GFDRR

Risk Analysis

World Bank Distance Learning

Natural Disaster Risk Management Program

Disaster Risk Management Online Program

Risk Analysis Course Manual

For Instructors

Global Facility for Disaster Reduction and Recovery

The World Bank/GFDRR
1818 H. Street N.W.
Washington, D.C. 20433, U.S.A.
Telephone: 202 458 4673
Email: *kdemeter@worldbank.org*

Authors
Bijan Khazai, James Daniell and Heiko Apel, Center for Disaster Management and Risk Reduction Technology, Germany.

Review
Katalin Demeter, Global Facility for Disaster Reduction and Recovery (GFDRR)

Production and Printing
Adrian Feil, World Bank

Graphic Design
Hernan Gigena, World Bank

Acknowledgement
The Risk Analysis Course is part of the World Bank online program in disaster risk management. It was developed within the India Capacity Building Program in Risk Reduction financed by the Global Facility for Disaster Reduction and Recovery. The Risk Analysis Course and the Course Manual is the result of collaboration with the Center of Disaster Management and Risk Reduction Technology (CEDIM) at Karlsruhe Institute of Technology (KIT) in Karlsruhe, Germany and German Research Centre for Geoscience (GFZ) in Potsdam, Germany. The manual has benefited from the support of Ghadeer Ashram and Berna Yekeler.

Tribute to GFDRR
Since its establishment in September 2006, the Global Facility for Disaster Reduction and Recovery (GFDRR) has evolved into a partnership of 37 countries and 6 international organizations: ACP Secretariat, Arab Academy, Australia, Bangladesh, Belgium, Brazil, Canada, Colombia, China, Denmark, Egypt, European Union, Finland, France, Germany, Haiti, India, Indonesia, Ireland, Italy, Japan, Luxembourg, Malawi, Mexico, The Netherlands, New Zealand, Norway, Portugal, Saudi Arabia, Senegal, Spain, South Africa, South Korea, Sweden, Switzerland, Turkey, United Kingdom, United States, Vietnam, Yemen, IFRC, UNDP, UN/International Strategy for Disaster Reduction and The World Bank.

About the Authors:

Dr. Bijan Khazai is a senior research scientist at Karlsruhe Institute of Technology's Center for Disaster Management and Risk Reduction Technology (CEDIM). He holds Masters and Doctoral degrees in Geotechnical Earthquake Engineering from the University of California at Berkeley. He worked on developing GIS-based landslide hazard assessment models in the San Francisco Bay Area, on the socio-economic assessment of recovery and reconstruction processes in Iran, Sri Lanka, Pakistan and New Orleans and in a number of applied projects in Istanbul, Amman, Metro Manila and Mumbai.

Dr. Heiko Apel is a senior scientist at GFZ, the German Research Centre for Geoscience. He graduated in Geoecology at the Technical University of Brunswick, Germany where he also obtained his Doctoral degree in environmental risk assessment. Currently he is working on several aspects of flood risks with a major focus on hazard mapping, probabilistic risk assessment on large scales and uncertainty assessment, and the monitoring of inundation dynamics in floodplains.

James Daniell is undertaking his doctorate in Earthquake Loss Estimation as a General Sir John Monash Scholar at the Geophysical Institute of Karlsruhe Institute of Technology. He has recently completed an Erasmus Mundus Masters in Earthquake Engineering and Engineering Seismology at the University of Pavia, Italy, and University Joseph Fourier, France. He has completed Civil and Structural Engineering, Geophysics and Geology degrees from the University of Adelaide, Australia. His research interests involve rapid loss estimation of global earthquake losses, scenario-based disaster modelling, socio-economic vulnerability, historic disaster data catalogues and disaster loss estimation software.

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I. Introduction

1.1 Objective of the Manual

The objective of this course manual is to support the course facilitators in the understanding of the subject matter during the delivery of the online Risk Analysis course. It complements the course content by providing the facilitators with an overview of the learning materials—presentations, case studies, and readings—and explains how the case studies and readings link to the presentations as well as how they reinforce the main points of each module. This course manual also provides the facilitators with step-by-step solutions to the knowledge checks, assignments and End-of-Course Project. It also includes guidance on how to lead and structure discussions during the course, recommended initial and follow-up questions, and guidelines for preparing discussion summaries.

1.2 How to Use the Manual

Distance learning is an entirely different mode of learning than face-to-face. The role of the facilitator is very important and the contributions made by a facilitator can significantly enhance the overall learning process. This course manual has been designed as a complementary document to the learning content in the Risk Analysis course, and is intended to be a helpful resource to the facilitator. It has been developed based on the timeline of the course. The facilitator should review this manual and use it to:

- Understand the content, learning objectives and learning outcomes of each of the modules.
- Understand the main themes and key issues of each of the module sessions.
- Understand why the case studies and readings were selected and how they link to the main themes and reinforce the key issues of a module.
- Learn about objectives of the assignments and work out the assignments using the step-by-step solution template.

- Apply the suggested solution templates for grading assignments and the End-of-Course Project (ECP)
- Learn techniques for facilitating the course.
- To prepare and formulate questions that emphasize the material's main points, by referring to the recommended initial and follow up questions.
- Familiarize themselves with the expected outcome of discussions and accordingly prepare discussion summary for each module.
- Prepare summary table of questions and topics for discussion in each week.
- Receive additional resources from references provided in the manual in preparation of a more in depth understanding of the learning content in the discussions.

1.3 Structure of the Manual

The manual is structured along the timeline of the delivery of the three modules Risk Analysis course. The course duration is five weeks. During the first three weeks, participants should review the course modules considering one module each week. The following two weeks are allocated for the preparation of the End-of-Course Project. Chapter 2 provides a description of the course objectives, structure, and expectations, while Chapter 3 outlines the pre-course activities which are to be completed before the course kickoff. Chapters 4, 5 and 6 of the manual complement week 1, 2 and 3 of the risk analysis course respectively. These chapters provide a description of the main terms, key issues, learning objectives and learning outcomes for each of the modules of the course, for Module1: Fundamental Elements of Risk Analysis; Module2: Earthquake Risk Analysis and Module3: Flood Risk Analysis. The chapters also provide short summary of each of the case studies and readings, reasons for their selection and explanations regarding how they link to and reinforce the main points and messages of the presentations. Finally, they also include materials supporting the activities of each of the modules, answer keys to the knowledge checks, step-by-step solution templates and checklists for reviewing and grading the assignments. They also include guidance for use of the discussion forum. Chapter 7 complements the activities of week 4–5 of the risk analysis course, and includes a description and step-by-step solution to the end of the course project, as well as an answer key to the final exam. A summary table following the weekly schedule of questions and topics for discussions and participant's performance evaluation criteria are provided in Chapter 8 and 9 of the course manual. The final chapter provides additional references and a glossary supporting the terminology used in the risk analysis course.

