Chapter 4. Data Needed for More Complete Loss Estimation Study

Figure 4.1 shows the steps that are typically performed in assessing and mitigating the impacts of a natural hazard such as an earthquake, hurricane or flood. In order to estimate regional losses resulting from a natural disaster, you need to have an understanding of both the size of the potential event (hazard identification) and the characteristics of the population and the environment that will be impacted (inventory collection). For example, a flood that occurs near a densely populated region will cause different types of losses than one that occurs in a mostly agricultural region. Similarly, the economic impacts of an earthquake in a highly industrialized region will be different from those in a region that predominantly supports a service economy. Thus, to reliably model the losses in your region, you will need to collect a wide variety of data so as to be able to characterize the buildings and lifelines, the population, and the structure of the local economy.

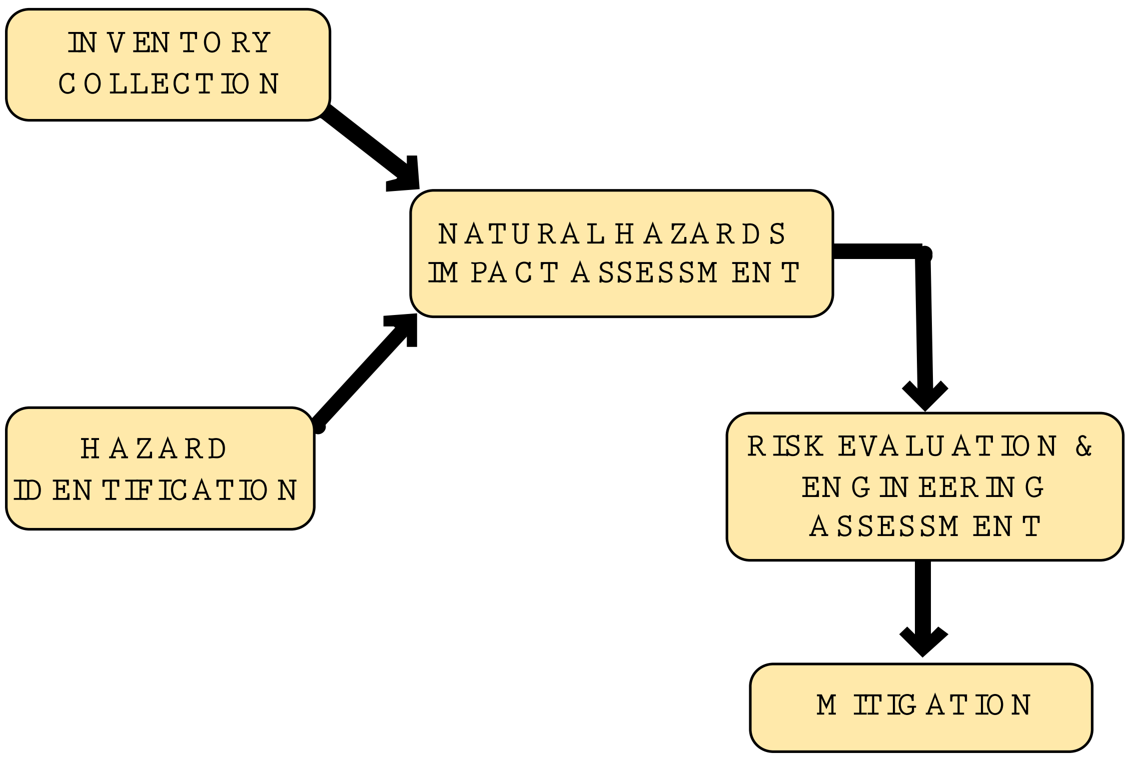


Figure 4.1 Steps in assessing and mitigating losses dues to natural hazards.

