Chapter 2
Overall Approach and Framework of Methodology

This chapter describes the overall approach used by the developers to meet the objectives of the project, the components and subcomponents of earthquake loss estimation and their relationship within the framework of methodology.

2.1 Vision Statement

The overall approach for the project is based on the following "vision" of the earthquake loss estimation methodology.

> *The earthquake loss estimation methodology will provide local, state and regional officials with the tools necessary to plan and stimulate efforts to reduce risk from earthquakes and to prepare for emergency response and recovery from an earthquake. The methodology will also provide the basis for assessment of nationwide risks of earthquake loss.*
>
> *The methodology can be used by a variety of users with needs ranging from simplified estimates that require minimal input to refined calculations of earthquake loss. The methodology may be implemented using either geographical information system (GIS) technology provided in a software package or by application of the theory documented in a Technical Manual. An easily understood User Manual will guide implementation of the methodology by either technical or non-technical users.*

The vision of earthquake loss estimation requires a methodology that is both flexible, accommodating the needs of a variety of different users and applications, and able to provide the uniformity of a standardized approach. The framework of the methodology includes each of the components shown in Figure 2-1: Potential Earth Science Hazard (PESH), Inventory, Direct Physical Damage, Induced Physical Damage, Direct Economic/Social Loss and Indirect Economic Loss. As indicated by arrows in the figure, modules are interdependent with output of some modules acting as input to others. In general, each of the components will be required for loss estimation. However, the degree of sophistication and associated cost will vary greatly by user and application. It is therefore necessary and appropriate that components have multiple levels (multiple modules) of detail or precision when required to accommodate user needs.

Framing the earthquake loss estimation methodology as a collection of modules permits adding new modules (or improving models/data of existing modules) without reworking the entire methodology. Improvements may be made to adapt modules to local or regional needs or to incorporate new models and data. The modular nature of the methodology permits a logical evolution of the methodology as research progresses and the state-of-the-art advances.

