	RES6	450	6	14	11	57	77
7	COM1	610	11	27	15	43	58
8	COM2	690	26	24	11	34	46
9	COM3	290	14	13	11	58	79
10	COM4	470	2	18	14	55	75
11	COM5	050	11	12	16	96	130
12	COM6	310	3	14	17	93	125
13	COM7	410	5	14	13	69	96
14	COM8	530	10	9	10	83	113
15	COM9	440	12	11	9	62	84
16	COM10	270	13	55	14	19	26
17	IND1	200	14	13	8	44	59
18	IND2	200	14	13	8	44	59
19	IND3	200	14	13	8	44	59
20	IND4	200	14	13	8	44	59
21	IND5	200	14	13	8	44	59
22	IND6	200	14	13	8	44	59
23	AGR	690[2]	36	26	6	16	22
24	REL	090	12	18	17	71	97
25	GOV1	670	12	16	12	57	76
26	GOV2	490	5	11	17	83	112
27	ED1	570	5	18	14	58	78
28	ED2	150	13	11	11	73	99

NOTES

1 Costs from Means *Average, 2 story residential* model

2 Agricultural costs based on Means #690 (warehouse) with steel frame, metal exterior cladding , no partitions/ceiling/finishes, no heating, electrical service only/no lighting, minimum reinforced slab on grade.

Table 15C.2: Non-structural Costs, Drift/Acceleration Ratios & Costs

Class #	Total $ / sq. ft.	NS %	Total NS $ / sq. ft.[1]	NS(Drift) %	NS (Drift) $ / sq. ft.	NS (Acc) %	NS (Acc) $ / sq. ft.
1	66	75	49	65	32	35	17
2	44	75	34	50	17	50	17
3	84	82	69	50	34	50	35
4	88	84	70	50	35	50	35
5	84	78	65	50	32	50	33
6	77	80	62	50	31	50	31
7	36	62	36	40	14	60	22
8	46	50	23	40	9	60	14
9	79	73	57	40	23	60	34
10	78	80	59	40	24	60	35
11	130	77	100	40	40	60	60
12	125	83	104	40	42	60	62
13	96	81	77	40	31	60	46
14	113	81	91	40	36	60	55
15	84	77	65	40	26	60	39
16	26	42	9	40	4	60	5
17	59	73	43	15	6	85	37
18	59	73	43	15	6	85	37
19	59	73	43	15	6	85	37
20	59	73	43	15	6	85	37
21	59	73	43	15	6	85	37
22	59	73	43	15	6	85	37
23	22	38	8	15	1	85	6
24	97	70	69	40	28	60	41
25	76	72	55	40	22	60	33
26	112	84	94	40	38	60	56
27	78	77	60	60	36	40	24
28	99	76	99	60	60	40	29

[1]Figure obtained by multiplying total cost by (100 - structural cost % - F&S cost %)/100

APPENDIX 15 D. Lifeline Subcomponent Information (Damage Ratios & Fraction of Value)

Table 15D.1. Subcomponents for the Railway System(G&E, 1994)

Sub-Component	Fraction of Total Component Value	Damage State	Damage Ratio
Fuel Facilities			
Electric Backup Power	2 %	slight moderate	0.20 0.70
Tanks	86 %	slight moderate extensive complete	0.20 0.40 0.85 1.00
Pump Building	2 %	slight moderate extensive complete	0.10 0.40 0.80 1.00
Horizontal Pumps	5 %	extensive	0.75
Electrical Equipment	5 %	moderate	0.50
Dispatch Facilities			
Electric Backup Power	30 %	slight moderate	0.20 0.70
Building	20 %	slight moderate extensive complete	0.10 0.40 0.80 1.00
Electrical Equipment	20 %	moderate	0.80
Railway Bridges			
Column		slight extensive complete	0.05 0.25 0.8
Abutment		slight moderate extensive	0.02 0.075 0.15
Connection		moderate extensive	0.01 0.02
Deck		slight	0.05

Table 15D.2. Subcomponents for DC Substations (G&E, 1994)

Subcomponent	Fraction of Total Component Value	Damage State	Damage Ratio
Building	35 %	slight moderate extensive complete	0.10 0.40 0.80 1.00
Equipment	65 %	moderate	0.80

Table 15D.3. Subcomponents for the Bus System (G&E, 1994)

Subcomponent	Fraction of Total Component Value	Damage State	Damage Ratio
Fuel Facilities			
Electric Backup Power	2 %	slight moderate	0.20 0.70
Tanks	79 %	slight moderate extensive complete	0.20 0.40 0.85 1.00
Building	11 %	slight moderate extensive complete	0.10 0.40 0.80 1.00
Pumps	4 %	extensive	0.75
Electrical Equipment	4 %	moderate	0.50
Dispatch Facilities			
Electric Backup Power	15 %	slight moderate	0.20 0.70
Building	30 %	slight moderate extensive complete	0.10 0.40 0.80 1.00
Electrical Equipment	55 %	moderate	0.80

Table 15D.4. Subcomponents for Port, Ferry and Airport Systems (G&E, 1994)

