CHAPTER 2 COST CONSIDERATIONS AND DEFINITIONS

2.1 GENERAL

This chapter presents a discussion of cost categories and factors that may influence rehabilitation costs. To develop reasonable cost ranges for the seismic rehabilitation of existing buildings it is important that the various costs and the factors that influence these costs be clearly understood. It is equally important that the user understands these costs and influence factors when applying the methods presented in this report to determine cost ranges for an actual building inventory.

2.2 DEFINITION AND CATEGORIZATION OF COST COMPONENTS

A close examination of several of the existing FEMA documents that address cost issues related to the seismic rehabilitation of existing buildings provides insight into the complexity involved in the development of a typical cost methodology. Those documents include FEMA 156/157, FEMA 173/174, and FEMA 227/228, see Table 2.2.1. The two categories of costs described in the FEMA documents are direct costs and indirect costs. A definition of direct costs as found in FEMA 156 is: "The direct costs represent the bill received by the owner from the contractor." Actually, the definition of direct costs should be broadened to be those costs incurred by the actual rehabilitation work, usually paid for by the owner. Indirect costs, on the other hand, are costs which come about as a result of the rehabilitation work and affect the owner, the tenants, the community, or other related groups. Comerio, 1989 defines indirect costs as "those costs difficult to measure as a result of rehabilitation, mainly the loss of income and opportunity costs."

In this study, the cost of the relocation of occupants is considered a "direct", non-construction cost because this cost is essentially an extension of premium construction costs associated with having occupants in the building at the proposed time of construction. Ongoing rental from relocation, however, is considered similar to the loss of business or other opportunity and is therefore categorized as "indirect." Financing is an independent variable unrelated to the project characteristics and dependent on the type of owner. Short term project costs do not include the additional costs due to financing thus, financing is categorized as an "indirect" cost. For the purposes of benefit-cost studies, financing costs are normally included automatically when considering the time value of money and are incorporated into the discount rate. Labeling financing costs as "direct", in addition to using a discount rate, is appropriate only for benefit cost consideration. Financing sources include banks, federal agencies, revenue bonds, and private companies. In all cases where external financing is required, the financial costs depend on the ability of the owner to secure financing as dictated by the marketplace.

Contractor general conditions, profit, and project contingencies are sometimes considered separate costs, particularly when creating cost estimates from subcontractor material and labor prices. This method of cost estimating is not appropriate until a specific seismic rehabilitation scheme is developed and is, therefore, not used in this study. Each construction cost component is assumed to include its proportional share of these construction overhead-type costs. Actual construction costs can be estimated by simply summing the "direct" construction cost components.

Using the cost distinctions given in the FEMA documents as a base, several modifications were made as part of this study to further clarify and complete the categorization of rehabilitation costs. The first change is in the dividing of direct costs into two sub-categories: construction costs and non-construction costs. The distinction between these two sub-categories is most clearly delineated by describing the construction costs as the amount paid to the contractor and by describing the non-construction costs as the amount paid to anyone other than the contractor in order to complete the project. For the purpose of developing typical cost ranges, these two sub-categories were, where possible, quantified as separate and specific amounts. Otherwise, the non-construction costs can be taken as a percentage of the overall project cost.

Direct construction costs, however, need to be further subdivided into two parts, seismic and non-seismic. Seismic direct costs are those associated with costs directly incurred in actually making the building better able to withstand seismic forces. Non-seismic costs, on the other hand, are those that are often incurred ("triggered") by the seismic construction work. (At times these are referred to as "collateral costs").

The taxonomy of costs used in this report is therefore shown in Table 2.2.2, and discussed below.

TABLE 2.2.1 SUMMARY OF REHABILITATION COST COMPONENTS

FEMA 156 AND 157 - "TYPICAL COSTS FOR SEISMIC REHABILITATION OF EXISTING BUILDINGS"	
DIRECT COSTS • construction materials and labor (contractor overhead and profit included) • professional and permit fees	INDIRECT COSTS • financing • occupant interruption/relocation • increased rents • change in property value • reduction in affordable housing
FEMA 173 AND 174 - "ESTABLISHING PROGRAMS AND PRIORITIES FOR THE SEISMIC REHABILITATION OF BUILDINGS"	
Costs for Rehabilitation: DIRECT COSTS • construction (primary cost) • architectural and engineering design • material testing, permits, and approvals • financing and relocation • mitigation program administration	INDIRECT COSTS • loss of revenue during construction • change in property value • occupant relocation • change in housing stock • social impacts • mitigation program administration
Costs due to earthquake damage: DIRECT COSTS • damage	INDIRECT COSTS • social trauma • housing losses • business and industry loss • unemployment • tax impact/increased cost of services to community
FEMA 227 AND 228 - "A BENEFIT-COST MODEL FOR THE SEISMIC REHABILITATION OF BUILDINGS" REFERENCE DOCUMENT FOR COST INFORMATION: "SEISMIC COSTS AND POLICY IMPLICATIONS, COMERIO, 1989.	
DIRECT COSTS • structural construction • architectural demolition and refinishing directly related to seismic rehabilitation • engineering fees • permit, testing, and legal fees • financing	INDIRECT COSTS • loss of rent and other income opportunities • construction delays • financial constraints