4.1 Developing a Regional Inventory

In developing a regional inventory, it is almost impossible from a cost point of view to individually identify and inventory each man-made structure. Some important structures such as hospitals, schools, emergency operation centers, fire stations, important bridges, and electrical power substations may be identified individually, but the majority of buildings in a region are grouped together collectively and identified by their total value or square footage. To permit modeling of spatial variation in types and occupancies of buildings, a region is built up from sub-regions, and the inventory is collected for each sub-region. In the earthquake loss estimation methodology, **census tracts** are used as the basic sub-region unit, and all regions are built up by aggregating census tracts. Thus for each census tract, your inventory might consist of the number of square feet of wood frame buildings, the number of square feet of unreinforced masonry buildings and so on for each building type. Figure 4.2 shows the inventory of single-family residential construction in a region. Note that the value of single-family residential construction is stored and displayed for each census tract in the region.

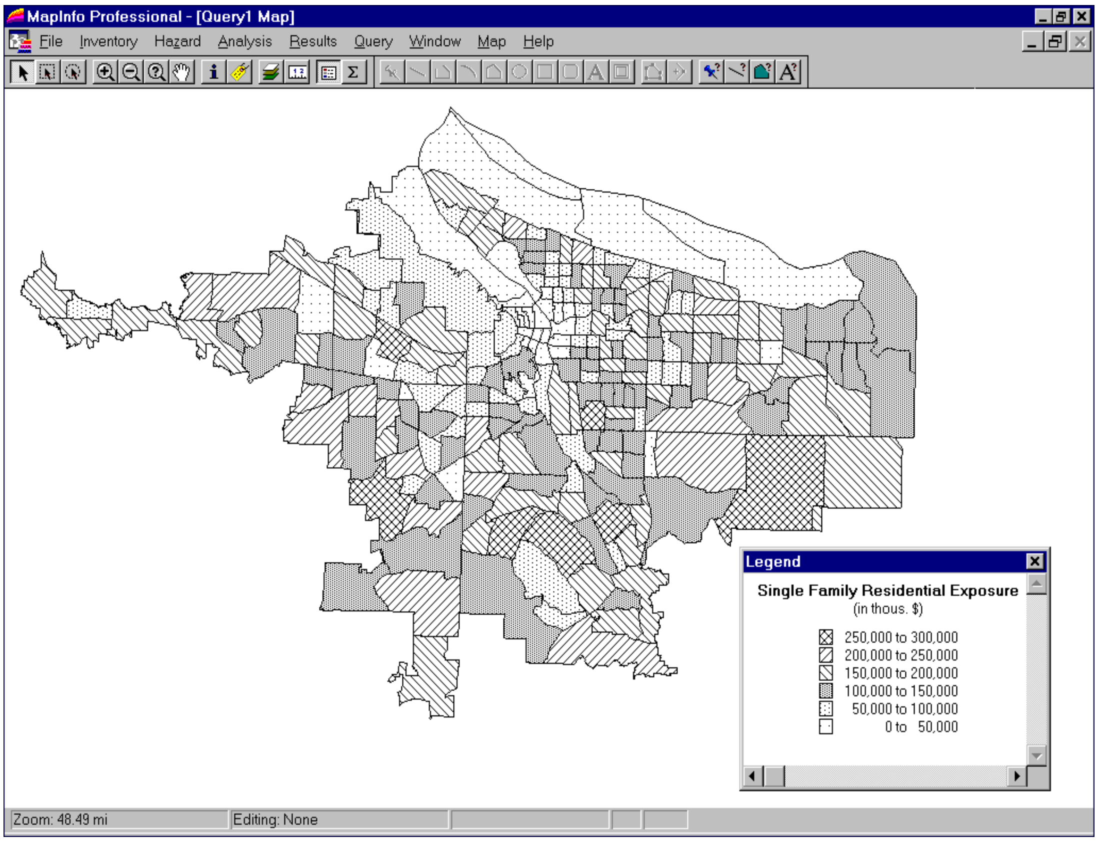


Figure 4.2 Value of single-family residential homes (RES1) by census tract.