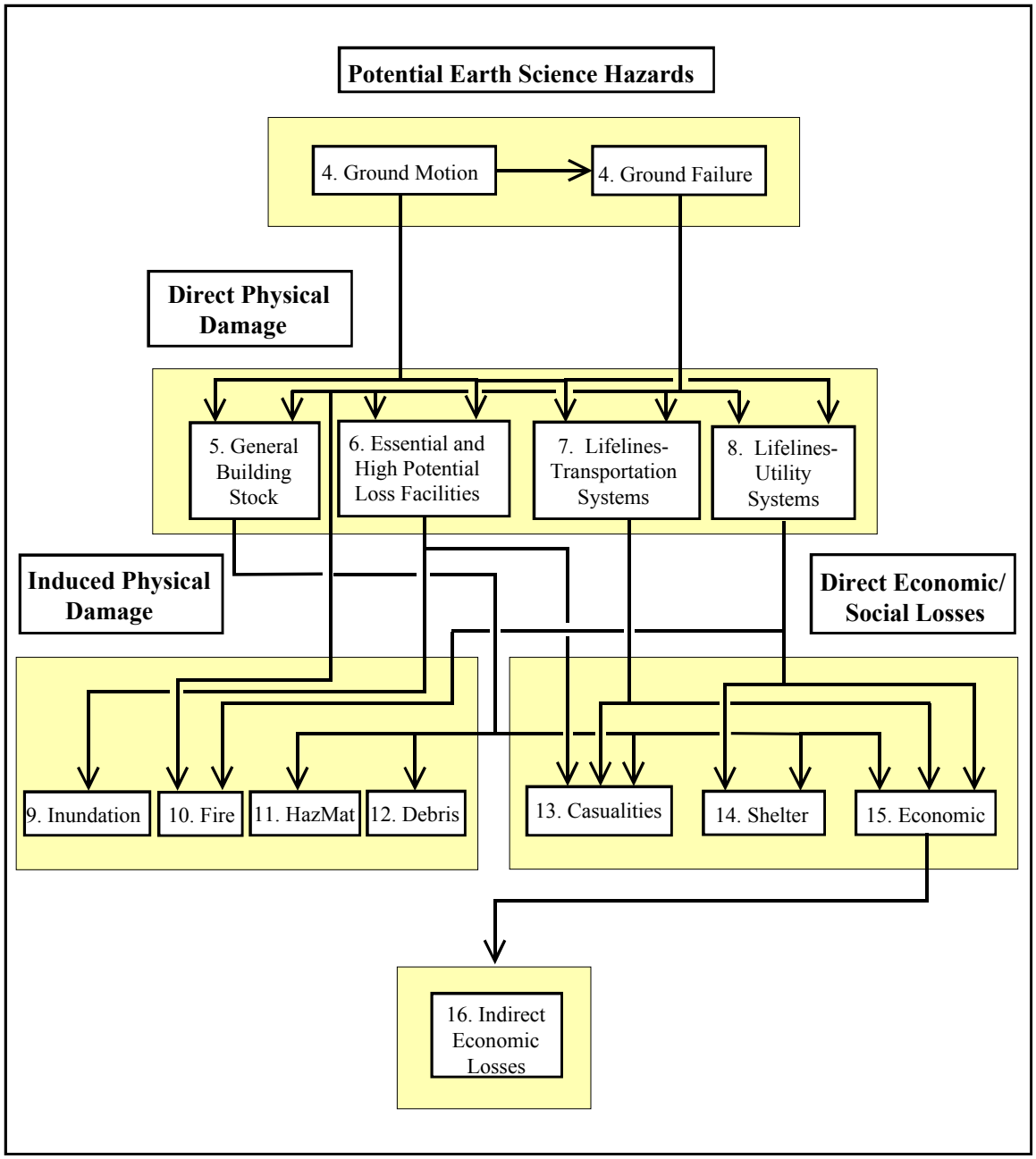

Figure 2.1 Flowchart of the Earthquake Loss Estimation Methodology.

Most users will implement the methodology using the GIS-based software application provided by NIBS. After initial inventory entry, the program will run efficiently on desktop computer. The GIS technology provides a powerful tool for displaying outputs and permits users to "see" the effects of different earthquake scenarios and assumptions. A *User Manual* will guide users in program manipulation, input of new data, and changes to existing data.

Certain users may not wish to use the software application, or may want to augment the results with supplementary calculations. In such cases, users can refer to the *Technical Manual* for a complete description of models and data of each module. The *Technical Manual* is useful to technical experts, such as those engineers and scientists that have conducted previous earthquake loss studies, but might be inappropriate for non-technical users.

Both technical and non-technical users are guided in the application of the methodology by the *User Manual*, which addresses important implementation issues, such as:

(1) Selection of scenario earthquakes and PESH inputs
(2) Selection of appropriate methods (modules) to meet different user needs
(3) Collection of required inventory data, i.e., how to obtain necessary information
(4) Costs associated with inventory collection and methodology implementation
(5) Presentation of results including appropriate terminology, etc.
(6) Interpretation of results including consideration of model/data uncertainty.

The three project deliverables are shown in Figure 2.2.

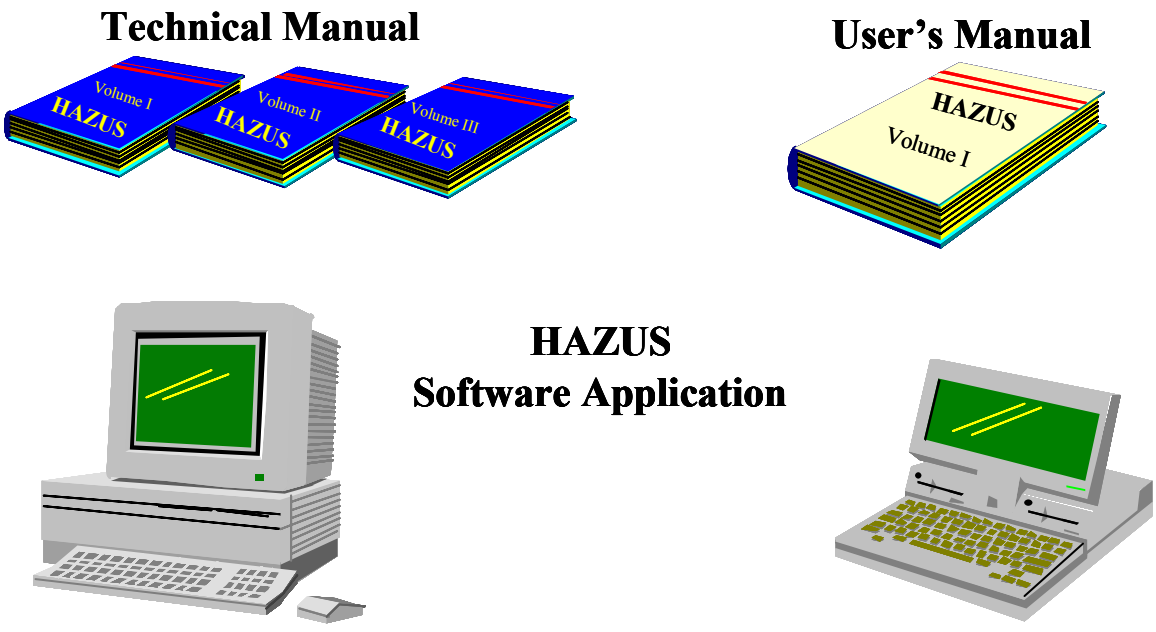

Figure 2.2 Project Deliverables.