TABLE 2.2.2 DIRECT REHABILITATION COST COMPONENTS AS DEFINED IN THIS STUDY

CONSTRUCTION COSTS	NON-CONSTRUCTION COSTS
Seismic • Structural rehabilitation work (typical costs) • Non-structural rehabilitation work • Demolition and restoration • Damage repair Non-seismic • System improvements • Disabled access improvements • Hazardous material removal	• Project management • Architectural and engineering design fees • Relocation • Testing and permits

2.3 SEISMIC RELATED CONSTRUCTION COSTS

The costs presented in this section are categorized as seismic-related construction costs because they are dictated directly by the decision to perform seismic rehabilitation work. These costs exclude items that do not directly improve the seismic performance of the building, such as additional improvements made to the architectural, electrical, mechanical, plumbing, or other systems of the building. The cost components are defined and discussed below (some of the definitions in Sections 2.3. to 2.6 are adapted from Recht Hausrath & Associates, 1992):

- **Structural Rehabilitation Costs:** The cost for structural work performed by the contractor and the subcontractor. This is the only cost that is estimated in Volume 1 of this study.

- **Non-Structural Rehabilitation Costs:** The cost to reduce the risk of failure of certain non-structural elements of the building. This includes consideration of cladding, hazards relating to the failure of exterior walls (including parapets), and other elements that may interact with structural systems because these elements are normally included in structural rehabilitation projects. This would also include consideration of interior building systems (architectural and mechanical/ electrical/plumbing [MEP]) and "occupancy use equipment" which is equipment required to enable the building to fulfill its primary mission (e.g., medical equipment in a hospital or computers in a data center). Furniture, office equipment, and supplies are not normally included as non-structural components that can be rehabilitated because their seismic resistance is primarily dependent on the care given by the users.

- **Demolition and Restoration Costs:** The cost for architectural work necessitated by the structural work. Included are items such as demolition and replacement costs for wall and ceiling finishes, removal and reinstallation of electrical and mechanical equipment, and reroofing as necessary to install the lateral force resisting elements in the building.

- **Cost to Repair Existing Elements Used as Part of the Lateral Force Resisting System:** The cost to repair any of the existing lateral force resisting elements that have been damaged because of previous earthquakes, ground settlement or deterioration.

2.4 NON-SEISMIC-RELATED CONSTRUCTION COSTS

The costs presented in this section are categorized as non-seismic-related construction costs because they are costs pertaining to those items that do not directly improve the seismic performance of the building but may be "triggered" by the seismic rehabilitation. These costs can be difficult to quantify because they can vary greatly depending upon the individual building characteristics and the applicable regulations or code requirements.

Systems Improvement Costs:

- **Fire and Life Safety:** The building or fire department may require an owner to upgrade fire protection and other life safety provisions. This work can involve such items as improving the fire rating of certain walls and providing sprinklers, fire escapes, increased exits, fire stops at boundary zones in the building, and emergency lighting and fire alarm systems. Even if not required, the owner may decide to make these improvements in addition to the rehabilitation work.

- **Mechanical, Plumbing and Electrical Renovation:** In some cases, the owner may also be required by the building or fire department to upgrade the mechanical, plumbing and electrical systems of the building. Again, an owner may take the opportunity to upgrade the mechanical, plumbing and electrical systems of a building at the same time as seismic rehabilitation even when not required.

- **Architectural Renovation:** When seismic rehabilitation work is anticipated owners often take the opportunity to make architectural renovations and improvements beyond the architectural demolition and refinishing costs associated with the rehabilitation work. Substantial savings may result because: 1) occupants will be disrupted only once, 2) the contractor's general conditions are fairly fixed and may not increase much if the time or work does not increase substantially, and 3) the demolition and removal costs of architectural finishes do not increase. Architectural renovation costs are often hard to separate from the costs due directly to seismic rehabilitation in cost estimates and as Comerio, 1989 shows, they can add a very large premium to the cost of the total project. On the other hand, plans for a complete architectural renovation present an ideal opportunity to also seismically rehabilitate a building. The efficiency of combining such projects is the same in either case.

- **Damage Repair Costs:** The cost to repair structural damage from previous earthquakes, settlement, or deterioration in elements of the building not affecting the seismic performance of the building.

- **Hazardous Material Removal Costs:** The cost to remove hazardous materials, such as asbestos, lead paint, or contaminated soil. Asbestos-containing materials in a building become a potential health hazard when they are disturbed and the asbestos fibers are released into the air near occupants not taking proper safety precautions. As long as the asbestos-containing materials are not disturbed and remain in good condition, they do not pose a hazard. The following building materials may be found to contain asbestos (NIBS, 1986): (1) sprayed or troweled on surface material on ceilings and walls); (2) thermal insulation around pipes, ducts, boilers, tanks (pipe and boiler insulation); (3) fireproofing on structural members; and (4) a variety of other products such as ceiling and floor tiles, roofing felts and shingles, and wall boards. Asbestos was used commonly in buildings prior to 1973 (NIBS, 1986). Typically, asbestos is removed prior to construction by a specialty contractor under a separate contract. Another hazardous material that may be found in older buildings is lead-based paint, which is used primarily to prevent rust on steel structures. The primary risk due to lead based paint occurs when construction workers inhale the lead dust or lead fumes caused by blasting, welding, or spray painting. An increase in construction cost is likely to occur because of requirements to provide paper protection and washing facilities for workers dealing with lead coated steel.

