1. Direct Economic Losses in the Northridge Earthquake: A Three-Year Post-Event Perspective

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The Northridge earthquake will long be remembered for the unprecedented losses incurred as a result of a moderate-size event in a suburban area of Los Angeles. Current documented costs indicate that this event is the costliest disaster in U.S. history. Although it is difficult to estimate the full cost of this event, it is quite possible that total losses, excluding indirect effects, could reach as much as $40 billion. This would make the Northridge earthquake less severe than the Kobe event, which occurred exactly one year after the Northridge earthquake, but adds a bit of realism that a Kobe-type disaster is possible in the U.S. This paper attempts to put into perspective the direct capital losses associated with the Northridge earthquake. In doing so, we introduce the concept of hidden and/or undocumented costs that could double current estimates. In addition, we present the notion that a final estimate of loss may be impossible to achieve, although costs do begin to level off two years after the earthquake. Finally, we attempt to reconcile apparent differences between loss totals for two databases tracking similar information.

INTRODUCTION

In the aftermath of a damaging earthquake, there are immediate demands for a rapid assessment of direct capital impacts, that is, for an overall estimate of repair costs to buildings including structural and nonstructural components and contents as well as to lifelines and other infrastructure. The sources of these demands are diverse. The news media, always preoccupied with "how big? how bad? and how much?" will press public officials for this information as quickly as speculative data are available. Most important for recovery, however, are the estimates demanded by federal law under the Stafford Act as part of a request for a Presidential Disaster Declaration. This estimate must be submitted in the days following the event and is typically based on limited data, speculation and, more recently, on

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analytical models. These early estimates and the process in which estimates give way to actual losses, the comparison of these early estimates with later figures, and the broader context of loss determination are the subjects of this paper.

Overall loss estimates become available as piecemeal reports from various sources. The insurance industry provides its estimate of loss based on claims and settlements; post-disaster safety assessments provide damage and loss estimates based on cursory but rapid inspections; and state and federal programs including Individual and Public Assistance yield figures based on grants and loans made to victims. The overall direct loss figure must be assembled from these various sources and with great care given the idiosyncrasies of these data. Determining when an accurate overall figure becomes available is also problematic and one often hears the original, and very preliminary direct damage estimate being quoted months and even years after the disaster has occurred.

The Northridge earthquake, the most recent of California's earthquake disasters, was the first in which a major effort was made to carefully assemble earthquake damage data using new technologies including large scale data management systems. These data present a fascinating picture of the diverse economic, political and sociological factors that accompany disaster recovery. In this paper, we will trace the emergence of a loss estimate for the Northridge earthquake and, in so doing, will attempt to capture the larger and sometimes colorful context of the development of these loss figures. We will also examine the process of estimating losses and it will be readily apparent that having the best information available on seismic hazards and the built environment is not a guarantee that eventual losses in large urban earthquakes can be precisely predicted.

The painful truth is that we are not very good at initial estimation and, despite having the luxury in the long-term post-disaster period to carefully assess our losses, we are not very good at achieving a final loss figure either. Damage data assembled in the Northridge earthquake reveal several disturbing trends: large discrepancies between projected losses based on building inspector information and data received from insurance companies, the continuous upward adjustment of insured losses with time, and the lengthy period of time during which losses accumulate. The importance of accurate loss estimates as well as a final and credible direct loss total is clear—timely and effective emergency response and early recovery depend on credible initial loss estimates, and the calibration of loss estimation models and evaluation of disaster recovery and mitigation programs, in short- and long-term recovery and reconstruction, are facilitated by improved final loss estimates.

OVERVIEW OF CURRENT DOCUMENTED COSTS

Before proceeding with a detailed analysis of estimated and actual earthquake losses from the Northridge earthquake, we provide a brief but concise statement of current documented costs, as we know them now. This discussion will center on two important topics: the overall loss in the event and the ramping up of losses with time. Both factors are important in understanding the true impact of this disaster on the economic recovery of the region.

Table 1 provides a summary of current documented costs resulting from the Northridge earthquake. The table includes federal and state costs as well as insured losses and costs to repair most damaged lifelines. What is not included in this summary are repair costs outside of insurance coverage (e.g., deductibles, costs above insurance limits), commercial loans to repair damaged structures, some lifeline repairs and damage not reported or repaired.

Table 1. Current total estimated costs and estimate of the non-federal share for the Northridge Earthquake (source: State Dept. of Insurance and OES, Dec. 1995)

	Total Estimated Costs	**State of CA Share**
Public assistance	$ 4.5 billion	$ 0.45 billion
Hazard mitigation	$ 0.92 billion	--
Repairs of transportation structures and roadways	$ 0.327 billion	--
Utilities	$0.3 billion	
Individual/Family Grant programs (including state supplemental grant and mental health)	$ 0.25 billion	$ 0.06 billion
Small Business Administration	$ 4.03 billion	0
Disaster Housing/Mortgage Assistance	$ 1.2 billion	0
California Employment Development Dept.	$ 0.041 billion	$ 0.041 billion
State Board of Control	$ 0.055 billion	$ 0.055 billion
Privately Insured Residential Claims	$8.4 billion*	--
Privately Insured Business Claims (including a small amount of public agencies that had insurance)	$4.1 billion	--
American Red Cross	$ 0.036 billion	--
Salvation Army	$ 0.001 billion	--
Total	~$ 24 billion	~$ 1 billion