2.2 Project Objectives

The development of an earthquake loss estimation methodology has been defined by the eight General Objectives outlined in the NIBS/FEMA "Task Plan for Tasks 2 and 5," October 18, 1993. The following sections summarize the approach taken to meet each objective.

Accommodation of User Needs

The methodology utilizes a modular approach with different modules addressing different user needs. This approach avoids the need to decide on who is the designated user. The needs of most, if not all, users are accommodated by the flexibility of a modular approach.

The GIS technology permits easy implementation by users on desktop computers. The visual display and interactive nature of a GIS application provides an immediate basis for exchange of information and dialog with end-users of the results. The *User Manual* provides appropriate terminology and definitions, and user-oriented descriptions of the loss estimation process.

State-of-the-Art

The methodology incorporates available state-of-the-art models in the earthquake loss estimation methodology. For example, ground shaking hazard and related damage functions are described in terms of spectral response rather than MMI. Modules include damage loss estimators not previously found in most studies, such as induced damage due to fire following earthquake and indirect economic loss. A nationally applicable scheme is developed for classifying buildings, structures and facilities.

Balance

The methodology permits users to select methods (modules) that produce varying degrees of precision. The *User Manual* provides guidance to users regarding the selection of modules that are appropriate for their needs and which have a proper balance between different components of earthquake loss estimation.

Flexibility in Earthquake Demand

The methodology incorporates both deterministic (scenario earthquake) and probabilistic descriptions of spectral response. Alternatively, the proposed methodology accepts user-supplied maps of earthquake demand. The software application is structured to also accept externally supplied maps of earthquake ground shaking.

"Uncertainty" in earthquake demand due to spatial variability of ground motion is addressed implicitly by the variability of damage probability matrices (DPM's) or fragility

curves. Uncertainty in earthquake demand due to temporal variability (i.e., earthquake recurrence rate) or uncertainty in the magnitude of earthquake selected for scenario event may be readily evaluated by the users.

Once the data is input into the software application, any number of scenario events can be evaluated. The *User Manual* provides guidance for the consideration of uncertainty, including that associated with earthquake demand.

Uses of Methodology Data

The *User Manual* provides recommendations for collecting inventory data that will permit use of the data for non-earthquake purposes. Inventory information will come from databases supplied with the methodology and/or collected in databases compatible with the software. Such data will be available to users for other applications.

Accommodation of Different Levels of Funding

The methodology includes modules that permit different levels of inventory collection and associated levels of funding. For example, the methodology permits simplified (Default Data Analysis) estimates of damage and loss, using primarily default data supplied with the software application. These estimates of damage/loss do not require extensive inventory collection and can be performed on a modest budget. More precise damage/loss (User-Supplied Data Analysis) estimates require more extensive inventory information at additional cost to the user. The *User Manual* provides guidance to users regarding trade-offs in cost and accuracy of results.

Standardization

The methodology includes standard methods for:

(1) Inventory data collection based on census tract areas
(2) Using database maps of soil type, ground motion, ground failure, etc.
(3) Classifying occupancy of buildings and facilities
(4) Classifying building structure type
(5) Describing damage states
(6) Developing building damage functions
(7) Grouping, ranking and analyzing lifelines
(7) Using technical terminology
(8) Providing output.

Non-Proprietary

The methodology includes only non-proprietary loss estimation methods. The software application is non-proprietary to the extent permitted by the GIS-software suppliers.

2.3 Description of Loss Estimation Methodology

The earthquake loss estimation methodology is an improvement over existing regional loss estimation methodologies, since it more completely addresses regional impacts of earthquakes that have been omitted or at best discussed in a qualitative manner in previous studies. Examples of these impacts are service outages for lifelines, estimates of fire ignitions and fire spread, potential for a serious hazardous materials release incident, and indirect economic effects. In addition, strength of this methodology is the ability to readily display inputs and outputs on GIS-based maps that can be overlaid. By overlaying maps the user is able to experiment with different scenarios and ask "what if" questions.

As discussed in Section 2.1, the methodology is modular, with different modules interacting in the calculation of different losses. Figure 2.1 shows each of the modules and the flow of information among them. It can be seen that, because of the complexity of earthquake damage and loss estimation, the model is complex. One advantage of the modularity of the methodology is that it enables users to limit their studies to selected losses. For example, a user may wish to ignore induced physical damage when computing direct economic and social losses. This would eliminate the lower left portion of the flow diagram along with corresponding input requirements. A limited study may be desirable for a variety of reasons, including budget and inventory constraints, or the need to obtain answers to very specific questions.