- **Costs to Provide Access for the Disabled:** The cost to provide improved accessibility to disabled individuals as required by federal, state and local laws. The federal requirements are contained in the Americans with Disabilities Act (ADA) which was signed by President Bush on July 26, 1990. The ADA is "designed to remove barriers which prevent qualified individuals with disabilities from enjoying the same employment opportunities that are available to persons without disabilities." (ADA Handbook, 1991). The costs associated with the implementation of the ADA are discussed in more detail in Volume 2.

2.5 NON-CONSTRUCTION COSTS

The costs presented in this section are categorized as non-construction because these costs are not construction costs. Typically, these costs are paid to persons other than the contractor.

Non-construction costs include:

- **Management Costs:** The costs necessary to manage the project. These costs may include performing analyses to determine the impact of various levels of rehabilitation; determining the scope and organization of the project; obtaining financing; hiring, answering questions, paying and negotiating with design consultants, testing laboratories, and contractors; addressing city requirements and the concerns of affected tenants and clients; and handling the many other tasks needed to successfully complete a rehabilitation project. Assigning a management cost is often quite difficult because money does not necessarily change hands when an owner chooses to manage the project without outside assistance such as a construction manager.

- **Design Fees, Testing and Permitting Costs:** These three items are often grouped together by estimators. Design fees cover the costs of design professionals such as structural engineers, architects, geotechnical engineers, civil engineers, surveyors, and cost estimators required to perform the studies and design work necessary for structural work and architectural refinishing work. In order to ascertain the structural characteristics of existing materials, a testing lab may be hired during the design process. Once construction has begun, testing and inspection firms are often hired to verify that the contractor is performing the work in general conformance with the design documents and to perform tests and inspections required by the building codes. Obtaining a building permit requires paying a fee to the building department to cover their plan checking, field inspection, and recording costs.

- **Relocation Costs:** The cost to relocate occupants and equipment due to the disruption expected by the construction. The nature of the rehabilitation scheme may make occupancy during construction infeasible because of interference with normal business operations or added costs due to additional constraints on the construction if the occupants are not relocated.

2.6 COST INFLUENCE FACTORS

The magnitude of rehabilitation costs will be affected by many factors, including the characteristics of the building, the seismic zone, the rehabilitation criteria used, and the conditions of occupancy. The significance of these influence factors in determining the typical cost was studied as part of this project and will be discussed in more detail in Chapter 4 of Volume 1 and also in Volume 2. The number of influence factors used in this document for determining typical costs was determined by the analysis of the data and professional judgement. Definitions and discussion of influence factors that were considered in this cost analysis follow:

- **Seismicity:** The seismicity is based on NEHRP map areas 1 - 7. Regions of the country are divided into these areas based on expected earthquake activity. Costs of rehabilitation are dependent on the seismic map area because it dictates the design forces which, in turn, often influence the scope of structural work.

- **Performance Objectives:** The performance objectives are defined by three general categories: 1) life safety; 2) damage control; and 3) immediate occupancy. These performance objectives determine the level of rehabilitation for a building which, in turn, influences the cost of the rehabilitation. Life safety allows for unrepairable damage as long as life is not jeopardized and egress routes are not blocked. Damage control is intended to protect some feature or function of the building beyond life safety, such as protecting building contents or preventing the release of toxic materials. Immediate occupancy is characterized by minimal post-earthquake disruption with some non-structural repairs and cleanup.

• **Structural System:** There are many reasons why different structural systems lead to different costs. One of the most important is that the number of, extent of, and criteria used for the rehabilitation activities are typically quite different. Masses and original design force levels can be quite different. Also, the existence of an independent vertical load-carrying frame in multi-story buildings substantially lowers the seismic hazard. Table 1.2.1 defines the FEMA building types that were used to classify the structural system.

• **Occupancy Class:** Some estimates have attributed a cost impact to the occupancy type of a building. For example, assembly buildings with large open spaces often require special or more unusual rehabilitation solutions. Industrial buildings tend to have higher story heights, forcing more out-of-plane bracing; but they have fewer openings in the existing masonry walls, potentially allowing for less in-plane strengthening. They may also have lower architectural refinishing costs because they lack interior finishes. Table 2.6.1 identifies the categories of occupancy that were used in this study. Figure 2.6.1 shows the number of buildings in the database in each occupancy or class for the life safety performance objective. The occupancy classifications are as follows:

- Assembly - Theaters, Churches, or other assembly buildings.
- Commercial/Office - all buildings used for the transaction of business, for the rendering of professional services, or for other services that involve limited stocks of goods or merchandise.
- Factory/Industrial/Warehouse - Factories, Assembling Plants, Industrial Laboratories, Storage, etc.
- Institutional/Educational- Schools, Hospitals, Prisons, etc.
- Mall/Retail - Retail Stores or Shopping Malls.
- Parking - Parking Garages or Structures.
- Residential - Houses, Hotels, and Apartments.