II. About The Course

2.1 Course Description

One of the objectives of the WB Disaster Risk Management Program (DRMP) is to provide cutting-edge knowledge in Disaster Risk Management for public officials, decision makers and others involved in implementing disaster risk reduction agendas. The course on "Risk Analysis" is jointly developed by the World Bank and the Center of Disaster Management and Risk Reduction Technology (CEDIM) within the Karlsruhe Institute of Technology in Karlsruhe, Germany, and the Geo Research Center (GeoForschungsZentrum, GFZ) in Potsdam, Germany.

The Risk Analysis course introduces the available concepts, methods and tools to assess risk, with a special focus on earthquakes and floods. The course includes presentations (in Microsoft PowerPoint format with corresponding written and audio transcripts), case studies, readings, knowledge checks, exercises, discussion forums, a comprehensive glossary, an end of the course project and a final exam. It is richly appended with outside reading references.

The course is structured around the following three modules:

Module 1: Fundamental Elements of Risk Analysis: This module introduces basic concepts and defines hazard, exposure and vulnerability, and risk. It reviews the key components of a risk-based approach and the result of the risk assessment process, including risk mapping, scenario analysis, and loss and damage estimation. It also introduces methods of a multi-risk analysis for comparison and ranking of risks.

Module 2: Earthquake Risk Analysis: This module reviews the components of earthquake risk analysis. It starts with the characteristics of the hazard followed by description of the impact under different soil conditions and site characteristics. Next, the module looks into the steps involved in vulnerability and exposure analysis. The earthquake risk analysis methods illustrated for physical infrastructure (buildings and lifelines) as well as for the direct and indirect socioeconomic impacts such as business interruption or psycho-social impact. The module concludes with an overview of tools available for earthquake loss estimation and scenario analysis.

Module 3: Flood Risk Analysis: This module looks at flood hazard, flood risk and flood simulation analysis. It explains the basic hydrologic parameters and flood types followed by and explanation of the hydrologic cycle and the development of a flood plain. The module presents flood risk assessment methods—frequency analysis, hydrologic modeling (1-D) and hydraulic modeling (2-D)—together with the data requirement of these methods. The module concludes with tools for flood simulation analysis. It illustrates how these tools can be used to increase coping capacity through better flood risk communication, preparedness and evacuation.

2.2 Course Objective

The objective of the Risk Analysis course is to develop a broader understanding of risk analysis procedures and methods used by practitioners and policy makers. It also intends to enhance the use and effectiveness of risk assessment in disaster risk management decision-making. The Risk Analysis course introduces the concepts, methods and tools to assess hazard, risks and losses associated with earthquakes and floods. It facilitates a broader understanding of the fundamental elements and main components of risk analysis. It demonstrates how risk analysis is applied to formulate disaster risk reduction policies. While the course does not provide technical details of advanced methodologies or specific methods, it helps participants to understand the processes involved in carrying out flood and earthquake risk analysis. It also introduces participants to the tools, models used to assess losses—direct and indirect—and methods to quantify the overall impact of earthquakes and floods. Participants learn the assumptions involved in risk estimations and as a result will be able to judge and appreciate the information presented in risk maps. Participants will also apply the theoretical concepts they have learned through carrying out a set of simple risk analysis exercises.

2.3 Course Outline and Structure

The course is structured around three modules: 1) Fundamentals of Risk Analysis, 2) Earthquake Risk Analysis, and 3) Flood Risk Analysis. Thematically, Module 1 gives the foundations of the course by reviewing the basic concepts and approaches in hazard, vulnerability and risk analysis. Basic features and characteristics introduced in Module 1 are applied in Module 2 and 3 to earthquake and flood risk analysis, respectively. Each module emphasizes the importance of risk analysis in the disaster risk assessment paradigm, which also includes risk perception and risk communication. While all three modules devote considerable time to clarify terminology, conceptual frameworks and various approaches used in risk analysis, the course is designed to be hands-on. It is expected that participants will acquire the necessary knowledge to carry out a simplified earthquake and flood risk analysis using basic tools by the end of the course.

Below is a short overview of the three modules of the Risk Analysis course. In terms of organizational structure, the risk analysis course is composed of two learning components: a "learning content" component and an "activities" component. Before the first week of the course, during Week 0, students are expected to become familiar with the course platform (Moodle), read the introductory materials and complete the pre-course activities. In the last 2 weeks of the course, students should work on the end of the course project, take a final exam and evaluate the course.

Learning Content:

- *Presentations:* Each module includes 3 presentations (15–20 slides each) and corresponding written and audio transcripts.
- *Case Studies:* Each module includes 2 case studies which are selected to illustrate the application or implementation of a particular approach covered in the presentations. The case studies are selected from peer-reviewed literature and written by acclaimed scientists and practitioners in the field of earthquake and flood risk analysis. The case studies, where applicable, include information on using risk analysis in policy formulation.
- *Readings:* Each module includes a minimum of three readings which are selected to provide more depth in understanding of some of the most important concepts reviewed in the presentations. Readings can be an implementation example or a review of concept. They are taken from the peer-reviewed literature and selected based on their relevance to the main terms reviewed in the presentations.
- *Individual Readings:* Supplementary readings for students interested in exploring concepts presented in the module in more depth provided in each module. As these readings are optional, neither the knowledge checks nor the final exam will cover them.

Activities:

- *Knowledge Checks:* These include questions related to presentations, case studies and readings of individual modules.

- *Discussion Forum:* During the course delivery, course instructors facilitate discussions on topics and issues covered in the course materials. The discussions are structured according to the timeline of the course and follow the stream of modules. The course manual includes guidance on discussion topics and provides questions linked to the learning contents. The questions help participants to understand the learning materials and also facilitate peer learning. Participants are required to proactively participate in the discussions and post minimum of two (2) substantive contributions each week.
- *Assignments:* The assignments and the End-of-Course Project serve as important instruments to reinforce the most important concepts of the course through a learning-by-doing approach. The assignments have a necessarily analytical focus and their completion is necessary to appreciate the quantitative methodologies and processes of risk analysis.
- *End-of-Course Project*: The End-of-Course Project, as an exercise, pulls together the content learned in the three modules and assignments. It requires participants to apply this knowledge by carrying out a multi-risk analysis for a fictional city. While the assignments come with manuals that take the students through a step-by-step process of solving the problem at hand, the end of the course project, which is based on the three assignments, provides all the background information required for solving the problem, but does not provide instructions on how to solve it.
- *Final Exam:* The final exam is a selected list of questions covered in the knowledge checks.

For a course that introduces a quantitative methodology the assignments and the End-of-Course Project are very important learning tools. This manual provides the assignment background information, the answers, and step-by-step solution templates. The completion of assignments is necessary in order to successfully carry out the End-of-Course Project. The End-of-Course Project requires participants to solve a problem based on what they have learned in the assignment, so that they are not just stepping through a manual, but must demonstrate that they have understood the concepts.