* The State Department of Insurance update of the Northridge privately insured residential losses is broken down as follows:

coverage A (structures)	5.6 billion
coverage B (appurtenant structures)	0.6 billion
coverage C (contents)	2.0 billion
coverage D (loss of use)	0.2 billion
Total =	8.4 billion

According to Table 1, the total cost of the Northridge earthquake exceeds $24 billion. As suggested earlier, this total represents a lower bound since not all capital costs are included in this summary. A crude attempt at estimating losses not covered by earthquake insurance or damage not reported suggests that the $24 billion estimate may be low by as much as $20 billion. Although it is difficult to substantiate the $20 billion estimate, we know that (1) deductibles (or partial deductibles) were paid on at least 260,000 claims, and (2) roughly 60 percent of policy holders in the affected area did not have earthquake insurance coverage. Assuming that the average replacement value of a residential structure is about $150,000 and that the average deductible level is 10 percent, a deductible estimate of $3.9 billion is calculated. Additionally, if we assume that a significant proportion of the 60 percent without homeowners insurance also experienced damage at the same damage rate as insured properties, then an additional $18 billion of damage is estimated. It is assumed that some of the $3.9 billion and $18 billion would be covered by Individual Assistance grants or Small Business Administration loans, thus making the uncovered amount of repairs around $20 billion.

If we further consider commercial and industrial losses that come out of self-insurance, then a $44 billion total loss estimate is not unreasonable. The precise amount of the "loss-bearing" category has not been documented in the databases that we are discussing. Instead, indirect evidence for these losses borne by homeowners, businesses and industries themselves would need to be derived through economic studies focusing on such matters as regional savings depleted through the earthquake and of new debts originated for reconstruction.

Figure 1 shows a plot of losses with respect to time after the earthquake. Losses that are noted include insured losses to private and commercial properties, building damage estimates provided by local building and safety (B&S) departments, public assistance (PA) costs, hazard mitigation grant program (HMGP) costs, individual assistance (IA) program costs and loans administered under the Small Business Administration (SBA) program. In addition, a plot of total losses or costs (insured losses, PA, HMGP, IA and SBA) is included.

Figure 1 shows that some costs or losses are known within a matter of months. These include IA, PA and building and safety estimates of damage or loss. Why IA and PA amounts would be known so soon after the earthquake is easily explained. Since some IA monies are directed towards housing assistance and mortgage/rental assistance programs, most of these disbursements would be made during the initial period of the disaster. PA monies and estimates of damage provided by building and safety departments would also be determined early in the disaster; in both cases, inspections would be performed quickly in order to facilitate public safety.

Insured losses and loans provided under the SBA program require a more lengthy disbursement process. More detailed inspections are needed and in some cases, comprehensive reviews are required to ensure that the damage reported is indeed earthquake related. Therefore, it is not surprising to see damage or loss totals for these programs continuing to increase one year after the event. In all cases, however, losses have generally leveled off two years after the earthquake.

In the sections that follow, we attempt to discuss how damage was measured by different organizations and agencies after the earthquake. Important in these discussions is the distinction between damage estimates and actual loss totals.

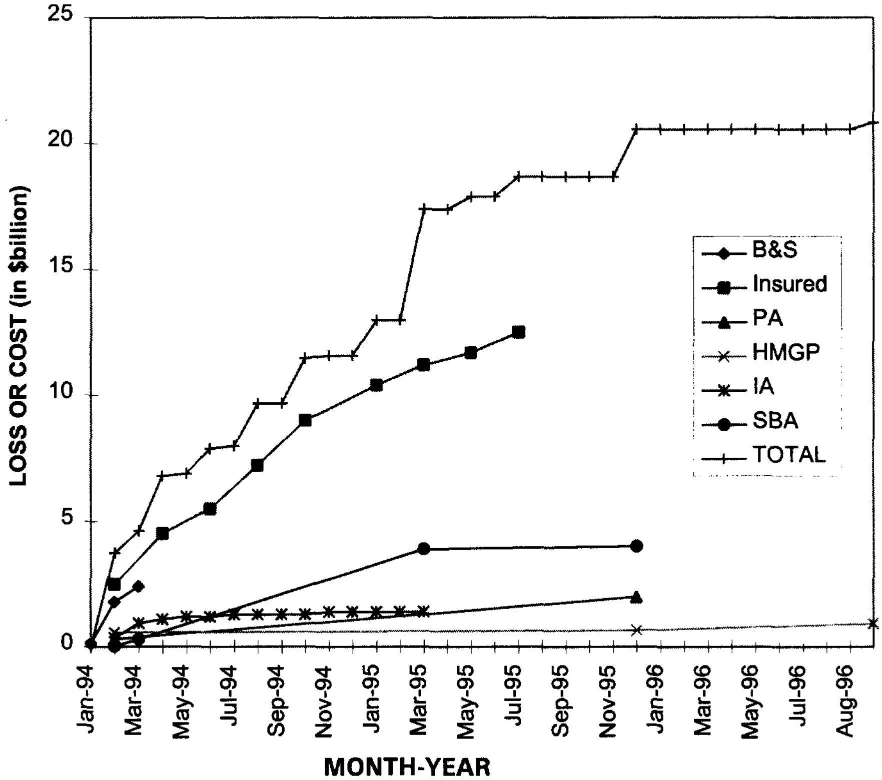

Figure 1. Loss or cost totals with time (B&S – Building & Safety; Insured – Insurance losses; PA – Public Assistance; HMGP – Hazard Mitigation Grant Program; IA – Individual Assistance; and SBA – Small Business Administration).