In the methodology, the residential, commercial and industrial buildings that are not identified specifically are called the **general building stock**. General building stock is inventoried by calculating, for each census tract, the total square footage of groups of buildings with specific characteristics (i.e., calculating the total square footage of low-rise unreinforced masonry structures). Collecting even this "simplified" inventory can be problematic. There are rarely reliable and complete databases that provide the necessary information such as building size, building occupancy, building height and structural system that could be used to obtain total values for each census tract. Therefore, in general, inferences are made about large groups of buildings based on land use patterns, census information, business patterns, assessors' files, insurance files, etc. Inferences can take the form, "if this is a residential area, 50% of the buildings are single family wood structures and 50% are multi-family wood structures". While there are inaccuracies in the inventory of general building stock due to inferences that are made, the error tends to be random and can be accounted for in the probabilistic aspects of the methodology. Similar types of inferences are made with respect to lifeline systems (e.g., the number of miles of water supply pipe in a census tract may be inferred from the miles of streets).

In contrast to the inventory of general building stock which is maintained in terms of total value per census tract, facilities that have some special significance, such as essential facilities or components of lifeline systems, can be maintained in the database by individual location. Correspondingly, losses for essential facilities and some lifeline components are computed for individual facilities, while losses for general building stock are calculated by census tract. While some inferences can be used for site-specific facilities when data are unavailable, often you will have better access to databases about these facilities than you will for general building stock. Sometimes there will be few enough of these facilities that you can actually go to the site and collect the required inventory information. Sources of inventory information and how to go about collecting it are discussed in Chapter 5.

4.2 Standardizing and Classifying Data

There are two issues that must be considered in the development of an inventory: classification of data, and collection and handling of data. Classification systems are essential to ensuring a uniform interpretation of data and results. As discussed earlier, it is almost impossible, from a cost point of view, to identify and individually inventory each building or component of each lifeline. Thus losses in a regional study are estimated based on general characteristics of buildings or lifeline components, and classification systems are a tool to group together structures or lifeline components that would be expected to behave similarly in a seismic event. For each of the types of data that must be collected to perform a loss study, a classification system has been defined in this methodology.

The building classification system used in this methodology has been developed to provide an ability to differentiate between buildings with substantially different damage and loss characteristics. In general, buildings behave differently due to the types of structural systems they have (i.e. wood versus steel), the codes to which they were designed, their heights, their shapes or footprints, and local construction practices. As a consequence of the variations in design, shape, height etc., no two buildings will behave exactly the same when subjected to an earthquake. Therefore, **model building types** are defined to represent the average characteristics of buildings in a class. Within any given building class there will be a great deal of variation. The damage and loss prediction models in this methodology are developed for model building types and the estimated performance is based upon the "average characteristics" of the total population of buildings within each class.

Table 4.1 provides a summary of the 36 model building types that have been defined in the methodology. Each model building type is defined by a short description of the representative structural system. These short descriptions can be found in Appendix B. It can be seen in the table in Appendix B that there are 16 general model building types (shown in bold) with some building types being subdivided by height. In addition, the seismic design level, which reflects the relationship between design quality and extent of damage, can be used to further classify each model building type. Four design levels are defined in the methodology: High-Code, Moderate-Code, Low-Code and Pre-Code. For a detailed discussion of how the classification system was developed and the characteristics that were used to differentiate classes, see Chapters 3 and 5 of the Technical Manual.

General building stock is also classified based on occupancy. The occupancy classification is broken into **general occupancy** and **specific occupancy** classes. For the methodology, the general occupancy classification system consists of seven groups: residential, commercial, industrial, religion/non profit, government, education and lifelines. Specific occupancy consists of 28 classes. Occupancy classes are used to account for the fact that contributions to losses are from damage to both the structural system and non-structural elements, and the types and costs of non-structural elements are often governed by the occupancy of the building (i.e., in a warehouse there may be few expensive wall coverings, whereas a bank may have expensive lighting and wall finishes). If the structural systems of these two buildings experience the same amount of damage, the costs to repair the bank will be greater than the warehouse due to the more expensive finishes. Other issues related to occupancy may also be important, such as rental costs, number of employees, type of building contents and importance of function. Finally, a great deal of inventory information, such as county business patterns or census data, is only available by occupancy.