Course Completion:

Submitting the End-of-Course Project and all three module assignments, passing the Final Test and participating in module discussions are necessary to meet the course completion requirements and receive a certificate. Participants completing all requirements can receive 130 points. To pass the course, participants need to collect at least 90 points. In addition they need successfully pass the final test and also submit the End-of-Course Projects. Both the End-of-Course Project and the Final test are graded. The following table shows the points allocated to each component. 30

points are allocated to the End-of-Course Project and 25 points for passing the test. The remaining 75 points are allocated to successful completion of the assignments in each module (15 points per module) and participation in module discussions. To pass the course, a score of at least 70% is needed.

Please note that the Final Test can be taken only once, while the Knowledge Checks allow 3 trials.

Table 2.1 Course Activity Grading System

Activity	Point Allocation
Module 1 Assignment	15
Module 2 Assignment	15
Module 3 Assignment	15
End of Course Project	30
Final Test	25
Active participation in	
Module 1 discussion	10
Module 2 discussion	10
Module 3 discussion	10
Total Points	**130**

2.4 Timeline

The online course assumes that participants spend 10 to 15 hours each week with learning as well as the individual and group activities. Table 2.1 indicates the timeline of the course and the number of hours allocated for each of the activities in the risk analysis course. The course activities span through 6 weeks, week 0 is for pre-course activities such as getting familiar with course objectives, structure and tools and also carrying out the pre-course exercises, followed by 5 weeks of facilitated learning. During week 1 through week 3 participants review the three modules of the course, one module per week. During week 4 and 5 participants work on the end of the course project (ECP), a final test and a course evaluation. Instructors continue to provide assistance to participants to complete their assignments and also guide the discussions investigating topics not covered earlier. During week 6, instructors grade the End-of-Course Project, evaluate individual performances, and award certificates.

The Risk Analysis course runs for 5 weeks. By the end of every week, the facilitator should cover all aspects of the module in the discussion forum. Each participant should participate in the discussion with a minimum of two substantive discussion points and/or postings per week. Instructors need to prepare discussion summaries after every week and post it as a last item on the weekly discussion as a conclusion. It also indicates that the discussion topic is closed and participants need to move to the next discussion topic. The summary of discussion should be posted within a reasonable time limit, preferably by the time the new discussion topic is opened.

Table 2.2 Course Timeline and Time Allocation to Course Components

Timeline	Time Allocation					Total
Week 0 – Pre-course Activities	Pre-course Assignment (2h)	Course Introduction (1h)		Familiarization with course tools (2h)		5h
Week 1 – Module 1	Presentations (2h)	Case Studies (2h)	Readings (3h)	Quizzes, Assignments, Discussions (6h)	Individual Readings (2h)	15h
Week 2 – Module 2	Presentations (2h)	Case Studies (2h)	Readings (3h)	Quizzes, Assignments, Discussions (6h)	Individual Readings (2h)	15h
Week 3 – Module 3	Presentations (2h)	Case Studies (2h)	Readings (3h)	Quizzes, Assignments, Discussions (6h)	Individual Readings (2h)	15h
Week 4–5 – End-of-Course Tasks	End-of-Course Project (10h)	Final Exam (2h)	Course Evaluation (1h)	Discussions (2h)		15h
Week 6 – Closing Tasks for Instructors	Grade the End-of-Course Project, evaluate individual performances and award certificates					

Participants should submit assignments and the End-of-Course Project (ECP) according to a timeline determined by the facilitators. As the assignments are the foundations for the ECP, the submitted assignments should be evaluated within a week, and before the work on ECP starts. The ECP should be evaluated in reasonable time limit after the course.

2.5 Target Group

The course is useful for professionals from national and local agencies dealing with disaster risk management; for public officials and local authorities in charge of development planning and policy reform in the realm of disaster risk reduction; and for practitioners working in risk reduction, emergency and recovery planning. The course requires a higher education degree. Scientific or engineering background can be helpful to better understand the methodological aspects of earthquake and flood risk analysis, however, it is not necessary. Basic skills in mathematics and familiarity with use of spreadsheet programs are the prerequisites of the course. Completing the WB "Comprehensive Disaster Risk Management" and "Earthquake Risk Reduction" courses are suggested before taking the "Risk Analysis" course.

Table 2.3 Course Prerequisites and Requirements

Prerequisites	Requirements
Completion of "Comprehensive Disaster Risk Management Framework" Course	Timely submission of assignments, including End-of-Course Project
Basic Skills in Mathematics (Algebra)	Active participation in weekly discussions
Familiarity with using Spreadsheet Programs (e.g. Microsoft Excel)	Passing the Final Test
Ability to dedicate a minimum of 15 hours per week on course work	Filling out the evaluation form
Higher education degree	
Scientific or engineering background is a plus but not necessary	

While the course on risk analysis does not require specialized or professional skills to complete (beyond basic mathematical skills and familiarity of using spreadsheet programs), it is a time-intensive course. Each of the modules could easily be expanded into a three-module course of its own; instead they have been combined into one with hands-on exercises that reinforce the concepts and teach the process and methods of risk analysis by doing. Thus, the importance of the activity component should be emphasized by the facilitator. It is also important that participants are able to spend a minimum of 15 hours per week working on the material.

2.6 Course Expectations

A large majority of disaster risk-related activities are focusing on the assessment of risk (in many cases, on hazards only) and carried out by technical experts. As a result, often these efforts are not utilized by the community affected by disaster. There is a general perception that natural disasters are "technical" problems and have to be addressed by technical people. The intention of this course is to provide "non-technical" people with the basic understanding of risk analysis—general concepts, important elements and critical tools and approaches—using a language understandable to them.

Following the successful completion of the course, participant will be familiar with the concepts and up-to-date methods of earthquake and flood risk analysis. Because of the hands-on focus of the course through analytical assignments and an End-of-Course Project, participants also will be able to carry out a simplified risk analysis. Needless to say, risk analysis is a complex technical endeavour and carrying out a detailed risk analysis requires many years of academic and professional training. However, an understanding of the basic processes and steps in risk analysis (as they apply to earthquakes and floods in this case) by all members of the community involved in disaster risk reduction, is a necessary first step towards integrating scientific methods into the practice of disaster risk management.