DAMAGE DATA: ESTIMATES AND ACTUAL LOSSES

On the surface, we can easily distinguish between an estimate of loss and an actual loss. An estimate is a "guess" based on limited data whether that data is derived from cursory observation as in a "windshield" survey of damage or sophisticated loss estimation models. An actual loss can be portrayed in an equally simple manner as a record of the real cost of repairs in terms of a cash transfer between parties. Estimates are typically made both before and after a damaging earthquake has occurred, often as part of a planning scenario before the event or as loss estimates for specific purposes (e.g., rapid loss estimates for response decision-making or for federal disaster assistance) after the event. As the process of repairing damage proceeds, estimates give way to actual losses, carefully compiled until a total direct capital loss is finally achieved. Unfortunately, this simple version of estimates and actual losses and the transition from one to the other is far more complex. In the sections that follow, we will first introduce the most significant sources of estimates and actual losses (see Table 2) then provide a comparative analysis of these data.

Table 2. Types of loss estimates and actual losses

Estimates	Actual Loss
Preliminary Damage Assessment (PDA)	Insured Property
Building Safety Inspection	Permit Valuation
Early Post-Earthquake Damage (EPEDAT)	Public and Individual Assistance (PA/IA)

ESTIMATES

Loss estimation has been a standard fixture in assessing potential losses both before and after a disaster. Much of the remainder of this paper will involve a discussion of loss estimation and there is much to be said due to the variety of forms, uses and influences that shape it. In the context of the Northridge earthquake, we will discuss three sets of estimates of direct capital losses: the Preliminary Damage Assessment required by the Stafford Act as one component of eligibility for federal disaster assistance; estimates of damage and loss prepared in the Post-Earthquake Safety Inspection Program by local building officials; and, a new approach to loss estimation in which quantitative models and real-time seismology are linked to produce rapid loss estimates as a decision support tool for emergency response.

The Preliminary Damage Assessment (PDA)

The PDA is the first official damage estimate prepared after a major disaster and is a joint effort of the state in which the disaster occurs and the Federal Emergency Management Agency to determine the financial magnitude of the event for federal disaster assistance purposes. In general, this estimate is typically derived from reconnaissance, often "windshield" surveys conducted by the affected jurisdictions during the first 48 to 72 hours after the earthquake (OES 1992). Survey data are aggregated at the county level, and reported to the OES regional office where they are again aggregated and reported to the state operations center. The state operations center is then responsible for providing the Governor with a composite loss estimate. Scientific and technical assessments also factor into the PDA to the extent that these assessments are available from seismologists, geologists and engineers.

Safety Inspection Estimates

Immediately following a damaging earthquake, local building and safety departments organize teams of inspectors to identify damaged buildings posing a danger to public safety. The process of judging the safety of a particular building is often based on guidelines provided by a handbook entitled *ATC 20—Procedures for Post-earthquake Safety Evaluation* *of Buildings* (ATC 1989) and is conducted in accordance with the state's Post-Disaster Safety Assessment Plan (OES 1992). Inspectors are instructed to affix a colored tag on an inspected structure with green indicating that the building has been inspected and no hazards have been discovered, yellow allows limited entry and acknowledges that potentially dangerous conditions exist and red announces unsafe conditions and that no one may enter. During these safety assessments, inspectors also provide rough estimates of repair costs for individual buildings. These estimates represent a repair cost estimate and/or damage estimate as a percentage of replacement cost, based on the known value of the structure.

Rapid Post-Earthquake Loss Estimates

The Early Post-Earthquake Damage Assessment Tool (EPEDAT) is a GIS-based software that rapidly estimates building and lifeline damage, casualties and the number of displaced persons given the magnitude and location of an earthquake (Eguchi et al. 1997). EPEDAT was developed by EQE International, Inc. for the California Governor's Office of Emergency Services to serve both the emergency response and pre-event planning needs of the agency. Immediately following the January 17 earthquake, data and models that were to be the basis for EPEDAT in Southern California were utilized and, though the system was not fully operational at the time, produced total direct loss estimates that were used along with traditional reconnaissance surveys to prepare the Preliminary Damage Assessment. EPEDAT also produced estimates of Northridge shaking intensities, deaths and injuries and the number of displaced persons (Goltz 1996).

ACTUAL LOSS DATA

Actual loss data as distinguished from loss estimates have the following properties: they represent a real cash transfer from one party to another for repair of damage and they can occur only after the occurrence of a disaster. While we can point to actual loss calculations and cumulative losses for an economic sector (e.g., direct capital losses for public facilities), the question as to whether a final overall loss figure can be attained remains uncertain, and ironically would be an estimate.

Insured Losses

After an earthquake that has caused damage to insured property, inspectors are dispatched to evaluate damage reported by those with earthquake coverage. This coverage, which is offered as a separate endorsement to standard property and casualty insurance policies, may include damaged contents, driveways, block walls, superficial cracks, and stained carpets. Also included in some policies are additional living expenses, automobile damage and medical costs. Once an inspection has been made and adjusters have evaluated the costs of repairs or replacement and deductibles have been factored, an actual transfer of funds is made between the insurance company and the insured. The amount of this transfer is then reported to the California Department of Insurance, which maintains records on total insurance payouts for a particular disaster.