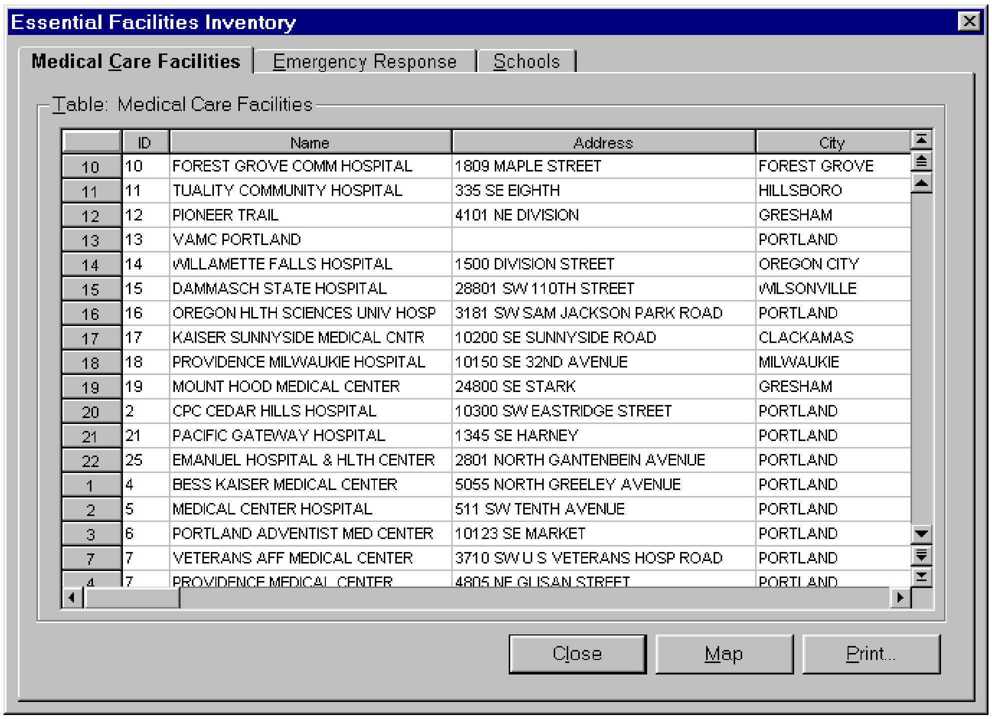
Classification systems developed for soils, model building types, building occupancies, essential facilities, high potential loss facilities, and lifelines are listed in Appendix A. Descriptions of the characteristics of lifeline components are found in Appendix C.

Table 4.1 Structural Building Classifications (Model Building Types)

No.	Label	Description	Height			
			Range		Typical	
			Name	Stories	Stories	Feet
1 2	W1 W2	Wood, Light Frame (≤ 5,000 sq. ft.) Wood, Commercial and Industrial (> 5,000 sq. ft.)		1 - 2 All	1 2	14 24
3 4 5	S1L S1M S1H	Steel Moment Frame	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 13	24 60 156
6 7 8	S2L S2M S2H	Steel Braced Frame	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 13	24 60 156
9	S3	Steel Light Frame		All	1	15
10 11 12	S4L S4M S4H	Steel Frame with Cast-in-Place Concrete Shear Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 13	24 60 156
13 14 15	S5L S5M S5H	Steel Frame with Unreinforced Masonry Infill Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 13	24 60 156
16 17 18	C1L C1M C1H	Concrete Moment Frame	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 12	20 50 120
19 20 21	C2L C2M C2H	Concrete Shear Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 12	20 50 120
22 23 24	C3L C3M C3H	Concrete Frame with Unreinforced Masonry Infill Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 12	20 50 120
25	PC1	Precast Concrete Tilt-Up Walls		All	1	15
26 27 28	PC2L PC2M PC2H	Precast Concrete Frames with Concrete Shear Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 12	20 50 120
29 30	RM1L RM2M	Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms	Low-Rise Mid-Rise	1-3 4+	2 5	20 50
31 32 33	RM2L RM2M RM2H	Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 12	20 50 120
34 35	URML URMM	Unreinforced Masonry Bearing Walls	Low-Rise Mid-Rise	1 - 2 3+	1 3	15 35
36	MH	Mobile Homes		All	1	10