III. Pre-Course Activities

3.1 Background Profile

Participants have already filled out a profile as part of signing up on the Moodle platform. This profile, however, does not include information on the skills and professional background of the participants. As part of the pre-course activities participants are asked to provide the following information for their personal profile. This additional information will allow facilitators to assess the skills and knowledge of participants and help in setting the stage for the discussions and interactions with participants. The questionnaire is as follows:

1. Your name:			
2. Please summarize your main responsibilities and key functions:			
3. Please summarize your background in terms of your training and experience in carrying out or using outcomes of risk assessments:			
4. Please evaluate your skills with respect to the following subjects:			
	Degree of Capability		
Subject	**High**	**Medium**	**Low**
Computer Skills			
Familiarity with Geographic Information Systems			
Familiarity with Earthquake Science/Field			
Familiarity with Flood Science/Field			
Engineering			

5. Please mark the sector you are involved in (you can mark more than one if applicable)

- ☐ Policy/Governance/Inter-institutional finance
- ☐ Research & Development/ Knowledge Management
- ☐ Human Resources
- ☐ IT/GIS
- ☐ Emergency Management
- ☐ Public Safety, Security and Defense
- ☐ Land-use Management
- ☐ Building Safety
- ☐ Environmental and Natural Resource Management
- ☐ Communication and Awareness Raising
- ☐ Training and Capacity Building
- ☐ Other (Please Specify):

At the beginning of the first week facilitators can compile the information from the “Personal Profile” of participants and share the results through the file sharing. Learning this information about their peers may help encourage the discussions and the peer learning process.

3.2 Risk Profile Exercise

As part of pre-course activities participants are asked to complete a simple "Risk Profile" exercise. The exercise prepares participants for the topic covered in Module 1. Facilitators can reflect on these results in the initial questions of the discussion forum. The Risk Profile exercise includes three blocks.

Participants are asked to do some preliminary research and fill out the survey document with data regarding the hazard, vulnerability and risk profiles for a district or city or region of their choice. The results of this survey should be used in the course discussions. The text of the profile exercise follows below.

Part 1: Hazard Identification			
What is the name of the district, city or region you have selected for this exercise?			
Which floods and/or earthquakes have caused damage in the selected district? Describe impact in terms of lives lost, people displaced, cost of physical properties lost, etc. Identify where you would find supporting documentation.			
Disaster Type	*Date of Occurrence*	*Description of the Impacts*	*Reference*
Earthquake			
Flood			
Describe the hazard in terms of severity if it does occur, frequency with which it could occur, and geographic area that could be affected.			
Hazard Type	*Severity (e.g. Magnitude of event)*	*Frequency (e.g. Return Period)*	*Geographic Area (Area in square kilometers affected by the event)*
Earthquake			
Flood			
Part 2: Vulnerability			
Briefly describe the population's vulnerability to flood and earthquake hazards in the selected district. (Vulnerability describes how people, buildings, and infrastructure are susceptible to damage created by the type of hazard).			
Hazard Type	*Physical Vulnerability*	*Social Vulnerability*	*Environmental Vulnerability*
Earthquake			
Flood			

Part 3: Risk Reduction
Briefly describe three measures that could be undertaken that could reduce the vulnerability for this city, district, or region with respect to the hazard in question.
Suggested Mitigation and Risk Reduction Measures
1.
2.
3.

Part 1: Hazard Identification

The Risk Profile exercise contains three parts. Please do some preliminary research and fill out this document with data regarding the hazard, vulnerability and risk profiles for a district or city or region of your choice. The results of this survey will be used in the course discussions.

What is the name of the district, city or region you have selected for this exercise?

Which floods and/or earthquakes have caused damage in the selected district? Describe impact in terms of lives lost, people displaced, cost of physical properties lost, etc. Identify where you would find supporting documentation.

Disaster Type	*Date of Occurrence*	*Description of the Impacts*	*Reference*
Earthquake			
Flood			

Describe the hazard in terms of severity if it does occur, frequency with which it could occur, and geographic area that could be affected.

Hazard Type	*Severity (e.g. Magnitude of event)*	*Frequency (e.g. Return Period)*	*Geographic Area (Area in square kilometers affected by the event)*
Earthquake			
Flood			

Part 2: Vulnerability

Briefly describe the population's vulnerability to flood and earthquake hazards in the selected district. (Vulnerability describes how people, buildings, and infrastructure are susceptible to damage created by the type of hazard)

Hazard Type	*Physical Vulnerability*	*Social Vulnerability*	*Environmental Vulnerability*
Earthquake			
Flood			

Part 3: Risk Reduction

Briefly describe three measures that could be undertaken that could reduce the vulnerability for this city, district, or region with respect to the hazard in question.

Suggested Mitigation and Risk Reduction Measures

IV. Module 1: Fundamentals of Risk Analysis

4.1 Module Description

The risk analysis terminology, concepts, approaches and methods are very diverse, as they come from a wide range of disciplines and application areas. The first session of this module introduces the concepts and objectives of disaster risk analysis and its role in disaster risk assessment. The latter includes risk perception and risk communication. In the first session, we explain the direct and indirect impacts of disasters, summarize the main components and applications of risk analysis, and provide a generalized overview of the risk analysis process. The second session reviews the main elements of risk analysis including hazard and vulnerability analysis. The role of vulnerability analysis receives special attention as usually it is overlooked during risk analysis. Vulnerability analysis is important because it is an area in which all stakeholders can contribute to the risk analysis process. This session concludes with a detailed review of the risk analysis process reflecting the inter-relationships between the various elements and sub-elements of risk. The final session of the module returns to the conceptual definition of risk using a more rigorous notion and concept of probability to frame risk. This allows the introduction of some important approaches in risk analysis, including probabilistic risk analysis, deterministic (scenario) risk analysis, loss and damage estimation, risk indexing and risk mapping, multi-risk analysis, cost-benefit analysis, and participatory risk analysis. By the end of the first module, the participant should be equipped with an understanding of the fundamentals of risk analysis that will be reinforced when they are applied in the specific cases of earthquake and flood risk analysis in modules 2 and 3.

4.2 Learning Objective

The introductory module reviews basic concepts and terminologies in risk analysis.

Aims of this module are to become familiar with:

- Terminology, definitions and key concepts of disaster risk
- The role of risk analysis in the greater paradigm of disaster risk assessment
- Ways risk analysis can help disaster managers and decision makers
- Basic elements and processes in risk, hazard and vulnerability analysis
- Concepts of exposure, susceptibility, capacity and resilience
- Notions of acceptable risk, return period, and exceedance probability
- Differences between a probabilistic and deterministic (scenario) risk analysis
- Sources of uncertainty in risk analysis

At the end of the module, you will understand:

- What are the different frameworks and concepts of risk,
- What are the different direct and indirect impacts of disasters and how they are assessed
- How hazard and vulnerability are combined to produce risk
- How to use exceedance probability curves for determining a risk profile
- Criteria for applying the methods and tools in carrying out risk analysis including multi-risk analysis, loss and damage estimation, cost-benefit analysis and participatory risk analysis

4.3 Main Terms

Session 1:
Risk, Hazard, Vulnerability, Coping Capacity, Risk Perception, Acceptable Risk, Loss, Damage, Disaster Impact (Direct, Indirect, Tangible, Intangible), Risk Analysis, Risk Management, Risk Communication

