

EARTHQUAKE LOSS ESTIMATION METHODOLOGY

HAZUS[®]99
TECHNICAL MANUAL

Developed by:

Federal Emergency Management Agency
Washington, D.C.

Through a cooperative agreement with:

National Institute of Building Sciences
Washington, D.C.

Preface

Earthquakes pose a threat to life and property in 45 states and territories. As the United States has become more urbanized, more frequent smaller earthquakes in the 6.5 to 7.5 Magnitude range now have the potential of causing damage equal to or exceeding the estimated \$40 billion from the 1994 Northridge earthquake. Earthquakes in urban areas, such as Kobe, Japan and Izmit, Turkey, are grim reminders of the kind of damage that may result from larger earthquakes, like the San Francisco event of 1906 and eastern events that occurred in New Madrid in 1811-12.

The Federal Emergency Management Agency is committed to mitigation as a means of reducing damages and the social and economic impacts from earthquakes. FEMA, under a Cooperative Agreement with the National Institute of Building Sciences, has developed HAZUS[®]99 (HAZUS[®] stands for “Hazards U.S.”), the second edition of the standard, nationally-applicable methodology for assessing earthquake risk. Significant enhancements have been added to HAZUS[®]99, particularly, a disaster response application to facilitate the use of HAZUS[®] in the immediate post-disaster environment. HAZUS[®]99 and the preceding edition of the earthquake loss estimation methodology, HAZUS[®]97, represent the dedicated efforts of more than 130 nationally-recognized earthquake and software professionals.

HAZUS is an important component of FEMA’s *Project Impact*, a national movement to create safe and disaster-resistant communities. FEMA is making HAZUS[®] available to all states and communities, including the almost 200 now participating in *Project Impact*, and the private sector. Communities find HAZUS[®] to be a valuable tool in promoting a broader understanding of potential earthquake losses and in helping to build a community consensus for disaster loss prevention and mitigation.

Since the first release of HAZUS[®], FEMA has been expanding the capability of HAZUS[®] by initiating loss estimation models for flood and hurricane hazards. Preview versions of these flood and hurricane models are being readied for release in 2002.

I am pleased to disseminate this manual to state and local users.

A handwritten signature in black ink that reads "Michael J. Armstrong". The signature is written in a cursive style with large, flowing loops.

Michael J. Armstrong
Associate Director for Mitigation
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Foreword

The work that provided the basis for this publication was supported by funding from the Federal Emergency Management Agency (FEMA) under a cooperative agreement with the National Institute of Building Sciences. The substance and findings of that work are dedicated to the public. NIBS is solely responsible for the accuracy of the statements and interpretations contained in this publication. Such interpretations do not necessarily reflect the views of the Federal Government.

The National Institute of Building Sciences (NIBS) is a non-governmental, non-profit organization, authorized by Congress to encourage a more rational building regulatory environment, to accelerate the introduction of existing and new technology into the building process and to disseminate technical information.

Individual copies or bulk rate orders of this report are available through the National Institute of Building Sciences. For information contact:

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MESSAGE TO USERS

HAZUS is designed to produce loss estimates for use by state, regional and local governments in planning for earthquake loss mitigation, emergency preparedness and response and recovery. The methodology deals with nearly all aspects of the built environment, and with a wide range of different types of losses. The methodology has been tested against the experience from several past earthquakes and against the judgment of experts. Subject to several limitations noted below, HAZUS has been judged capable of producing results that are credible for the intended purposes.

Uncertainties are inherent in any such loss estimation methodology. They arise in part from incomplete scientific knowledge concerning earthquakes and their effect upon buildings and facilities, and in part from the approximations and simplifications necessary for comprehensive analyses. The possible range of uncertainty, possibly a factor or two or more, is best evaluated by conducting multiple analyses, varying certain of the input parameters to which losses are most sensitive. This *User's Manual* gives guidance concerning the planning of such sensitivity studies.

Users should be aware of the following specific limitations:

HAZUS is most accurate when applied to a class of buildings or facilities, and least accurate if applied to a particular building or facility.

Accuracy of losses associated with lifelines may be less than for losses associated with the general building stock.

Based on several initial abbreviated tests, the losses from small magnitude (less than M 6.0) earthquakes appear to be overestimated.

Uncertainty related to the characteristics of ground motion in the Eastern U.S. is high. Conservative treatment of this uncertainty may lead to overestimation of losses in this area, both for scenario events and when using probabilistic ground motion.

Pilot and calibration studies have as yet not provided an adequate test concerning the possible extent and effects of landslides and the performance of water systems.

The indirect economic loss module is new and experimental. While output from pilot studies has generally been credible, this module requires further testing.

HAZUS should be regarded as a work in progress. Additional improvements and increased confidence will come with further experience in using HAZUS. To assist us in further improving HAZUS, users are invited to submit comments on methodological and software issues by letter, fax or e-mail to:

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What is New in HAZUS99?

- The ground motion model has been revised by implementing new algorithms for calculating the distance to the fault rupture plane and accounting for earthquakes that rupture across multiple fault segments. New attenuation functions have been added for Hawaii (Munson & Thurber) and the Eastern United States (Lawrence Livermore National Lab). Details of these changes are included in Chapter 4 of the *Technical Manual*.
- A new bridge model based on the nonlinear performance of bridges has been implemented along with a revised bridge classification scheme and updated national bridge inventory. Details of these changes are included in Chapter 7 of the *Technical Manual*.
- For the probabilistic analysis of building damage, revised fragility curves have been added that are compatible with the USGS probabilistic ground motion maps. These new fragility curves, however, are still under review by the Earthquake Committee. In addition, **HAZUS99** now has the capability to automatically compute annualized loss estimates for buildings. Details of these changes are included in Chapters 5 and 16 of the *Technical Manual*.
- HAZUS99 now includes a network analysis model for potable water systems. Although the model is fully functional, the results generated are still under review by the Utility Lifeline Subcommittee. Details of these changes are included in Chapter 8 of the *Technical Manual*.
- The indirect economic loss model has been improved to accommodate weekly and monthly inputs in the first two years after an earthquake event. Details of these changes are included in Chapter 16 of the *Technical Manual*.
- **HAZUS99** includes a new application that can directly link **HAZUS** with Tri-NET. This capability will allow **HAZUS** to monitor Tri-NET and to automatically create a study region and execute the analysis when an earthquake is broadcast. In addition, **HAZUS99** response and recovery capabilities have been enhanced with the addition of a “ground truthing” option. This special feature allows users to incorporate observed damage information for use in post-event operational response. Details of these changes are included in Chapter 9 and 12 of the *User's Manual*.
- **HAZUS99** has been optimized for greater speed.
- In addition to several new summary reports, a comprehensive summary report of analysis results has been added. The report, about 20 pages in length, contains text and tabular data about the study region, the earthquake scenario selected, and the results.
- The capability to save and recall map workspaces has been added.
- Several databases in HAZUS99 have been added: updated USGS probabilistic ground motion maps and US source maps, a revised hospital database, a new national bridge inventory, an updated hazardous material site database and a new national railroad track database.