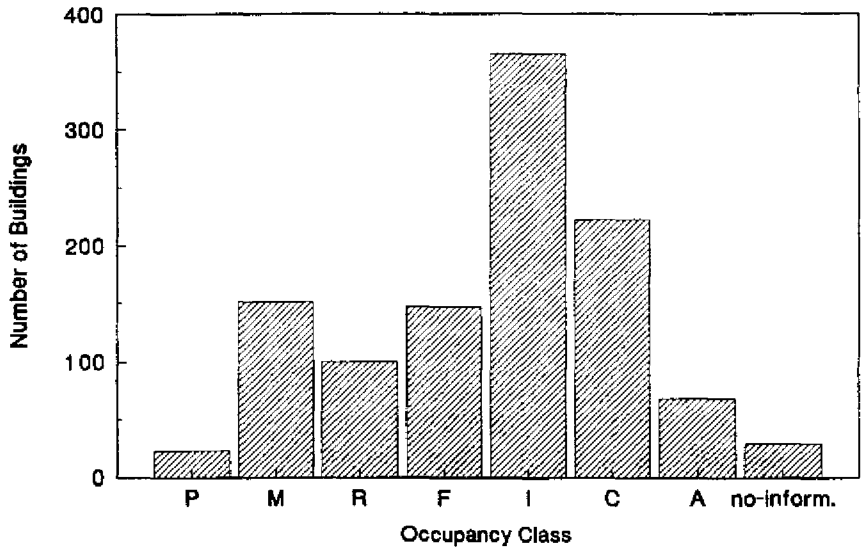

FIGURE 2.6.1 NUMBER OF BUILDINGS IN DIFFERENT OCCUPANCY CLASSES
(LIFE SAFETY PERFORMANCE OBJECTIVE)

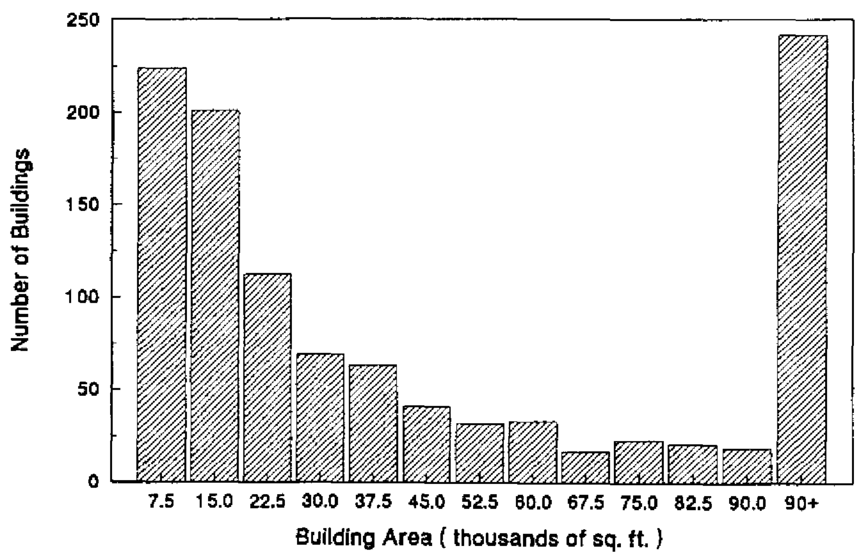

FIGURE 2.6.2 NUMBER OF BUILDINGS IN DIFFERENT BUILDING AREAS
(LIFE SAFETY PERFORMANCE OBJECTIVE)

TABLE 2.6.1 OCCUPANCY CLASS

CLASS	DESCRIPTION
A	Assembly
C	Commercial/Office
F	Factory/Industrial
I	Institutional/Educational
M	Mall/Retail
P	Parking
R	Residential

- **Building Area:** The total square footage of the building. Figure 2.6.2 shows this distribution of data by building area.

- **Number of Stories:** The number of stories can have a significant cost impact in most estimates. In taller buildings, overturning and shear forces may require a proportionately greater cost to improve the foundation. Figure 2.6.3 shows the distribution of the cost data for life safety as a function of the number of stories.

- **Building Age Characteristics:** Age can be an important cost factor because older buildings often require more new lateral elements an also because the existing structural system may suffer detioration. Also, the presence of ornamentation or other significant architectural or historic fabric will influence the design options available to the engineer. Often, the least expensive engineering rehabilitation technique will be unacceptable because of its visual incompatibility with the building fabric. In some instances, it may also be unacceptable to remove significant finishes because of the potential for damage, necessitating more costly, alternative measures.