Session 2:
Hazard Analysis, Intensity, Severity, Magnitude, Frequency, Duration, Multi-hazard Analysis, Vulnerability, Exposure, Fragility, Susceptibility, Coping Capacity, Resilience, Adaptation, Intervention, Fragility Curves, Sectors of Vulnerability, Components of Vulnerability, Scales of Analysis in Vulnerability, Indicators, Social Vulnerability, Physical Vulnerability, Exposed Assets

Session 3:
Probability, Likelihood, Uncertainty, Exceedance Probability, Interval of Recurrence (Return Period), Average Annual Loss, Probabilistic Risk Analysis, Deterministic Risk Analysis, Scenario Analysis, Loss Estimation, Risk Matrix Analysis, Multiple Risk Mapping, Cost-Benefit Analysis, Participatory Risk Analysis

4.4 Key Points to Emphasize

During the first week of the course the following key messages should be emphasized through facilitated discussions. To support the work of the facilitators we also explain the relevance of the learning materials to the following main messages.

Mainstreaming risk analysis into Disaster Risk Management Processes: Many consider risk analysis as a separate, independent, and well-defined discipline of its own. However, the theory and methodology of risk analysis is part of the broader context of disaster risk assessment, which also includes risk perception and risk communication. It is a major challenge to incorporate the results of risk analysis into the various policy dialogues and operations of local authorities, such as land use planning. The objective in this module is to highlight the importance of risk analysis as not only a "technical" exercise, but also as an essential step in disaster risk reduction. The discussion of the disaster risk assessment paradigm in Session 1 is a key topic, which sets up the stage for the exchanges on the importance of risk analysis, and the process and applications that provide the tools for decision making and engaging stakeholders in the risk management process.

Better understanding of the elements of risk analysis: Many still equate risk analysis with hazard analysis. While the session starts with a basic overview of the steps and components of the hazard analysis process, more time is devoted to vulnerability analysis, as this is an area where all stakeholders can provide significant input into the process of risk analysis. Additionally, this is an element common to the earthquake and flood risk analysis modules, whereas hazard is treated distinctly and in more detail in those modules. Frequently risk analysis is based on analyzing vulnerability only with respect to physical systems (e.g. buildings, lifelines, critical infrastructure). Here, we need to emphasize that vulnerability is not restricted to the physical systems alone and that there are many dimensions and components of vulnerability that also have to be considered while analyzing risk. Session 2 of the module takes participants through the classification of vulnerability and develops the understanding of the root causes, components and scales of vulnerability, its dependency on hazard and how it can be understood as an interaction between exposure, fragility/susceptibility, and coping capacity according to the latest thinking in vulnerability research.

Many tools for analyzing risk: The choice of instrument and approach in analyzing risk depends on the objective of the analysis and available information about hazard and vulnerability. There is no ideal approach in analyzing risk and many tools in this area are available. Session 3 describes different tools from the most rigorous quantitative approaches, such as a probabilistic risk analysis, to more qualitative and subjective approaches, such as participatory risk analysis.

Participants will learn not only about the variety of available methods and approaches employed in risk analysis, but also will be able to discern what approach might work best for particular problems and how to consult with the appropriate technical experts.

4.5 Learning material and activities

4.5.1 Presentations

Session 1: Basic Concepts of Risk Analysis

Objective
In this opening session of the risk analysis course we introduce the general concepts and terminologies of risk and the basic elements and objectives of risk analysis. The session also explains the process of risk analysis as consisting of a scientifically based process of evaluating hazards and the vulnerability to those hazards, and then estimating the resulting impact. Risk is an inherent part of daily life and there are many different concepts of risk. In this session we focus on the processes and methods related to quantifying disaster risk. This session provides the ontology of risk analysis, how risk analysis fits into the larger paradigm of disaster risk assessment and how risk analysis can be used by decision makers and stakeholders. The objective is to emphasize that risk analysis is more than just a mere exercise for the experts to understand the impact of potential hazards. It is above all a process that provides the tools for decision-making and engaging stakeholders in the risk management process. It provides critical information, empowers individuals and communities, and allows them to take ownership of the information. This session is followed by a more in-depth discussion of the elements of risk (hazard and vulnerability) in the second session. The last session of the module reviews the various methods and tools in risk analysis.

Key Points:

- Disaster risk terminology, definitions and key concepts
- The notions of probability, acceptable risk and risk perception
- The basic elements and processes in risk analysis
- Understanding risk as a dynamic process of hazard and vulnerability
- The difference between direct and indirect impacts
- Risk analysis as a basic component of the disaster risk assessment paradigm
- How risk analysis can help disaster managers and decision makers
- The main applications of risk analysis

Session 2: Elements of Risk Analysis: Hazard and Vulnerability

Objective

In this session we review the basic elements of the risk analysis process: hazard and vulnerability. The concepts learned in Session 1 are further explored and the concepts and components of hazard and vulnerability are detailed. As the earthquake and flood risk analysis modules will cover the hazard analysis with respect to these two hazards in detail, this session focuses on the steps and components of the hazard analysis process independent of the type of hazard. Special attention is given to the vulnerability aspect of risk as vulnerability is usually overlooked in the risk analysis process. It is emphasized that vulnerability is not restricted to the physical systems alone and there are many dimensions and components of vulnerability that also have to be considered for a holistic analysis of risk. The session intends to provide participants with a forward-looking perspective of risk analysis.

Key Points:

- The basic elements and processes of hazard analysis
- The basic dimensions and elements in vulnerability analysis
- The concepts of multi-hazard, exposure, susceptibility and resilience
- The spatial, dimensional and temporal components of hazard analysis
- The root causes and dynamic pressures associated with progression of vulnerability
- Scales, sectors and components of vulnerability analysis
- The use of indicators in vulnerability analysis
- Coupling and interaction between hazard and vulnerability
- The dependency of vulnerability on hazard

Session 3: Instruments and Approaches of Risk Analysis

Objective

There are many methods and instruments available in risk analysis. Some are very detailed and precise, while others offer greater depth of focus, more participation and better understanding of the interconnections among the different components. It is not within the scope of this module to cover all instruments of risk analysis. However, the objective of Session 3 is to provide participants with a sample of several different methods covering both ends of the spectrum. Accordingly, this session covers probabilistic risk analysis, which is the most rigorous method available in risk analysis and participatory risk analysis, a qualitative methodology that brings in subjective perceptions into the risk analysis process. This session concludes the module on the fundamental concepts of risk analysis. However, the instruments and approaches introduced in this session, such as probabilistic or deterministic risk analysis, are reinforced when the participants see their implementation in the case of specific hazards in modules two and three.