Permit Valuation Damage

Prior to the initiation of repairs to earthquake damaged property, owners may be required by the city in which the property is located to apply for, and be granted, a building permit. One purpose of the building permit is to derive fees proportional to the cost of improvements, including the estimated repair cost, and improvements that may include a number of features not evaluated through rapid building inspections. These include repairs to driveways, block walls, superficial cracks, and other repairs. The data from the permit application includes a detailed statement of the work to be done and the costs of repair. This information is maintained, and under some circumstances, aggregated, as was the case in the Northridge earthquake.

Public/Individual Assistance

The Federal Public Assistance Program becomes available in an impacted community in a presidentially declared disaster. Under this program, assistance is provided through grants to eligible entities that include state agencies, local jurisdictions, and private nonprofit organizations that provide services of a governmental nature (e.g., educational institutions, utilities, libraries, etc.). Available grants cover at least 75% of the eligible costs (90% in Northridge), the remaining costs are the responsibility of the applicant or, in some instances, the state pays the remainder. To be eligible, the work must be required as a result of the declared disaster event, located within the designated disaster area and be the legal responsibility of the applicant. The type of projects for which an applicant may be reimbursed include debris removal, emergency protective measures and work to restore an eligible facility to its pre-disaster status.

Post-disaster Individual Assistance is provided by FEMA, the State of California, and the Small Business Administration. These agencies administer a number of different programs available to individuals and small businesses including disaster loans to individuals and businesses through SBA. Individuals may be eligible for low interest rate loans for damage to homes of up to $200,000 and personal property losses of up to $40,000. Businesses may be eligible for loans of up to $1,500,000; Disaster Housing Assistance Program assists people who cannot or should not live in their homes because of damage or other disaster related reasons; Disaster Mortgage and Rental Assistance Program assists people who, as a result of the disaster, have lost their jobs or businesses and face foreclosure or eviction from their homes; and the Individual Family Grant Program available to individuals and families for a variety of post-disaster needs.

COMPARATIVE ANALYSIS

In this section, the estimates and actual loss data are compared to provide some insight into the complex process of bringing direct capital losses into focus after a major damaging earthquake. It will become readily evident that the process involves many organizational actors with differing interests, that inconsistencies and disparities in the data are common and that considerable work is needed to develop a more rational process of loss determination.

SAFETY INSPECTION ESTIMATES AND INSURANCE INDUSTRY LOSSES

Losses actually paid by insurance companies in the Northridge earthquake vary significantly from estimates contained in the safety inspection reports assembled by local jurisdictions. There are a number of reasons for the discrepancies:

- their purposes differ substantially, that is, one process seeks to compensate those insured for losses while the other is conducted to ensure safety;
- insurance evaluations are more thorough and are both more intensive and extensive, including loss to contents and the costs of additional living expenses; and
- variations in the criteria used for estimating damage and losses (e.g., liberal payout criteria versus very cursory loss estimation criteria).

In addition, recall that local jurisdictions prepared estimates of dollar loss as part of a process whose main purpose was safety and that the result was an estimate. Insurance figures represent actual compensated losses.

Damage inspection team members are not typically cost estimators and are not necessarily aware of replacement values. Furthermore, because of the need to inspect many buildings in a short period of time, they generally inspect only areas that are visually accessible. Hence, they may not notice damage in building interiors, and may not be concerned with replacing carpets or repainting walls. On the other hand, insurance inspectors are experienced adjusters and conduct a thorough inspection of all insured property. Many adjusters, however, are not experts at assessing earthquake damage and their inspections may include damage that is caused by previous earthquakes or is not earthquake damage at all.

Other factors may also make insurance data diverge from building damage data. Insurers have often contended that they are faced with adverse selection, or a collection of properties with greater than average risk of sustaining damage in an earthquake. Adverse selection may arise because the insured knows more about the risk than the insurer. The area most heavily impacted by the Northridge earthquake overlaps significantly with that of the 1971 San Fernando earthquake. We know that those who have suffered losses in the past are more likely to insure against future losses than those who have suffered no losses. Thus, while the percentage of homeowners statewide who carry earthquake insurance is approximately 20-25%, coverage in the areas most heavily impacted by Northridge was 35–40%. Another source of adverse selection is "underinsurance," which occurs when the value at risk (and by implication the deductible, if this is stated as a percentage of the value of risk) is significantly underestimated as on a "replacement value" policy in which the replacement value is not kept up-to-date. Hence, "average" risk estimates based on replacement value will underestimate the risk for underinsured policies.

Another adverse factor arises when retroactive codes are developed that guide repair and reconstruction activities. The typical policy may cover replacement value, but to obtain a permit, the homeowner may be required to comply with these new codes. Hence, the new "replacement value" may reflect higher seismic standards and hence a greater value than the replacement value as determinable before the disaster. After the Northridge earthquake, for example, the City of Los Angeles enacted several significant modifications to the building code. These made permits conditional on their compliance with new seismic retrofit requirements, which in turn increased repair and replacement costs after the disaster. We indicated at the outset that loss determination is a political process and the adjudication of insured losses can be influenced by a number of factors. These include potential regulatory and legal punitive action toward insurers who generate complaints among consumers, tradeoffs between making smaller payouts and costs to litigate questionable small claims, insurer image and desire to retain market share and assure consumers of their solvency, and preparedness in training adjusters to distinguish between recent earthquake-related damage and damage from previous settlement and other causes. Reputedly, property and casualty insurers were extremely liberal in their payouts after the Northridge earthquake. This liberality has not, however, characterized insurance payouts after every disaster. Insurance carriers may have modified their claims settlement practices after the 1992 Oakland fires that caused an outcry on pro-consumer grounds.