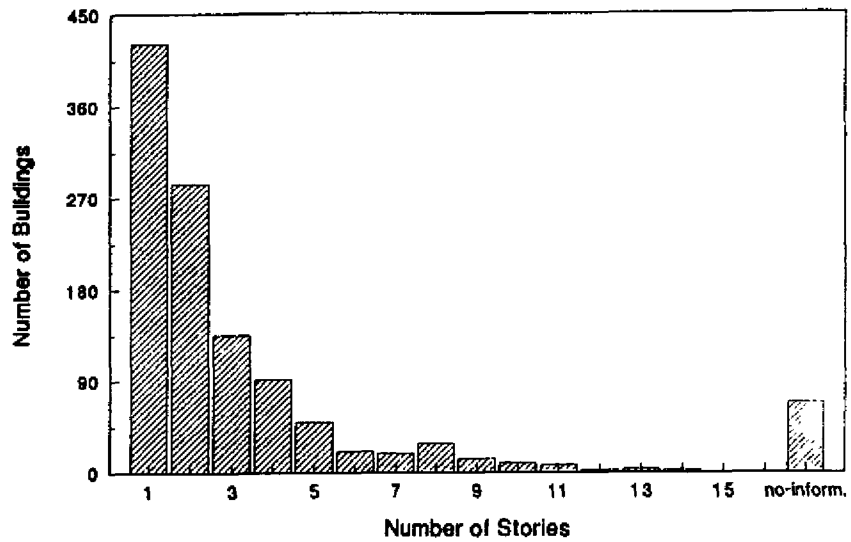

FIGURE 2.6.3 NUMBER OF BUILDINGS VERSUS NUMBER OF STORIES
(LIFE SAFETY PERFORMANCE OBJECTIVE)

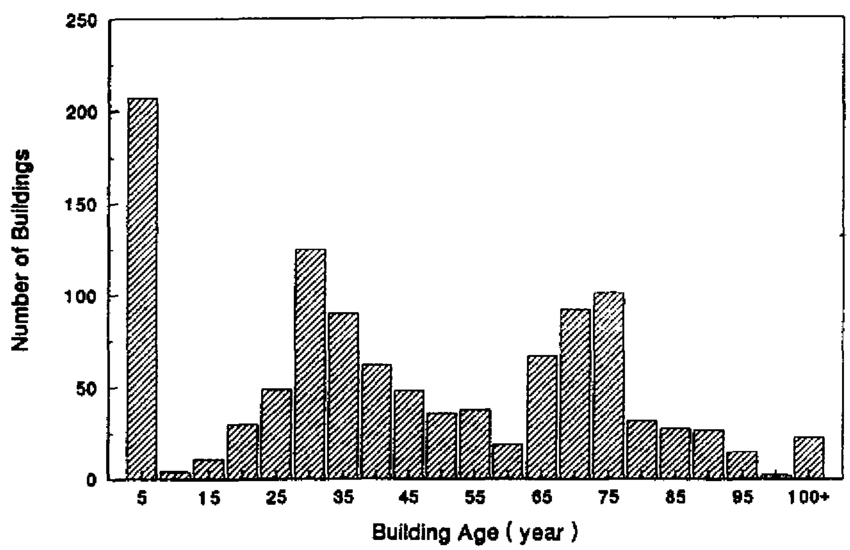

FIGURE 2.6.4 NUMBER OF BUILDINGS VERSUS BUILDING AGE
(LIFE SAFETY PERFORMANCE OBJECTIVE)

Figure 2.6.4 shows the number of buildings in the database as a function of age.

- **Occupancy Condition:** Seismic rehabilitation work involves noise, dust, and general disruption to building occupants. Table 2.6.2 defines the occupancy conditions considered in this study and Figure 2.6.5 shows the number of buildings in the database for each occupancy condition. Note that most of the buildings in the database had no information provided and, thus, this variable should be used with some caution. However, it is clear based on engineering experience that this is an important cost variable.

TABLE 2.6.2 OCCUPANCY CONDITION

CLASS	DESCRIPTION
IP	Occupants-in-place
TR	Occupants Temporarily Removed
V	Building Vacant

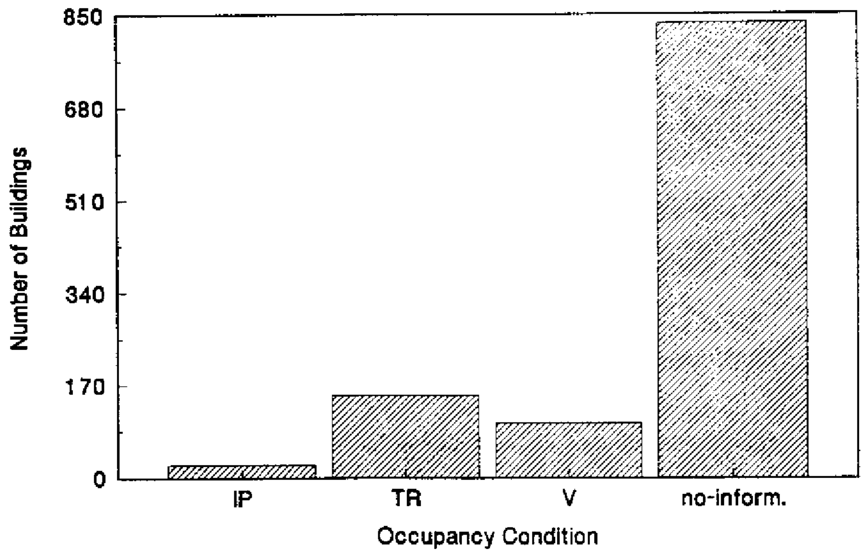

FIGURE 2.6.5 NUMBER OF BUILDINGS IN DIFFERENT OCCUPANCY CONDITIONS (LIFE SAFETY PERFORMANCE OBJECTIVE)

CHAPTER 3 COST DATABASE

3.1 GENERAL

The cost database is the backbone of the effort to obtain typical costs for the seismic rehabilitation of buildings. This chapter discusses the methods used in collecting and sorting the data including acceptance/rejection procedures and other quality control processes. The data points in the database for this report are either actual construction costs or costs from detailed seismic rehabilitation studies.