Key Points

- The probabilistic concept of risk
- The concepts of return period, loss-frequency curve, average annual loss
- The sources of uncertainty in risk analysis
- The difference between probabilistic and deterministic risk analysis
- Possible outcomes of a scenario analysis
- The depiction and ranking of risk through risk matrix and risk indexing
- Components of a loss estimation model
- The methodology of a cost-benefit analysis
- Uses of a participatory risk analysis

4.5.2 Case Studies

Overview

The learning materials include two case studies to reinforce the key points of Module 1. The first case study is from Istanbul, a city prone to earthquakes. It illustrates the use of indicator systems in risk assessment as a management and communication tool. The second case study from Bangladesh is an example of a participatory process in using risk analysis results for flood mitigation. Thus, both case studies provide a broad and general overview of risk analysis that focuses on the implementation of disaster risk management based on risk analysis results. Both case studies also look beyond physical vulnerability and suggest methods for integrating social and institutional vulnerability into the risk analysis process. Each of the case studies illustrate one of the hazards covered in the Risk Analysis course, and provide background reading on some of the particular issues that are dealt with in flood and earthquake risk analysis modules.

The importance of mainstreaming risk analysis into the disaster risk management process is one of the key messages of Module 1 and emphasized in Session 1. The first case study, through an implementation example, shows how risk analysis results can be integrated into the DRM operations of local governments using the case of the Istanbul Metropolitan Municipality. Another key message of Module 1 (in Session 2) is that vulnerability has many more dimensions than physical vulnerability. Both case studies underline this subject. The Istanbul case study presents an indicator approach, adapted from the indicator framework developed by Inter-American Development Bank (IADB), illustrating that risk can be assessed more holistically by integrating socio-economic vulnerability into the risk analysis process. The Bangladesh case study uses participatory tools such as social mapping, problem identification/prioritization, mobility charting and wealth ranking to integrate social disruptions into the risk assessment process.

Session 3 of Module 1 introduces different approaches in risk analysis. Among them are deterministic (scenario analysis) and risk indexing and participatory risk analysis. The case of Istanbul uses the results of a scenario analysis for direct physical impacts and combines them with social fragility and resilience factors using a risk indexing approach. The Bangladesh case study also implicitly uses results of a deterministic risk analysis however the focus is on various participatory learning tools that can be used to integrate these results for developing action plans with the community.

Understanding both case studies is necessary to accurately complete the End-of-Course Project. The Bangladesh case study provides background on how action plans can be developed and risk analysis results integrated into preparedness, mitigation and risk management (see part 4 of the case study). The Istanbul case study is also very important in this respect. Part 3 of the End-of-Course Project requires establishing the socio-economic impacts for a fictional city and participants are asked to use the methodology (with guidance) shown in the case study. To reinforce learning, Session 2 of Module 2 references the indicator framework adapted in the Istanbul case study and presents it from a different perspective, as well as one of the readings "Visions of Risk".

Case 1: Megacity Indicator Systems for Disaster Management

This case study describes how indicators can be used in risk assessment studies as a management and communication tool providing a framework to prioritize and decide on where to invest resources. It presents the development of megacity-relevant indicators and the application of the methodology and indicators as an interactive tool. The approach can be applied to creating similar frameworks for other cities and institutions to measure their own DRM state-of-practice and evaluate progress in urban DRR.

Key Points:

- Indicators are useful for mainstreaming risk analysis into disaster risk management
- A holistic view of risk requires the integration of other dimensions of vulnerability besides physical vulnerability
- Social vulnerability can be viewed in terms of resilience and fragility in society

- Scenarios are very useful for developing indicators and communicating risk
- The mainstreaming of risk analysis into the disaster risk management process requires ownership of indicators by involved stakeholders through a participatory process

Case 2: Hazard Mapping and Vulnerability Assessment for Flood Mitigation in Bangladesh
Hazard mapping and vulnerability assessment process is introduced for an urban flood risk analysis in the Gaibandha municipality of Bangladesh, where floods are recurring events. The community risk assessment and action planning project was carried out under the Bangladesh Urban Disaster Mitigation Project (BUDMP) from 2000 to 2005 and implemented by CARE Bangladesh under their Disaster Management Project (DMP), with technical and financial support from ADPC's Asian Urban Disaster Mitigation Program (AUDMP). Three areas of physical damage (buildings, critical infrastructure and lifelines), social disruptions (vulnerable groups, livelihoods and local institutions) and economic losses (direct and indirect loss) were considered in the analysis. For the vulnerability assessment, five major tools of the participatory approach were used and described in the study. The risk analysis findings were then integrated in the planning, preparedness and mitigation processes.

Key Points

- Active participation of the community and community ownership in using the results of risk analysis in planning, preparedness and mitigation can be achieved using participatory tools such as mainstreaming risk analysis into the risk management process
- Vulnerability assessment of institutional, cultural and socio-economic processes can be done using various participatory tools such as social mapping, problem identification/prioritization, mobility charting and wealth ranking

4.5.3 Readings

Overview
Four readings reinforce the learning content presented in Module 1. While each reading deals with different facets of the topics introduced in Module 1, they also complement each other as they overlap along several key themes of Module 1. Reading 1 and Reading 2 are on risk analysis tools and instruments addressed in Session 3. Both of these readings show how these tools can be used to mainstream the results of risk analysis into the disaster management process. Reading 3

provides a general overview of risk analysis and focuses on different dimensions of vulnerability, addressed in Session 2. The supplementary reading, Reading 4, complements Readings 1 and 2 by focusing on the integration of risk analysis into disaster management planning, from the perspective of megacities.

Reading 1 provides further depth to Case Study 1 by presenting more international indicator approaches in addition to the one which was adapted in Case Study 1. This reading also introduces different approaches in using indicators to transfer in a transparent way the results of risk analysis to disaster risk management and preparedness planning.

Reading 2 is based on a well-known international multi-risk analysis and risk indexing study conducted by the World Bank, known as the Hot-Spot Study. The hot-spot approach in developing a global risk map is one of the indicator approaches also reviewed in Reading 1: Visions of Risk. However, this reading is a country-level implementation which brings together landslide, draught, flood and earthquake risk in Sri Lanka. The reading reinforces lessons learned about temporal, spatial and dimensional aspects of hazard analysis and focuses mostly on a multi-hazard approach introduced in Session 2 while vulnerability is also addressed. The reading provides a good demonstration of a risk mapping introduced in Session 3.

Reading 3 is a broad study that covers all the elements of risk analysis, from hazard identification/analysis to frameworks for looking at vulnerability of society, institutions, built and critical infrastructure. As such it is a very good complementary reading to Session 2, which deals with these issues. However, the focus on a community-based approach and the notion of integrating the results into policy making and disaster management makes this reading also relevant to the themes addressed in Session 1 and Session 3.