The methodology has been developed with as much capability as possible. However, there are certain areas where methods are limited. For example, the methodology calculates potential exposure to flood (e.g., dam break) or fire (following earthquake) in terms of the fraction of a geographical area that may be flooded or burned, but does not have methods for rigorous calculation of damage or loss due to flooding or fire. Consequently, these two potential contributors to the total loss would not be included in estimates of economic loss, casualties or loss of shelter.

A limiting factor in performing a study and quality of the inventory is the associated cost. Collection of inventory is without question the most costly part of performing the study. Furthermore, many municipalities have limited budgets for performing an earthquake loss estimation study. Thus, the methodology is structured to accommodate different users with different levels of resources.

While most users will develop a local inventory that best reflects the characteristics of their region, such as building types and demographics, the methodology is capable of producing crude estimates of losses based on a minimum of local input. Of course, the quality and uncertainty of the results is related to the detail of the inventory and the economic and demographic data provided. Crude estimates would most likely be used only as initial estimates to determine where more detailed analyses would be warranted.

At the other end of the spectrum, a user may wish to make detailed assessments of damage to and service outages for lifelines. Detailed analyses of lifelines require

cooperation and input from utilities and transportation agencies. Lifeline systems require an understanding of the interactions between components and the potential for alternative pathways when certain components fail. Thus, without cooperation of utilities, the user is limited in the quality of analysis that can be performed.

The proposed loss estimation methods are capable of providing estimates of damage to and service outages for lifelines with a minimum of cooperation from lifeline operators. These estimates, of course, will have a great deal of uncertainty associated with them. However, they will be useful for planning purposes and for an initial estimate to determine where more detailed analyses would be warranted. Many lifeline operators perform their own detailed earthquake loss studies that incorporate detailed models of their systems.

Three types of analysis are defined to describe implementation of the methodology by users with different needs and resources. These types and their definitions are somewhat arbitrary, and the boundaries between the three types are not well defined. The three types are defined as follows:

Default Data Analysis: This is the simplest type of analysis requiring minimum effort by the user as it is based mostly on input provided with the methodology (e.g. census information, broad regional patterns of seismic code adoption and earthquake resistance of classes of construction, etc.). The user is not expected to have extensive technical knowledge. While the methods require some user-supplied input to run, the type of input required could be gathered by contacting government agencies or by referring to published information. At this level, estimates will be crude, and will likely be appropriate only as initial loss estimates to determine where more detailed analyses are warranted.

Some components of the methodology cannot be performed in a Default Data Analysis since they require more detailed inventory than that provided with the methodology. The following are not included in the Default Data Analysis: damage/loss due to liquefaction, landslide or surface fault rupture; damage/loss due to tsunamis, seiche or dam failure. At this level, the user has the option (not required) to enter information about hazardous substances and emergency facilities. One week to a month would be required to collect relevant information depending on the size of the region and the level of detail the user desires.

User-Supplied Data Analysis: This type of analysis will be the most commonly used. It requires more extensive inventory data and effort by the user than Default Data Analysis. The purpose of this type is to provide the user with the best estimates of earthquake damage/loss that can be obtained using the standardized methods of analysis included in the methodology. It is likely that the user will need to employ consultants to assist in the implementation of certain methods. For

example, a local geotechnical engineer would likely be required to define soil and ground conditions.

All components of the methodology can be performed at this level and loss estimates are based on locally (user) developed inventories. At this level, there are standardized methods of analysis included in the software, but there is no standardized User-Supplied Data Analysis study. As the user provides more complete data, the quality of the analysis and results improve. Depending on the size of the region and the level of detail desired by the user, one to six months would be required to obtain the required input for this type of analysis.

Advanced Data and Models Analysis: This type incorporates results from engineering and economic studies carried out using methods and software not included within the methodology. At this level, one or more technical experts would be needed to acquire data, perform detailed analyses, assess damage/loss, and assist the user in gathering more extensive inventory. It is anticipated that at this level there will be extensive participation by local utilities and owners of special facilities. There is no standardized Advanced Data and Models Analysis study. The quality and detail of the results depend upon the level of effort. Six months to two years would be required to complete an Advanced Data and Models Analysis.

To summarize, User-Supplied Data Analysis and Advanced Data and Models Analysis represent a broad range of analyses, and the line between one type of analysis and another is fuzzy. The above definitions are provided to understand the scope and flexibility of the methodology, not to limit its application. The primary limit on the type of analysis will be the user's ability to provide required data.

Even with perfect data, which can never be obtained, the methodology would not be able to precisely estimate earthquake loss. Simply put, predictive methods are approximate and will often have large amounts of uncertainty associated with damage and loss estimates. A discussion of uncertainty and guidance for users performing earthquake loss estimation is provided in the *User Manual*.