Table 3 provides damage estimates made by local building and safety inspection teams several months after the earthquake. As is evident from the table, the largest contributor to the overall total was the city of Los Angeles who estimated approximately $2.3 billion in repairs to buildings in the city. No attempt was made on the part of inspectors to estimate damage to nonstructural systems or contents.

Table 3. Damage estimates for Los Angeles County (source: Post-Northridge safety inspection assessments conducted by local building and safety departments, May 1995)

Jurisdiction	No. of Buildings Inspected	Damage Estimate ($)	No. of Buildings With Damage Estimates
Los Angeles County			
Agoura Hills	194	$157,900	194
Alhambra	340	No Estimates Supplied	
Arcadia	40	$61,300	37
Azusa	1	No Estimate Supplied	
Bellflower	13	$286,100	13
Beverly Hills	1,239	$8,669,580	1,238
Burbank	2,145	No Estimates Supplied	
Calabasas	1,017	No Estimates Supplied	
Commerce	7	$7,000	1
Compton	17	$215,000	3
Culver City	704	$4,447,750	611
Downey	3	No Estimates Supplied	
Glendale	2,341	$34,529,100	2,203
Hermosa Beach	15	$15,000	12

Jurisdiction	No. of Buildings Inspected	Damage Estimate ($)	No. of Buildings With Damage Estimates
Hidden Hills	94	$1,370,500	89
Huntington Park	6	No Estimates Supplied	
Inglewood	56	No Estimates Supplied	
La Canada/Flintridge	39	No Estimates Supplied	
La Habra Heights	4	No Estimates Supplied	
La Mirada	25	$946,525	23
Lakewood	25	No Estimates Supplied	
Los Angeles	85,997	$2,279,995,371	84,840
Manhattan Beach	300	No Estimates Supplied	
Maywood	4	$6,900	2
Montebello	9	No Estimates Supplied	
Norwalk	7	No Estimates Supplied	
Paramount	6	No Estimates Supplied	
Pasadena	260	No Estimates Supplied	
San Fernando	1,603	No Estimates Supplied	
San Marino	9	No Estimates Supplied	
Santa Clarita	4,939	$99,066,097	4,848
Santa Monica	2,101	$106,480,329	2,101
South Gate	51	No Estimates Supplied	
South Pasadena	4	No Estimates Supplied	
Torrance	7	No Estimates Supplied	
LA County	948	$25,650,100	948
Vernon	11	$191,000	11
West Hollywood	253	No Estimates Supplied	
Whittier	185	$256,900	22
Totals	105,019	$2,562,352,452	97,196

Table 4 summarizes Northridge insurance claims data as of March 31, 1995. These data show that insurance loss estimates far exceed those estimates derived from building inspection data. Also implicit in Table 4 are the various insurance coverages that extend beyond immediate physical hazards of primary interest to building damage inspectors:

automobile, burglary and theft, life, and other liability as well as business interruption and additional living expenses. Coverage of additional living expenses is included in some "earthquake" residential insurance policies. Also noteworthy is the fact that there is a huge discrepancy between the number of inspections carried out to establish these two data sets, 105,000 in the building safety process and over 333,000 insurance claims.

Table 4. Northridge estimated insured losses as of March 31, 1995 (source: California Department of Insurance)

Line of Business	Reported Claims	Claims Paid and Outstanding	Incurred Losses
Earthquake—Commercial	5,691	3,935	$1,057,834,892
Earthquake—Residential	219,021	185,180	$5,521,488,790
Earthquake—Undetermined	934	658	$52,574,473
Commercial Multiple Peril	19,584	9,372	$1,095,896,809
Homeowner Multiple Peril	128,072	74,468	$929,319,087
Other*	69,918	59,674	$1,545,409,345
Total	443,220	333,287	$10,202,523,395

*The "Other" category includes Accident & Health, Allied Lines, Commercial Automobile, Personal Automobile, Boiler & Machinery, Burglary & Theft, Farm-owners Multiple Peril, Commercial Fire, Residential Fire, Undetermined Fire, Glass, Commercial Inland Marine, Personal Inland Marine, Undetermined Inland Marine, Life, Other Liability, Other Commercial, Other Residential, Other Undetermined, and Workers Compensation.

The striking differences between insurance loss data and building inspection damage data may become less surprising and more understandable as the factors affecting these differences undergo further analysis. To illustrate how this process may occur, let us develop a line of reasoning that minimizes the differences. This line of reasoning, which needs further systematic evaluation, is as follows:

One means of comparing how close the initial building inspector estimates came with respect to insurance payouts is to estimate the average damage per structure from both data sets. Using the building inspectors' data, we calculate an average damage estimate per building of $26,362 (i.e., $2,562,352,452 divided by 97,196 buildings). As stated before, this estimate only includes repairs to building structures and excludes nonstructural repairs or replacement of contents.

To calculate a similar damage estimate using the insurance data file, two adjustments to the data must be made:

1. An estimate of the total amount paid in deductible by policyholders must be established. This is needed in order to estimate the total cost of repairs to damaged structures.
2. An estimate of the total cost to replace or repair contents, cost of additional living expenses, and other miscellaneous losses must be calculated. This information is needed in order to eliminate these costs from the total insurance industry estimate in order to focus only on structural repairs.