Reading 4 is offered as an optional reading as it introduces two important issues which are related to the fundamentals of risk analysis module, but not part of its core. Some case studies in Module 1 and Module 2 deal with megacities (i.e. Istanbul and Delhi), and the issue of urban flooding is also distinctly addressed in Module 3. The reading addresses the particular features of risk analysis in urban context and the risk trends in urban agglomerates. As such the reading relates to the scale of vulnerability analysis addressed in Session 2. The reading also provides a very comprehensive framework for integrating risk analysis results into disaster risk management planning known as the Disaster Risk Management Master Plan (DRMMP) developed by the Earthquake and Megacities Initiative. This approach has been implemented in Istanbul, Metro Manila, Kathmandu, and Amman and is currently being implemented in Mumbai.

Reading 5 is another optional reading introducing a disaster scenario for an earthquake in the San Francisco Bay Area. This reading links to Session 3 where scenario analysis and its applications were presented. It also provides a very good background on how action plans can be derived from disaster scenarios which is useful in completing Part 4 of the ECP.

Reading 1: A Review of International Indicators of Disaster Risk and its Management
This reading is an excerpt of Vision of Risk, a report prepared by ISDR. It reviews the performance and future applicability of disaster risk indexing by drawing on three international indexing initiatives. These initiatives provide the first comprehensive global and regional assessments of disaster risk. They point towards the ways in which indexing can contribute to enhanced transparency and effectiveness in development planning and disaster management. The three indexing projects under review are the Disaster Risk Indexing project (DRI) of the UNDP in partnership with UNEP-GRID; the hot-spot indexing project implemented by Columbia University and the World Bank, under the umbrella of the ProVention Consortium; and the Americas program of IDEA in partnership with the Inter-American Development Bank (IDB).

Key Points

- Lessons learned for global and regional assessments of risk reviewed from three international indexing initiatives.
- Socio-economic vulnerability indices can be calculated using mortality data.
- Indicators can be used to aid decision-makers in assessing disaster risk and risk management performance.
- Indicators can be based on an intrinsic understanding of vulnerability (IDB-IDEA framework), or can be measured in relation to specified individual or multiple hazard types (Hotspots and DRI framework) using statistical methodologies.
- Links to Session 2 with respect to using indicators in measuring vulnerability and the different dimensions of vulnerability.

Reading 2: Natural Disaster Risks in Sri Lanka – Mapping Hazards and Risk Hotpots
This reading is based on the case study from the World Bank Hazard Management Unit's "Natural Disaster Hotspot Case Studies". It presents the multiple disaster risk in the island of Sri Lanka and the approach taken in mapping the hazards and risk hot-spots. Through this case study we illustrate: (1) the methodologies needed for sub-national assessments of hazard, vulnerability, and hot-spots; (2) the interplay among hazards and vulnerability; and (3) how to assess the

consequences of multiple hazards and vulnerability factors. The elements considered in this study are simplified into categories of people, infrastructure, and economic activities.

Key Points

- Vulnerability analysis is much less precise than hazard analysis, however specific elements of people, economic activity and infrastructure vulnerability can be captured as proxies.
- Different hazards can be combined together in a multi-hazard indexing approach using various schemes for weighting the hazards.
- Multi-risk mapping provides a better approach for comparison of potential disaster impacts than multi-hazard mapping.
- Links to Session 2 on Multi-hazard mapping and to Session 3 on the Multi-risk Indexing approach to risk analysis.

Reading 3: Community Based Vulnerability Assessment (CVAT)
A risk and vulnerability assessment helps to identify people, property, and resources that are at risk from hazardous incidents or natural hazards. This information is important to help determine and prioritize the precautionary measures that can make a community more disaster-resilient. This reading is based on the Coastal Storms Program of the National Oceanic and Atmospheric Administration (NOAA) and demonstrates effective tools and methods for making vulnerability assessments. These tools and methods are easily adaptable to other communities and areas. In this reading we learn how to use the Community Vulnerability Assessment Tool (CVAT), an easy-to-use, adaptable, multi-step process to perform Hazard Identification and Hazard Analysis, Analysis of Critical Facilities, and Societal Vulnerability Analysis.

Key Points

- The difference between risk, hazard and vulnerability are important distinctions
- A relative priority matrix is a useful guiding tool for selecting the hazards to include in an assessment
- Multiple dimensions of vulnerability can be assessed and integrated using simple methods by community
- Link to Session 1 through a simple narrative of the distinction between hazard, vulnerability and risk
- Link to Session 2 through elaboration of methodology for measuring both hazard and vulnerability

- Link to Session 3 through presentation of a community based risk analysis approaches which uses risk matrix, risk indexing and participatory risk analysis instruments

Reading 4: Megacities and Megarisks

Through the examples of Mexico City and Mumbai this reading discusses the characteristics of megacity vulnerabilities and risk potential. It reviews the obstacles that keep megacities from developing an efficient approach towards disaster mitigation and presents a strategy that addresses these problems. The Disaster Risk Management Master Plan (DRMMP) as a key element for this strategy is presented based on the experience of the Earthquake and Megacities Initiative. The role of risk analysis in the DRMMP process is explained.

Key Points

- Special considerations with respect to vulnerability analysis must be taken into account for megacity-scale analysis
- Various factors contribute to the increase of vulnerability in megacities, such as high population exposure, complex and aging infrastructure, dependence of the population on services, and the lack of robustness of lifelines and critical infrastructure
- A gap exists between how the outcomes of a risk analysis can be used in disaster risk management planning—an approach that might overcome this is discussed
- Link to Session 1 in integrating outcomes of risk analysis for preparedness, disaster mitigation, response planning and recovery planning
- Links to Session 2 in presentation of root causes, dynamic pressures and unsafe conditions leading to vulnerability in the case of megacities, as well as discussion of scales, sectors and components of vulnerability

Reading 5: Risk of a Major Earthquake in the Bay Area, and Likely Disaster Scenarios

Since the 1906 San Francisco earthquake, the San Francisco Bay Area has grown tremendously and the population has increased ten-fold. Part of the population has moved into the San Francisco Bay margins, some on reclaimed land, areas that are more prone to earthquakes. The area is also increasingly dependent on a complex infrastructure of utilities, roadways, and communications. What would happen if there was a repeat of the 1906 earthquake today? To answer this question, teams of experts were commissioned to conduct a comprehensive simulation and analysis of potential losses due to a repeat of the 1906 earthquake. The reading is the summary of findings from a scenario analysis for a major earthquake on the Hayward fault.

Key Points

- Disaster scenarios are powerful planning and preparedness tools and can be used to communicate the results of a risk analysis in a way that can be easily understood
- This optional reading links to Session 3 where scenario analysis and its applications are presented.
- This reading also provides a very good background on how action plans can be derived from disaster scenarios. This aspect will be useful in completing Part 4 of the ECP.