4.3 Inventory Databases

Once data have been collected, they can be accessed more easily and updated in the future if they are maintained in an orderly manner. Database formats have been developed for all of the data that you will collect to perform the loss study. An example of a database of medical care facilities as you would see it when using **HAZUS** is found in Figure 4.3. The database contains fields that allow you to store a variety of attributes about each facility. For example, in addition to the name, address and city of the medical facilities as shown in Figure 4.3, you have space to enter the zip code, the name and phone number of a contact at the facility, the class of facility (small, medium, large), the number of beds, the structural type and several other attributes. There is also a "comments" field that allows you to include any information that does not fit into other fields. Some of these fields are not shown in the figure but can be accessed if you scroll to the right. You will notice in this example that some of the facilities are missing information such as an address. A missing address does not prevent a facility from being included in the database or in the analysis. In order to be included, only the latitude, longitude and county need be specified while other attributes can be inferred (with corresponding uncertainty).

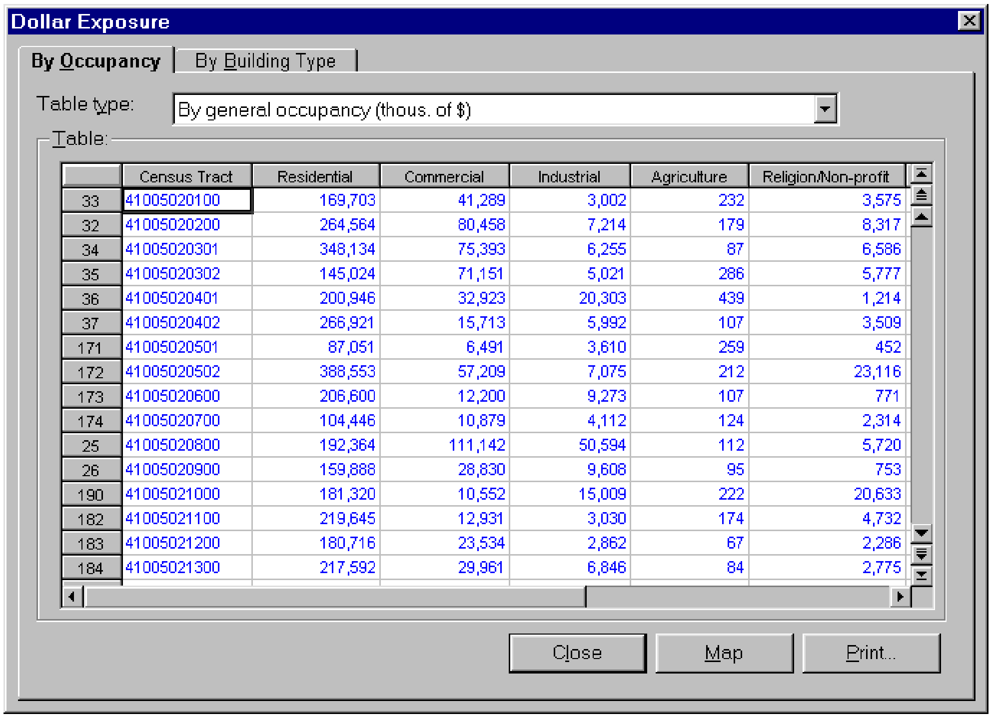


	ID	Name	Address	City
10	10	FOREST GROVE COMM HOSPITAL	1809 MAPLE STREET	FOREST GROVE
11	11	TUALITY COMMUNITY HOSPITAL	335 SE EIGHTH	HILLSBORO
12	12	PIONEER TRAIL	4101 NE DIVISION	GRESHAM
13	13	VAMC PORTLAND		PORTLAND
14	14	WILLAMETTE FALLS HOSPITAL	1500 DIVISION STREET	OREGON CITY
15	15	DAMMASCH STATE HOSPITAL	28801 SW 110TH STREET	WILSONVILLE
16	16	OREGON HLTH SCIENCES UNIV HOSP	3181 SW SAM JACKSON PARK ROAD	PORTLAND
17	17	KAISER SUNNYSIDE MEDICAL CNTR	10200 SE SUNNYSIDE ROAD	CLACKAMAS
18	18	PROVIDENCE MILWAUKIE HOSPITAL	10150 SE 32ND AVENUE	MILWAUKIE
19	19	MOUNT HOOD MEDICAL CENTER	24800 SE STARK	GRESHAM
20	2	CPC CEDAR HILLS HOSPITAL	10300 SW EASTRIDGE STREET	PORTLAND
21	21	PACIFIC GATEWAY HOSPITAL	1345 SE HARNEY	PORTLAND
22	25	EMANUEL HOSPITAL & HLTH CENTER	2801 NORTH GANTENBEIN AVENUE	PORTLAND
1	4	BESS KAISER MEDICAL CENTER	5055 NORTH GREELEY AVENUE	PORTLAND
2	5	MEDICAL CENTER HOSPITAL	511 SW TENTH AVENUE	PORTLAND