The total deductible paid by policyholders in this earthquake was estimated by first assuming that the average deductible was 10 percent. This is typical of most homeowner's policies in California and is generally consistent with the insurance damage data used in the current comparison. An average value of a structure of $150,000 is assumed based on a limited sample of insurance data reviewed in the affected areas. Using this information and knowing that the total number of claims on residential properties was roughly 260,000 leads to an estimate of deductibles of about $3.9 billion. Adding this total to the total for residential payouts ($5.521 billion for earthquake-residential and $0.929 billion for homeowners multiple peril) leads to $10.4 billion.

To estimate the amount of damage to contents and loss of use of the structure, we use information from R. Roth of the Department of Insurance.

> "... In the Loma Prieta earthquake, for every $100 of insured residential damage, there was an average of $20 of contents damage, and $10 of loss of use. It turned out that these ratios were the same for the 1994 Northridge earthquake, even though the dollar amounts were much greater."

Multiplying $10.4 billion by 70 percent and then dividing by 260,000 claims leads to $28,000 per structure. This amount can be compared to the $26,362 estimated from the building inspectors' data.

The foregoing line of reasoning shows that average structure losses may not be so radically different once various adjustment factors are used for the two data sets. The point to be emphasized here is that many factors affecting the comparison of the two databases, and until these factors are fully analyzed, we are comparing "apples with oranges," unlike, as in the above line of reasoning, "apples with apples."

BUILDING PERMIT AND SAFETY INSPECTION DATA

Building Permit Data

The building safety inspection database, compiled by local jurisdictions as part of their initial damage estimates, represents a damage "snapshot" in time, indeed, very early after the occurrence of the earthquake. Thus, it may prove instructive to examine additional longer-term data assembled by local jurisdictions for different, but related purposes. The City of Los Angeles Department of Building and Safety assembled two internal databases after the Northridge earthquake that we will compare with earlier estimates. The first is the permit valuation database ("Northridge Earthquake 1994 Permit Database"), and the second is the Northridge Earthquake "Initial and Current" Database.

The permit valuation database contains over 80,000 building records, tracking various permit data over time, including items such as permit type (e.g., repair, rebuild, demolition), issue date, valuation, and completion date. A breakdown of permit number, valuation, and status by type are provided in Table 5.

The Initial and Current database compares results from the initial inspection to the conditions reflected in the most recent inspection for over 100,000 structures. Data includes damage percent, dollar damages and postings. Postings are safety tags as assigned in post-earthquake inspections. A significant number of records in the database exist for structures that have had building permits issued, for which no post-earthquake safety inspection was performed. Permits were issued to repair, rebuild or demolish structures, while a Certificate of Compliance was issued by licensed contractors for single-family dwellings and duplexes where only a block wall, chimney, or roof was repaired or rebuilt.

Table 5. Summary of permits by type—City of Los Angeles Permit Valuation Database, February, 1996

Permit Type	Total Number of Permits	Total Permit Value ($1,000)	Work Complete % of Permits	Work Complete % of Dollars
Repair	63,138	1,196,629.5	42%	51%
Rebuild	19,444	279,232.3	43%	59%
Demolition	1,460	19,616.6	59%	82%
Grading	978	0.35	35%	0%
Miscellaneous	922	4,165.8	55%	45%
Sign	37	390.1	78%	61%
Total	85,979	1,500,034.7	42%	53%

In general, "current" damage estimates indicate damage yet to be repaired, and over time, these values decline toward zero. That is, as a building is repaired, its estimated damage is reduced by the amount of damage that has been repaired. Table 6 summarizes the difference between initial damage estimates and current damage estimates. According to the table, initial damage estimates exceeded two billion dollars. This may be compared to the estimate of roughly 2.3 billion dollars in Table 3. Current damage estimates are just under one billion dollars, indicating that as of February 1996, more than one billion dollars in damages (just over 50%) has been repaired. While 50% of dollar damages have been repaired, this represents repairs to only about 21% of damaged buildings (approximately 23,500 buildings). Possible reasons for this apparent disparity include (1) the most heavily damaged buildings were repaired first, or (2) some owners opted not to make repairs. The dollar estimate from the Initial and Current database is consistent with the amount of work that has been permitted, which for "repair" totals about 1.2 billion dollars.

Table 6. Comparison of initial and current damage estimates—City of Los Angeles Northridge earthquake database

	Estimated Unrepaired Damage ($1,000)	Number of Unrepaired Buildings with Dollar Damages Estimated
Initial Conditions	$2,083,630	110,312
Current Conditions	$980,978	86,803

Safety Inspection Database of March, 1994 and February, 1996

The March, 1994 Building and Safety inspection database of 105,019 buildings within Los Angeles County included 85,997 structures in the City of Los Angeles. The safety tags resulting from these inspections may be compared to similar data provided within the February, 1996 data, as shown in Table 7.

Table 7. Initial posting comparison—March 1994 Inspection Database and February 1996 Database for the city of Los Angeles

Initial Posting	March, 1994 Total Number of Structures	February, 1996 Total Number of Structures
Red	2,058	1,398
Yellow	8,841	8,200
Green	74,816	84,024
Unknown	282	---
Not posted – Permit issued	---	34,535
Not Posted - Certification issued	---	2,779
TOTAL	85,997	130,936

The major difference between the two databases is the inclusion of 37,314 buildings for which no safety inspection was performed after the earthquake. However, other differences are noteworthy. While the number of structures with post-earthquake inspection tags increased only 9 percent (from 85,997 to 93,622), this increase was not uniformly distributed among the safety tag types. The more recent database reflects a 30% drop in the number of red-tagged structures, a 7% drop in yellow-tagged structures, and a 12% increase in the number of green-tagged structures. It is possible that the March 1994 data set, developed in the early post-earthquake response period, may have some data entry errors associated with it. In addition, it is also possible that rectification of multiple inspections may have resulted in a change to the initial tagging estimate, which would be reflected in the later database.