3.2 DATA COLLECTION PROCESS

The process of collecting data for this study was developed so as to be as objective as possible. The strength of the database is intended to be its consistency regardless of the person or firm submitting data, the location and date of study of the projects examined, and the types of buildings and performance objectives selected.

The Data Collection Guidelines, as the two-page worksheet that guided the data collection effort is called, requests a broad range of information on a given project. Appendix A contains a copy of this worksheet and the list of data collected. The building framing, layout and codes used in the rehabilitation were obtained to assist in the quality control check. When critical information (area, costs, building type, NEHRP map seismic area, year of study, and performance objective) was unavailable, the worksheets were not added to the database. Where other information was missing the record was assumed to have a lower level of accuracy than those which were complete.

The cost basis was developed as follows:

- **Step One: Identification of Sources of Data**
  Lists of engineers and others familiar with seismic rehabilitation work were gathered. All members of the Advisory Panel were required to provide information on

rehabilitation projects. Firms and individuals on the lists were contacted, the project explained in brief and their help requested in collecting the data.

- **Step Two: Collect Data from First Edition Database**

The second step of the cost data collection was to examine the data which had been collected for the First Edition of the Typical Costs FEMA study done in 1988. While this data was generally much less complete than the newer information, approximately 60% of it was used in the new database because it was examined and found to be acceptable, especially for URM buildings.

- **Step Three: Collect New Data**

The individuals identified in Step One were contacted and the worksheets on the various projects were completed.

- **Step Four: Quality/Data**

Once the completed worksheets were collected, a careful process of quality assurance was undertaken. If necessary information was missing, the person who filled out the worksheet was contacted to help fill in any blanks. Costs were also checked to verify that non-structural costs were properly separated from structural costs

- **Step Five: Enter Costs into Database**

The information was entered into the database, after each worksheet was thoroughly reviewed for completeness and accuracy.

3.3 TIME AND LOCATION COST ADJUSTMENTS

Much of the information collected was from studies or construction done before 1993. To be consistent, all cost data in the database was indexed to March 1993. For this adjustment of cost the Engineering News Record's (ENR) 20-city average of building costs, called the Building Cost Index (BCI), which compares the historical costs of selected materials and labor to today's costs was used.

For costs associated with studies done before 1970, the index factor rises rapidly and for this time period the cost correction was done in consultation with Hanscomb Associates, a member of the Advisory Panel.

In addition to indexing the data based on the year of the study or construction year, costs from various parts of the country and Canada were referenced to the St. Louis location, to account for regional differences in labor and material rates. To account for these differences another correction was made to each cost data point. The Means Index relates costs in 250 cities in the United States and Canada. For each state, U.S. territory or Canadian province where data was collected, an average factor of all the cities in the state, territory or province was calculated and compared to the common location, which was chosen as Missouri. Missouri was selected to be the baseline state for this study solely because of its central geographic location. Thus, where all cities in Missouri were given a baseline of 1.00, all buildings in South Carolina, for example, were factored by 0.80. Canadian factors took into account the 1993 average exchange rate so that Canadian dollar amounts entered on the work sheets for buildings in Canada could be directly converted to U.S. dollars.

The factors correcting for the year of construction or study and the location factors were multiplied together to obtain a combined factor. All costs for each building were multiplied by the appropriate factor so that each building cost is relative to March, 1993 in Missouri dollars.

3.4 DATA QUALITY RATING

There is a notable variation in the quality of the cost data. The project goal was to not eliminate any data except that which lacked enough minimum information to be useful. Therefore, each cost data point was assigned a quality rating. Quality factors were calculated for each building cost data value, ranging from 1 (being the least accurate) to 10 (being the most accurate).

Care was taken to make the rating system as objective as possible so that another uncertainty, that of the engineer assigning the factor, would be minimized. The rating was determined as the sum of the following three parameters:

- **Date of study:** Design professionals today are more familiar with earthquakes, seismic rehabilitation methods and building performance. Consequently, the accuracy of their cost estimates has increased considerably. Therefore, the rating in Table 3.4.1 was given to each record based on the date of its cost study or construction.

TABLE 3.4.1 QUALITY/RATING DATE OF STUDY

DATE OF STUDY OR CONSTRUCTION	POINTS
Before 1973	1
Between 1973 and 1987	2
After 1987	3

- **Source and certainty of cost:** Each design professional was asked to check whether the cost estimate on the Data Collection Guidelines was from a study or actual construction. Also, the design professional rated his or her confidence in the costs as either Good, Fair or Poor. Based on these choices, the ratings in Table 3.4.2 were given.

