7. Combined Economic Losses, Deaths, and Injuries

7.1 Introduction

In this chapter we provide an overview of combined economic losses, consisting of direct and indirect economic losses, and a discussion of deaths and injuries.

At this point it is important to reiterate the purposes and key limitations of this study. As previously indicated, the overall purpose is to provide an overview of the national economic impact resulting from the seismic vulnerability of lifelines and the impact of their disruption. The Federal Emergency Management Agency is planning to use this report to emphasize the importance of maintaining functionality of lifelines after earthquakes and to assist in the identification and prioritization of hazard mitigation measures and policies.

Lifelines considered are transportation systems, energy systems, emergency service facilities, and water systems. Excluded from consideration because of the unavailability of inventory data or the need for more in-depth studies are telecommunication systems, nuclear and fossil-fuel power plants, dams, and certain highway, electric, and water facilities at the local distribution level.

Also excluded from consideration in the results are interaction effects between lifelines, secondary economic effects (the impact of a reduced capacity of one economic sector on a dependent sector), and damage resulting from landslide (due to lack of inventory data nationwide). These limitations and others described in Chapters 2, 4, and 5 tend to underestimate losses; other limitations (e.g., application of ATC-13 vulnerability functions to a relatively few structures) tend to overestimate the losses. Lack of capacity information for most lifelines was also a definite limitation. In the aggregate, due primarily to the exclusion of systems (e.g., dams and telecommunication systems), we believe the estimates presented in this report are, in fact, quite conservative.

This report is a macroscopic investigation at the national level and the results should not be used for microscopic interpretations. The results are not intended to be used to evaluate any particular regional utility or lifeline and no specific information on such specific facilities has been included.

7.2 Human Death and Injury

It is generally felt that lifeline performance and continuity of operation is vital to human survival in the modern, urban, world. Most observers believe that damage to lifelines would result in human death and injury. Analogous to direct damage to property and indirect economic losses, human death and injury resulting from lifeline damage can be categorized as follows:

1. Human death and injury caused by lifeline functional curtailment, where persons suffer as a result of deprivation of vital services; and

2. Human death and injury resulting from direct damage to lifelines (e.g., occupant injuries resulting from the collapse of an air terminal building).

Analysis and data on both of these aspects are virtually nonexistent. Following are discussions of these death and injury causes:

7.2.1 Casualties Due to Lifeline Functional Curtailment

Without the benefit of hard data it is difficult to estimate with high confidence the number of casualties that will result from curtailment of lifeline function. Our preliminary assessment is that human death and injury due to functional curtailment of lifelines can generally be expected to be very low. This is a fundamental assumption of this study, and will probably cause some debate. Each lifeline was considered, and this conclusion was found to hold, based on the following assumptions: (1) most vital installations that normally require a lifeline service have back-up emergency supplies, and (2) most lifelines have considerable elasticity in demand, and the level of service necessary for life maintenance is very low. Examples follow:

- Electricity. Persons can survive without power, even in the Northeast in the winter. Most hospitals and similar installations have emergency generators. Those that lack emergency generators can transfer patients to other sites.

- Water. Water for human survival is very minimal. Humans can survive without water for 48 or more hours, and water for human survival can be imported if necessary.

- Gas and Liquid Fuels. Gas and liquid fuel systems are probably the most critical of all lifelines, yet capacity is very elastic, and only short-term shortages are expected. Fuel for heating in the Northeast in the winter can be conserved if necessary by clustering people in school gymnasia, national guard armories, and so on.

- Rail, Air, and Highway Transportation. Transportation lifelines are highly redundant and thus very elastic; emergency food and medicines would be expected to be deliverable regardless of earthquake damage.

7.2.2 *Casualties Resulting From Lifeline Direct Damage*

Casualties can result from direct damage, especially catastrophic collapse, of lifeline components. Although few deaths occurred directly as a result of lifeline damage in U. S. earthquakes prior to 1989, life-loss due to lifeline failure was tragically demonstrated during the October 17, 1989, Loma Prieta, California, earthquake. Approximately two thirds of the 62 deaths from this earthquake resulted from the failure of a lifeline component--partial collapse of the Cypress structure, a double-decked highway viaduct in Oakland approximately 100 km from the earthquake source zone.

Although it can be argued that the deaths and injuries caused by lifeline failure in the Loma Prieta earthquake were the exception, not the rule, the vulnerability functions developed for this project suggest that substantial life-loss from lifeline component failure should be anticipated. Lifeline failures that could cause substantial life loss or injury include bridge failure, railroad derailment, and pipeline failure.

Unfortunately, data necessary for estimating life loss associated with these component failures are not readily available, precluding development of reliable casualty estimation methodology and data for lifeline structures.

7.3 Combined Direct and Indirect Economic Losses

Total dollar losses from direct damage and indirect economic losses have been taken from Chapters 5 and 6 and are combined and summarized herein for each scenario earthquake and lifeline in Table 7-1. The total losses for each scenario earthquake are as follows:

Earthquake	*Direct Plus Indirect Losses (in Billions, 1991$)*
Cape Ann	$13.3
Charleston	$15.1
Fort Tejon	$16.6
Hayward	$15.7
New Madrid, M = 8.0	$26.4
New Madrid, M = 7.0	$8.3
Puget Sound	$10.5
Wasatch Front	$5.4

Table 7-1 Total Direct Plus Indirect Dollar Losses for Each Scenario Earthquake and Lifeline (Billions of Dollars)

Scenario	*Electric*	*Highways*	*Water*	*Medical Care*	*Ports*	*Railroads*	*Airport*	*Natural Gas*	*Crude Oil*	*Refined Oil*	*Broadcasting Stations*	*Fire Stations*	*Total*
Cape Ann	$11.24	$2.06	$0.91	$0.49	$0.50	$0.03	$0.58	$0.00	$0.00	$0.00	$0.02	$0.01	$13.25
Charleston	$10.82	$2.05	$0.94	$0.57	$5.30	$0.18	$0.59	$0.00	$0.00	$0.00	$0.07	$0.01	$15.11
Fort Tejon	$9.66	$5.18	$5.27	$1.43	$2.65	$0.41	$1.57	$1.68	$4.38	$0.00	$0.03	$0.05	$16.58
Hayward	$12.21	$2.52	$4.38	$1.30	$1.46	$0.22	$0.44	$0.09	$0.00	$0.00	$0.02	$0.01	$15.66
New Madrid 8	$15.68	$13.19	$2.68	$1.30	$0.00	$0.71	$1.22	$0.34	$0.46	$0.23	$0.09	$0.01	$26.37
New Madrid 7	$5.17	$4.12	$0.85	$0.40	$0.00	$0.15	$0.31	$0.18	$0.13	$0.16	$0.03	$0.00	$8.29
Puget Sound	$8.29	$1.95	$0.90	$0.51	$0.79	$0.21	$0.62	$0.21	$0.00	$0.00	$0.05	$0.01	$10.48
Wasatch Front	$2.21	$3.85	$0.40	$0.20	$0.00	$0.05	$0.11	$0.04	$0.00	$0.00	$0.04	$0.00	$5.41