The major conclusions from this comparison of initial and current damage data are as follows:

1. Repair of damaged structures is a lengthy process. Two years after the Northridge earthquake, only about 50% of the damage (in terms of dollars) to structures within the City of Los Angeles has been repaired. This represents repairs to about 20% of the damaged buildings.
2. Using only the safety inspection database to indicate the number of damaged structures clearly underestimates the total. For Northridge, about 30% of damaged buildings as defined by the Permit Valuation Database had no safety inspection immediately after the earthquake. It is clear that most uninspected buildings suffered only minor damages, consistent with losses experienced by green-tagged structures. Although minor in nature, these losses are not insignificant.

LOSSES IN NORTHRIDGE AND OTHER EARTHQUAKES

California has been host to a long series of large and damaging events, many of them occurring within this century. Table 8 shows a fairly complete list of moderate and large earthquakes, beginning with the 1971 San Fernando earthquake. Most earthquake researchers would agree that this particular event was the catalyst for modern seismic design. This earthquake also set a precedent for thorough post-earthquake surveys and documentation. In total, since the 53 San Fernando earthquake, there have been roughly 190 deaths, 16,000 injuries and about $51 billion in total loss attributed to the 23 earthquakes that have occurred in California since 1971.

Figure 2 plots damage totals from Table 8 with earthquake magnitude. All damage totals have been normalized to 1994 dollars and therefore, should be comparable. According to the Governor's Office of Emergency Services (OES), these totals include the following costs: insured losses, structural damage, rental assistance, relocation costs, debris removal, individual and family grants and medical and funeral costs.

As the figure suggests, there is a general tendency for these losses to increase with magnitude. Some of the apparent reasons for the large scatter are (1) these earthquakes represent a mix of urban versus rural events, thus magnitude and loss may be poorly correlated; (2) the level of documentation may vary from one earthquake to another; (3) the amount of disaster assistance may vary among earthquakes due to political, economic or sociological factors; (4) there may have been significant differences in levels of preparedness and vulnerability between the affected areas; and (5) the application of differing methods for quantifying losses.

Figure 2 clearly shows that the Northridge earthquake has pushed the outer boundary of the loss-magnitude envelope. The only other earthquake that comes near Northridge is the 1989 Loma Prieta earthquake with losses in excess of $6.5 billion.

Table 8. California earthquakes since 1971 (source: California Governor's Office of Emergency Services)

Location	Year	Magnitude	Deaths	Injuries	Damage ($ Million)
Northridge	1994	6.8	57	9,000+	44,000
Big Bear	1992	6.7	-	-	48.5
Landers	1992	7.6	1	402	48.5
Cape Mend	1992	7.1	-	356	51.5
Joshua Tree	1992	6.1	-	10	.04
Sierra Mad	1991	5.8	1	30+	36
Upland	1990	5.5	-	38	11.2
Loma Priet	1989	7.1	63	3,757	6,500
Imp Co	1987	6.6	-	94	3.2
Whittier	1987	5.9	8	200+	430
Chalfant	1986	6.0	-	-	.5
Oceanside	1986	5.3	1	28	.9
Palm Spr	1986	5.9	-	-	6.6
Morgan H	1984	6.2	-	27	13.2
Coalinga	1983	6.4	-	47	42
Eureka	1980	7.0	-	8	2.7
Owens Val	1980	6.2	-	13	3.0
Livermore	1980	5.5	1	44	17.5
Imp Valley	1979	6.4	-	91	50.6
Gilroy-Hol	1979	5.9	-	16	0.8
Santa Barb	1978	5.7	-	65	13.8
Oroville	1975	5.9	-	-	0
Pt. Mugu	1973	5.9		-	3
San Fern	1971	6.4	58	2,000	1,766
TOTAL			190	16,226	53,049.54

Note: All losses have been normalized to 1994 dollars.

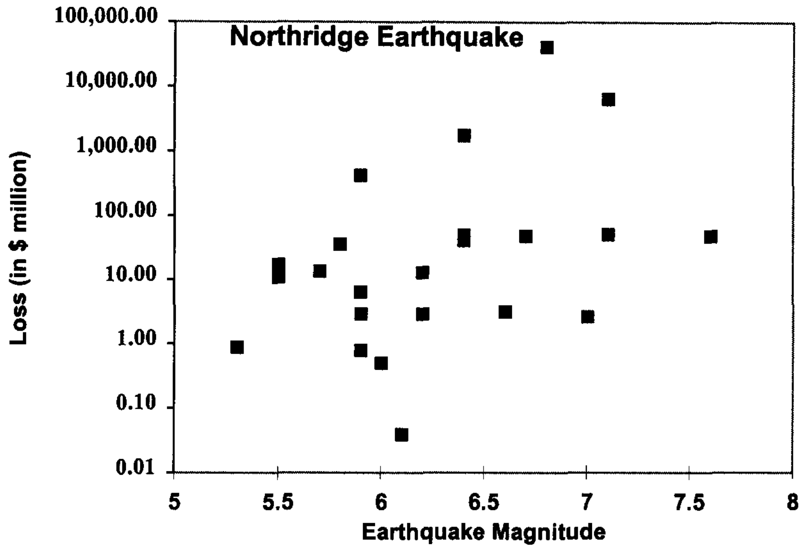

Figure 2. Plot of earthquake losses versus magnitude for recent California earthquakes.