TABLE 3.4.2 QUALITY RATING/SOURCE AND CERTAINTY OF COST

SOURCE	CONFIDENCE	POINTS
Unknown	Poor	0
Study	Poor	1
Study	Fair or Good	2
Actual	Poor	2
Actual	Fair	3
Actual	Good	4

- **Consistency of data:** In many instances the information provided for particular buildings or groups of buildings was sporadic and incomplete. Older or general studies of large numbers of buildings often contained minimal information. The familiarity and experience with seismic rehabilitation of the person filling out the worksheet would, in general, affect the quality of the data. So that no single characteristic would weigh too heavily on the point value given to this factor, the following procedure was used: seven characteristics were developed by which each record would be rated, with a 1 (positive) or a 0 (unknown or negative). These characteristics were: Were the worksheets complete and clearly filled out? Did the person or office submit many records or only a few? Were the reports from which the worksheets were prepared specific and complete? Was the engineer located in a region of high seismicity? Was the person or office submitting the forms a member of the Advisory Panel? Was the person filling out the worksheets a registered Structural Engineer or Architect? Was the person or firm submitting the information well recognized in the earthquake engineering profession?

Based on the total point value obtained from this list of characteristics, a rating was given for the consistency parameter as shown in Table 3.4.3:

TABLE 3.4.3 QUALITY RATING/CONSISTENCY OF DATA

SUM OF CHARACTERISTICS	POINTS
0-1	0
2-3	1
4-5	2
6-7	3

Figure 3.4.1 shows the number of buildings versus the quality rating for the three categories of the performance objective. Figure 3.4.2 shows the same plot as a function of the seismicity.

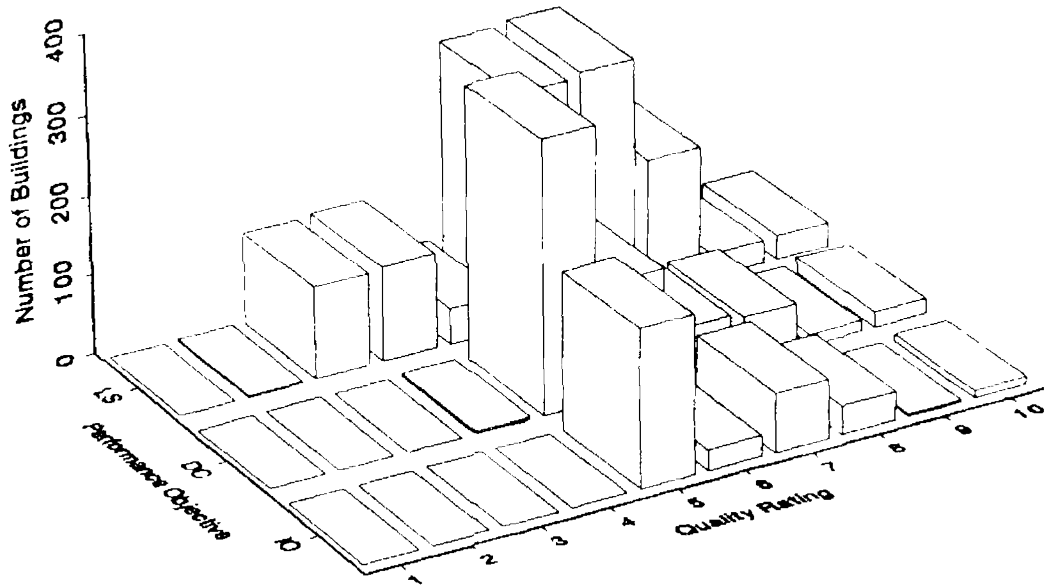

FIGURE 3.4.1 NUMBER OF BUILDINGS FOR DIFFERENT QUALITY RATING/ PERFORMANCE OBJECTIVE COMBINATIONS (WITHOUT URM BUILDINGS)