3	6	PORTLAND ADVENTIST MED CENTER	10123 SE MARKET	PORTLAND
7	7	VETERANS AFF MEDICAL CENTER	3710 SW U S VETERANS HOSP ROAD	PORTLAND
4	7	PROVIDENCE MEDICAL CENTER	4805 NE GLISAN STREET	PORTLAND

Figure 4.3 Database of medical care facilities.

Figure 4.4 shows an inventory database for general building stock. For general building stock, data are stored by census tract and for each census tract you will find the total monetary value for each of the seven general occupancy types: residential, commercial, industrial, agricultural, religious/non-profit, governmental and educational. For example, in census tract 41005020100, the value of residential construction is $169.7 million and for commercial construction is $41.3 million. You can also view the inventory in terms of each of the 28 specific occupancy types (RES1, RES2, RES3, etc.) by clicking on **By specific occupancy** in the **Table type:** box shown at the top of Figure 4.4.

You will find that data entry is in a familiar spreadsheet format to allow for easy entry and modification. Moving around in the database involves using the arrow keys at the bottom and to the right of the window. Discussion of how to display, print, modify and map your inventories is found in Chapter 7. All data are in a *.dbf format that can be read by Paradox, Dbase, Excel and a variety of other data management programs. The structures of all the databases that are maintained by **HAZUS** are found in Appendix E. A discussion of default databases is found in Section 3.5.



	Census Tract	Residential	Commercial	Industrial	Agriculture	Religion/Non-profit
33	41005020100	169,703	41,289	3,002	232	3,575
32	41005020200	264,564	80,458	7,214	179	8,317
34	41005020301	348,134	75,393	6,255	87	6,586
35	41005020302	145,024	71,151	5,021	286	5,777
36	41005020401	200,946	32,923	20,303	439	1,214
37	41005020402	266,921	15,713	5,992	107	3,509
171	41005020501	87,051	6,491	3,610	259	452
172	41005020502	388,553	57,209	7,075	212	23,116
173	41005020600	206,600	12,200	9,273	107	771
174	41005020700	104,446	10,879	4,112	124	2,314
25	41005020800	192,364	111,142	50,594	112	5,720
26	41005020900	159,888	28,830	9,608	95	753
190	41005021000	181,320	10,552	15,009	222	20,633
182	41005021100	219,645	12,931	3,030	174	4,732
183	41005021200	180,716	23,534	2,862	67	2,286
184	41005021300	217,592	29,961	6,846	84	2,775

Figure 4.4 Value of general building stock inventory.