Sub-Component	Fraction of Total Component Value	Damage State	Damage Ratio
Port Fuel Facilities			
Electric Backup Power	5 %	slight moderate	0.20 0.70
Tanks	70 %	slight moderate extensive complete	0.20 0.40 0.85 1.00
Pump Building	5 %	slight moderate extensive complete	0.10 0.40 0.80 1.00
Horizontal Pumps	10 %	extensive	0.75
Electrical Equipment	10 %	moderate	0.50
Ferry Fuel Facilities			
Electric Backup Power	3 %	slight moderate	0.20 0.70
Tanks	72 %	slight moderate extensive complete	0.20 0.40 0.85 1.00
Pump Building	5 %	slight moderate extensive complete	0.10 0.40 0.80 1.00
Horizontal Pumps	10 %	extensive	0.75
Electrical Equipment	10 %	moderate	0.50
Airport Fuel Facilities			
Electric Backup Power	6 %	slight moderate	0.20 0.70
Tanks	64 %	slight moderate extensive complete	0.20 0.40 0.85 1.00
Pump Building	6 %	slight moderate extensive complete	0.10 0.40 0.80 1.00
Horizontal Pumps	12 %	extensive	0.75
Electrical Equipment	12 %	moderate	0.50

Table 15D.5. Subcomponent for Potable Water System Components (G&E, 1994)

Sub-Component	Fraction of Total Component Value	Damage State	Damage Ratio
Water Treatment Plant			
Electric Backup Power	4 %	slight moderate	0.20 0.70
Chlorination Equipment	4 %	slight moderate	0.15 0.50
Sediment Flocculation	12 %	slight moderate	0.20 0.50
Chemical Tanks	20 %	slight moderate	0.20 0.75
Electric Equipment	30 %	moderate	0.60
Elevated Pipe	10 %	extensive complete	0.65 0.90
Filter Gallery	20 %	complete	1.00
Wells			
Electric Backup Power	16 %	slight moderate	0.20 0.70
Well Pump	34 %	extensive	0.75
Building	16 %	slight moderate extensive complete	0.10 0.40 0.80 1.00
Electric Equipment	34 %	moderate	0.60
Pumping Plants			
Electric Backup Power	16 %	slight moderate	0.20 0.70
Pumps	34 %	extensive	0.75
Building	16 %	slight moderate extensive complete	0.10 0.40 0.80 1.00
Electrical Equipment	34 %	moderate	0.60

Table 15D.6. Subcomponets for Waste Water Treatment (G&E, 1994)

Subcomponents	Fraction of Total Component Value	Damage State	Damage Ratio
Electric Backup Power	5 %	slight moderate	0.20 0.70
Chlorination Equipment	3 %	slight moderate	0.15 0.50
Sediment Flocculation	36 %	slight moderate extensive	0.20 0.50 0.80
Chemical Tanks	7 %	slight moderate	0.20 0.75
Electrical/ Mechanical Equipment	14 %	moderate	0.60
Elevated Pipe	8 %	extensive complete	0.65 0.90
Buildings	27 %	complete	1.00

Table 15D.7 Subcomponents for Crude & Refined Oil Systems(G&E, 1994)

Sub-Component	Fraction of Total Component Value	Damage State	Damage Ratio
Refineries			
Electric Backup Power	3 %	slight moderate	0.20 0.70
Electrical/ Mechanical Equipment	6 %	moderate	0.60
Tanks	42 %	slight moderate extensive complete	0.20 0.40 0.85 1.00
Stacks	42 %	extensive	0.80
Elevated Pipe	7 %	complete	1.00
Pumping Plants			
Electric Backup Power	30 %	slight moderate	0.20 0.70
Pump	20 %	extensive	0.75
Building	20 %	slight moderate extensive complete	0.10 0.40 0.80 1.00
Electrical/ Mechanical Equipment	30 %	moderate	0.60
Tank Farms			
Electric Backup Power	6 %	slight moderate	0.20 0.70
Electrical/ Mechanical Equipment	24 %	moderate	0.60
Tanks	58 %	slight moderate extensive complete	0.20 0.40 0.85 1.00
Elevated Pipes	12 %	extensive complete	0.65 0.90

Table 15D.8. Subcomponents for Electrical Substations (G&E, 1994)

Classification	Fraction of Total Component Value	Damage State	Damage Ratio
Transformers	68 %	extensive complete	0.50 1.00
Circuit Breakers	26 %	slight moderate extensive complete	0.17 0.33 0.67 1.00
Disconnect Switches	3 %	slight moderate extensive complete	0.17 0.42 0.67 1.00
Current Transformers	3 %	extensive complete	0.67 1.00

Table 15D.9. Subcomponents for Generation Plant (G&E, 1994)

Subcomponents	Fraction of Total Component Value	Damage State	Damage Ratio
Electrical Equipment	17 %	slight moderate	0.30 0.60
Boilers & Pressure Vessels	19 %	moderate	0.50
Vertical vessels	5 %	moderate extensive	0.50 0.80
Pumps	9 %	extensive	0.75
Horizontal vessels	14 %	complete	1.00
Large motor operated valves	5 %	complete	1.00
Boiler Building	17 %	slight moderate extensive complete	0.10 0.40 0.80 1.00
Turbine Building	14 %	slight moderate extensive complete	0.10 0.40 0.80 1.00

Table 15D.10. Subcomponents for Communication Centers (G&E, 1994)

Subcomponents	Fraction of Total Component Value	Damage State	Damage Ratio
Electric Power (Backup)	15 %	slight moderate	0.20 0.70
Switching Equipment	49 %	slight moderate extensive complete	0.05 0.20 0.60 1.00
Building	36 %	slight moderate extensive complete	0.10 0.40 0.80 1.00