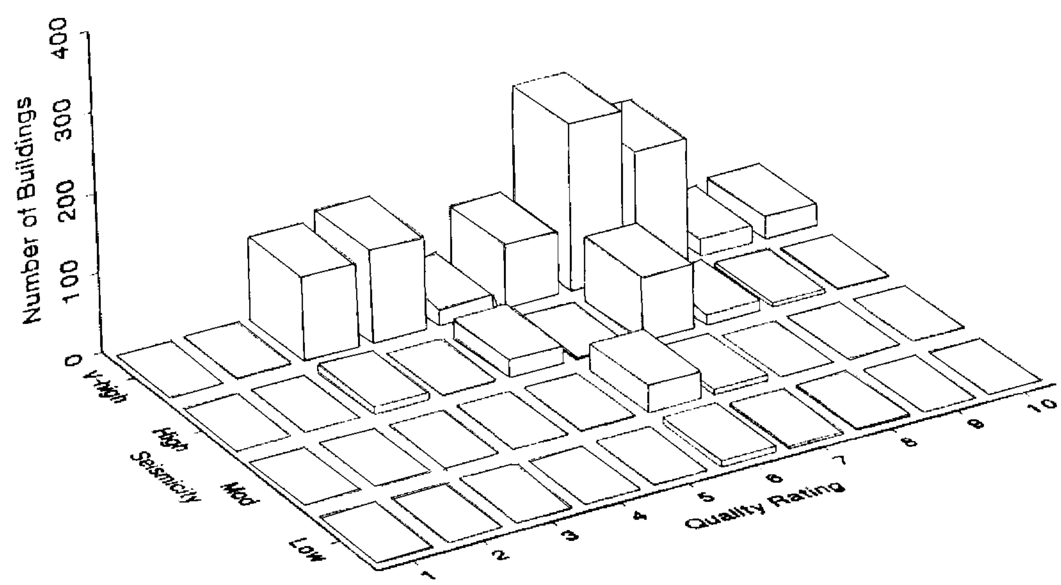

FIGURE 3.4.2 NUMBER OF BUILDINGS FOR DIFFERENT QUALITY RATING/
SEISMICITY COMBINATIONS
(LIFE SAFETY PERFORMANCE OBJECTIVE)

3.5 SUPER DATABASE

The database that was obtained by using the process described earlier contained 2088 cost data points and could have been directly used to develop the cost estimation coefficients in the methodology that is presented in Chapter 4 However, if that procedure had been followed, it would have not taken advantage of the information about the difference in quality between the cost data points as described and quantified in Section 3.4. Therefore, a super cost database was developed using the 2088 cost data values and their associated quality rating and a weighting process than incorporates the relative value of the cost data and the confidence in the value of that cost data.

The super database was developed by taking each of the original 2088 cost data points and, one at a time, using them to generate several new values of cost. For each original cost data value, the number of new cost values that go into the super database is a function of the quality rating of that data value, see Figure 3 5 1. For example, if the quality rating was 7, then 83 new cost data points would go into the super database.

Similarly, if the quality rating was 5 and not 7, then only 72 new cost data points would go into the super database. Therefore, the super database will contain more data for the higher quality rating. The value of each of the new cost data points that goes into the super database incorporates the increased confidence in the value of the cost that is associated with the higher quality rating of the data. Each new cost data point that was created for the super database was generated using a Monte Carlo Simulation Analysis (MCS) using an underlying lognormal probability distribution with a mean sample value equal to the cost of the original data point and a coefficient of variation related to the quality rating, see Figure 3.5.2. Repeating this for all original data points results in the super cost database that is used to perform the analysis that yields the cost estimation equations in Chapter 4. The details of this database generation are given in Volume 2.

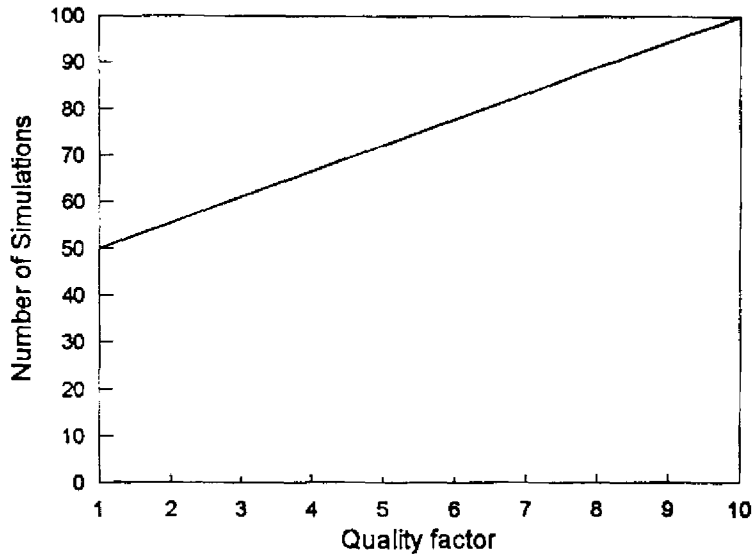

FIGURE 3.5.1 NUMBER OF SIMULATIONS FOR NEW COST DATA

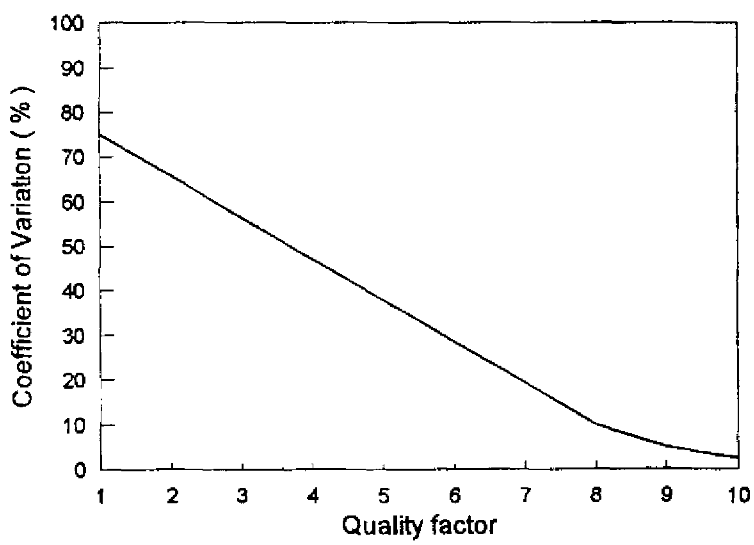

FIGURE 3.5.2 COEFFICIENT OF VARIATION FOR NEW COST DATA