4.4 Inventory Requirements

Each module in the earthquake loss estimation methodology requires a specific set of input data. The required data can take two forms. The first is inventory data such as the square footage of buildings of a specified type, the length of roadways or the population in the study region. These are used to estimate the amount of exposure or potential damage in the region. The second data type includes characteristics of the local economy that are important in estimating losses (i.e., rental rates, construction costs or regional unemployment rates). This section summarizes the inventory information that is needed to perform a loss study.

Table 4.2 lists the inventory required for each type of output that is provided in the methodology. You will find that there are varying degrees of difficulty in developing this inventory. For example, in your region excellent records may be available concerning the police and fire stations and schools. On the other hand you may find that it is difficult to obtain detailed information about some of the lifeline facilities. An issue that you will likely run into is that data you collect will have to be adjusted so that the inventory is classified according to the systems defined in the methodology. In some cases, you may find that you require a consultant to assist with the classification of data. Default values are provided for most of the input information (see Section 3.5). In Table 4.2, a star is placed next to those input requirements that do not have default values.

Table 4.2 Minimum inventory for the Earthquake Loss Estimation Methodology

Desired Output	Required Input
POTENTIAL EARTH SCIENCE HAZARDS (PESH)	
Intensities of ground shaking for scenario earthquake	Definition of scenario earthquake and attenuation functions, soil map
Permanent ground displacements	Liquefaction and landslide susceptibility maps
Liquefaction probability	Liquefaction susceptibility map
Landsliding probability	Landslide susceptibility map
GENERAL BUILDING STOCK	
Damage to general building stock - By occupancy or building type	Total square footage of each occupancy by census tract, occupancy to building type relationships
ESSENTIAL FACILITIES	
Damage and functionality of essential facilities	Location and building type of each facility
Loss of beds and estimated recovery time for hospitals	Number of beds at each facility
HIGH POTENTIAL LOSS FACILITIES	
Map of high potential loss facilities	Locations and types of facilities
Damage and loss for military installations	Location, building type, and value of military installations
TRANSPORTATION LIFELINES	
Damage to transportation components	Locations and classes of components
Restoration times of transportation components	Estimates of repair times for each level of damage
UTILITY LIFELINES	
Damage to utility components	Locations and classes of components
Restoration times of utility components	Estimates of repair times for each level of damage
INDUCED PHYSICAL DAMAGE	
Inundation exposure	Inundation map*
Number of ignitions and percentage of burned area by census tract	General building stock inventory, average speed of fire engines, and speed and direction of wind
Map of facilities containing hazardous materials	Inventory of facilities containing hazardous materials
Type and weight of debris	General building stock inventory and estimates of type and unit weight of debris
DIRECT SOCIAL LOSSES	
Number of displaced households	Number of households per census tract
Number of people requiring temporary shelter	Population including ethnicity, age, income
Casualties in four categories of severity based on event at three different times of day	Population distribution at three times of day

Table 4.2 (cont.) Minimum inventory for the Earthquake Loss Estimation Methodology

Desired Output	Required Input
ECONOMIC LOSSES	
Structural and nonstructural cost of repair or replacement	Cost per square foot to repair damage by structural type and occupancy for each level of damage
Loss of contents	Contents value as percentage of replacement value by occupancy
Business inventory damage or loss	Annual gross sales in $ per square foot
Relocation costs	Rental costs per month per square foot by occupancy
Business income loss	Income in $ per square foot per month by occupancy
Employee wage Loss	Wages in $ per square foot per month by occupancy
Loss of rental income	Rental costs per month per square foot by occupancy
Cost of damage to transportation components	Costs of repair/replacement of components
Cost of damage to utility components	Costs of repair/replacement of components
INDIRECT ECONOMIC LOSSES	
Long-term economic effects on the region	Unemployment rates, input/output model parameters