By most accounts, the Northridge earthquake is considered a moderate event in terms of earthquake magnitude. Furthermore, the hypocenter was located roughly 13 km below the surface and did not occur in the most populated area of Los Angeles. Had this event occurred 10 to 15 km southeast of its actual epicenter, the loss total being described in this paper could be an order of magnitude higher.

FINAL COMMENTS AND CONCLUSIONS

The question of whether a complete and accurate final dollar loss figure becomes available, even after years of careful compilation, is difficult to answer at this time. Indeed, it is more of a philosophical issue whether the final number produced represents actual direct dollar losses or remains an estimate. It is also questionable whether much effort is expended on actual losses after the initial pressure for a mandated early loss estimate has passed. A number of factors contribute to the problem of obtaining accurate and timely summaries of total direct loss. One factor, which was alluded to earlier, is that federal and state disaster assistance programs require early estimates of loss and there are few, if any, pressures to produce final loss figures. Thus, interest in such losses passes quickly from an urgent federal requirement to a matter of interest to the financial and academic sectors.

Some of the more programmatic reasons that losses are both slow to accumulate and of questionable reliability include (1) the administrative process for repair and restoration of public facilities is lengthy and cumbersome, (2) the resolution of questionable earthquake-induced damage on insured properties may involve long delays, and (3) hazard mitigation projects, designed to improve the earthquake resistance of the impacted community generally involve long evaluation periods including assessments of cost-effectiveness. In addition to time-consuming routine disaster assistance procedures, there is usually political overlay that not only influences the process and timing of loss accumulation and calculation, but the very definition of disaster losses. Competition between state and federal administrations, partisan politics, and election year grandstanding are also potential influences and, when present, may constitute significant influences on both the nature of loss and the pace of loss calculations.

We would be grossly unfair in our assessment if we singled out elected officials and agency administrators as the only political actors who influence losses and their enumeration. Interest groups are major players and the insurance industry, historical preservationists and others have factored heavily in the determination of earthquake losses. Consider, for example, the initial insured loss estimate in Northridge of $2.5 billion, in contrast with the current level of insured loss of $12.5 billion. Can this discrepancy be accounted for merely as poor loss estimation or were insurance settlements made strategically with an eye toward repeal of the requirement that property and casualty insurers offer earthquake coverage to all California homeowners?

Losses and their summation are more than a political and administrative process and also vary with fluctuations in the economy, new regulations and the discovery of new problems. Northridge was the first earthquake in which damage to moment-resisting steel-frame buildings was highlighted. Repair of these buildings represents a significant loss factor in this earthquake and an important variable in the estimation of future losses. Given that damage to these buildings may have occurred in previous events including the Whittier Narrows, Loma Prieta and Landers/Big Bear earthquakes, the question arises as to whether, or if, losses in those events should be adjusted to account for newly discovered damage and repair. Clearly, fluctuations in the economy over the period in which earthquake losses are tallied, new regulations associated with environmental hazards and historic preservation also influence repair costs and thus, the character and quantification of losses.

We mentioned at the outset that the Northridge earthquake represented a significant departure from previous disasters in the sophistication of technology available to track losses. The employment of these technologies to improve our understanding of losses and the recovery process is a matter of official foresight that merits recognition. The results of both the technology and foresight include an extensive earthquake damage database, much of which is presented in summary form in a two-volume report prepared by EQE International and the Governor's Office of Emergency Services (EQE 1995; 1997). These new technologies have served to clarify the loss identification and accumulation process but have not yet had the effect of reducing the influence of political, economic and programmatic factors discussed above.

The technologies that have produced a more coherent and focused view of loss include the employment of geographic information systems to store, geolocate and cross reference a huge amount of local, state and federal recovery program as well as insurance data. Model driven loss estimates were generated rapidly after the Northridge earthquake and factored into response and recovery decision-making for the first time and GPS (global positioning satellite system) was used to locate major incidents and recovery projects.

event had occurred closer to downtown Los Angeles, or had the magnitude been a half a unit higher, we could be speculating about loss totals on the order of $100 billion or more.

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REFERENCES

Applied Technology Council, 1989, *Procedures for Post-Earthquake Safety Evaluation of Buildings* (ATC-20), Redwood City, California.

Eguchi, Ronald T., Goltz, James D., Seligson, Hope A., Flores, Paul J., Blais, Neil C., Heaton, Thomas H., and Edward Bortugno, 1997, Real-time loss estimation as an emergency response decision support system: the early post-earthquake response tool (EPEDAT), *Earthquake Spectra,* **13**, 815–832.

EQE International, Inc. and the Governor's Office of Emergency Services, 1995, *The Northridge Earthquake of January 17, 1994: Report of Data Collection and Analysis, (Part A: Damage and Inventory Data)*, Irvine, California.

EQE International, Inc. and the Governor's Office of Emergency Services, 1997, *The Northridge Earthquake of January 17, 1994: Report of Data Collection and Analysis, (Part B: Analysis and Trends)*, Irvine, California.

Goltz, James D., 1996, Use of loss estimates by government agencies in the Northridge earthquake for response and recovery, *Earthquake Spectra,* **12**, 441–455.

Governor's Office of Emergency Services, 1992, *Post-Disaster Safety Assessment Plan*, Sacramento, California.