4.5 Relationship Between Building Types and Occupancy Classes

As discussed earlier, contributions to the loss estimates come from damage to both the structural system and the non-structural elements. Thus in order to estimate losses, the structural system must be known or inferred for all of the buildings in the inventory. Since much of the inventory information that is available is based on occupancy classes, inferences must be made to convert occupancy class inventory to model building types. The relationship between structural type and occupancy class will vary on a regional basis. For example, in California, the occupancy RES1 (single family dwelling) can be 95% W1 (wood, light frame) and 5% URML (unreinforced masonry bearing wall, low rise). In a city on the east coast, the relationship can be 40% W1, 50% URML and 10% RM1L (reinforced masonry bearing wall with wood or metal deck diaphragm, low rise).

In most cases, structures in a study region or census tract have been built at different times. As a result, some structures might have been built before 1950, some between 1950 and 1970 and others after 1970. An exception can be a large development that occurred over a short period in which most structures would have about the same age. Since construction practices change over time, so does the mix of structural types. For example, Table 4.3 shows a typical mix of low-rise model building types for west coast construction for occupancy class COM1 (retail trade). Looking at the building type S5L (low rise steel frame with unreinforced masonry infill walls) it can be seen that before 1950, 20% of stores were built using this structural system, whereas after 1970 none were.

Table 4.3 Distribution of Floor Area for Occupancy COM1, Low Rise West Coast Construction

Age	Model Building Type													
	2	3	6	9	10	13	16	19	22	25	26	29	31	34
	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML
Pre-1950	22%	2%		6%	3%	20%		17%	1%			6%		23%
1950 to 1970	34%	3%	1%	3%	2%	4%		13%	5%	10%	1%	18%	2%	4%
Post-1970	26%	9%	1%	2%	1%		6%	10%	1%	15%	5%	21%	3%	

While the relationship shown in Table 4.3 can be developed from data collected locally, **HAZUS** provides default mappings of specific occupancy classes to model building types. Three general mapping schemes have been defined and assigned depending upon whether a state is in the Western U. S., the Mid-West or the Eastern U. S. Table 3C.1 of the *Technical Manual* provides the regional classification for each state. <u>Default</u> mappings will be the same for regions that are created anywhere within a particular state. It will be up to you to modify these defaults to reflect characteristics that are specific to your local region.

In addition to geographical location, the distributions can also depend on when the buildings were constructed and whether they are low, medium or high-rise structures. Age is important because it affects the types of structures that exist in a region. For example, if most of the buildings in a region were built after 1970, there will be very few unreinforced masonry structures. An example of how age and height information affects the mix of building types is shown as follows:

Suppose you determined the following information:

All of the buildings in a census tract are low-rise
50% of the buildings were built before 1950
30% of the buildings were built between 1950 and 1970
20% of the buildings were built after 1970.

A new occupancy mapping can be calculated by combining the different mapping schemes presented in Table 4.3. The new occupancy mapping for COM1 would be determined by multiplying the first row of Table 4.3 by 0.5, the second row by 0.3, the third row by 0.2 and then summing. To calculate the modified occupancy mapping for the building type W2, the calculation would be:

$$0.5 \times 22\% + 0.3 \times 34\% + 0.2 \times 26\% = 26\%$$

The resulting occupancy mapping is shown in Table 4.4. Similar calculations would occur if you were also to include a mix of building heights.

Table 4.4 Modified Occupancy Mapping for COM1 to Include Age Mix

Specific Occupancy Class	Model Building Type													
	2	3	6	9	10	13	16	19	22	25	26	29	31	34
	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML
COM1	26%	4%	1%	4%	2%	11%	1%	15%	2%	6%	1%	13%	1%	13%

Modifying occupancy to model building type relationships in **HAZUS** is discussed in Chapter 7. Developing custom mapping schemes using local data and experts is discussed in Chapter 5. Developing mapping schemes using tax assessor or property records is discussed in Chapter 8.