4.5.4 Activities

Knowledge Check
The knowledge check questions are meant to deepen the key points from Module 1, Fundamentals of Risk Analysis. For each session, nine questions are formulated. The knowledge check also includes questions on lessons presented in the readings and case studies. The questions cover the theoretical foundations, methods, and approaches in risk analysis, as well as specific aspects from the selected case studies and readings.

Questions Related to Session 1: Basic Concepts of Risk Analysis

1. A disaster for a defined region A is preceded by which of the following predispositions?
    a. ○ The possibility of a triggering event can take place in region A.
    b. ○ Pre-existing vulnerability of people, infrastructure, organizations, and their inability to cope with the event in region A using their own resources.
    c. ○ The occurrence of a large disaster in the recent past.
    d. ☑ Both a. and b.

2. What is perception of risk influenced by?
    a. ○ How much in control we feel of a perceived risk or how much knowledge we have about it.
    b. ○ Cultural values, societal opinion and socio-economic background.
    c. ○ Past experience with the perceived risk.
    d. ☑ All of the above

3. Which of the following questions does risk analysis try to answer?
   a. ○ Probability of a hazard event occurring?
   b. ○ Consequences or impacts of the hazard event?
   c. ⊘ Both a. and b.
   d. ○ None of the above

4. What is an "Acceptable Risk"?
   a. ○ Risk associated with an event with low probability of occurrences.
   b. ○ Risk with insignificant consequences.
   c. ○ Risk with benefits that compensate for potential negative consequences.
   d. ⊘ All of the above

5. Which of the following statements, most accurately represents the expression of risk in the context of disasters?
   a. ○ Risk is derived as a multiplication between hazard and vulnerability.
   b. ○ Risk is derived as the addition between hazard and vulnerability.
   c. ⊘ Risk is derived as some function or interaction between hazard and vulnerability.
   d. ○ Risk is derived as the integral of hazard and vulnerability.

6. An element/asset is considered *vulnerable*, if it is:
   a. ○ Exposed to the hazard.
   b. ○ Fragile or susceptible to the hazard event
   c. ○ Does not have the capabilities or resources to withstand the negative impacts of the hazard event.
   d. ⊘ All of the above

7. Which of the following are not examples of tangible direct disaster impacts?
   a. ○ Cost of repair or replacing assets.
   b. ⊘ Disruption to businesses.
   c. ○ Loss of ecosystem amenity values
   d. ○ Loss of life and injuries.

8. What are the key components of the disaster risk assessment paradigm?
   a. ⊘ Risk Analysis, Risk Management and Risk Communication
   b. ○ Risk Analysis, Risk Awareness and Risk Perception
   c. ○ Risk Analysis, Risk Reduction and Risk Management
   d. ○ Risk Analysis, Risk Communication and Risk Reduction

9. Which of the following statements is not true? (Maybe more than one answer)
   a. ⊘ Risk analysis can be used to estimate potential impact on critical facilities, infrastructure and lifelines.
   b. ○ Risk analysis can be used to prepare and plan for a disaster and optimize the allocation of resources.
   c. ⊘ Risk analysis is just a tool for experts.
   d. ○ Risk analysis considers impacts to physical infrastructure only.

Questions Related to Session 2: Elements of Risk Analysis: Hazard and Vulnerability

1. Which of the following statements is a true description of the above map?
   a. ○ This map shows how big the earthquake risk is in the United States.
   b. ⊘ This map shows the intensity of earthquake hazard in the United States.
   c. ○ This map shows the distribution of earthquake impacts in the United States.
   d. ○ This map shows the level of earthquake damage in the United States.

2. What is the goal of a hazard analysis?
   a. ⊘ To determine where and over which extent a hazard will occur.
   b. ○ To determine how big a hazard will be in different locations over an affected area.
   c. ⊘ To determine how often will a certain event of a particular size occur.
   d. ○ To determine the impacts of an event, given that it occurs.

3. Why does a multi-hazard analysis have a high significance for planning effective countermeasures?
   a. ⊘ Analysis of multiple hazards can reveal the extent of impacted area from different natural hazards.
   b. ⊘ Analysis of only single hazards in an area might lead to a misjudgment of the potential risk from other participative hazards in the area.
   c. ○ A multiple hazards analysis addresses all the dimensions of vulnerability in a region.
   d. ⊘ A multiple hazards analysis provides a comparison of the intensity and force different hazards can occur in an area.
4. What are the three components of vulnerability?
   a. ⊘ Exposure
   b. ⊘ Susceptibility/fragility
   c. ○ Adaptation
   d. ⊘ Coping capacities/resilience

5. Which of the following can be considered as *root causes* of vulnerability according to the Pressure and Release Model?
   a. ○ Rapid population change
   b. ○ Unprotected buildings and infrastructure
   c. ○ Volcanic eruptions
   d. ⊘ Limited access to power and resources

6. According to the MOVE framework, which are the internal and external dimensions of vulnerability?
   a. ○ Exposure is the internal dimension of vulnerability; susceptibility and lack of resilience are the external dimensions of vulnerability.
   b. ⊘ Exposure is the external dimension of vulnerability; susceptibility and lack of resilience are the internal dimensions of vulnerability.
   c. ○ Exposure, susceptibility and resilience are internal dimensions of vulnerability; adaptation is the external dimension of vulnerability.
   d. ○ Physical, ecological, social, economic susceptibility are external dimensions of vulnerability; cultural and institutional susceptibility are internal dimensions of vulnerability.

7. Which of the following infrastructural qualities *does not* represent the concept of resilience?
   a. ⊘ Refinement in the system and its degree of technical complexity.
   b. ○ Robustness in the system to withstand external demands.
   c. ○ Resourcefulness in the system to mobilize needed resources and services in emergencies.
   d. ○ Rapidity in the system to overcome disruptions and restore stability quickly.

8. What information can be obtained from a "Fragility Curve"?
   a. ○ The degree of hazard intensity.
   b. ○ The geographic region affected by the hazard.
   c. ⊘ The degree of the damage as a function of the level of hazard experiences.
   d. ○ All of the above

9. Which of the following statements can be made about measuring vulnerability? (Maybe more than one answer)
   a. ○ Measuring vulnerability is a rational process and there are clear methodological frameworks for integrating vulnerability into risk analysis.
   b. ⊘ No clear guidelines are available on how to measure vulnerability, however, in practice indicators have been used broadly in economic, social and environmental analysis of vulnerability.

c. ○ Measuring vulnerability is not possible, as vulnerability has multiple dimensions and many cannot be observed.
d. ⊘ A common nomenclature for measuring vulnerability is necessary which refers to vulnerability in terms of the scale, the target group, sectors of interest, components of interest, scale of analysis and consequences which result as the outcome of vulnerability allows.

Questions Related to Session 3: Instruments and Approaches in Risk Analysis

1. What is the difference between deterministic and probabilistic risk analysis?
   a. ⊘ In the deterministic risk analysis a postulated event is assumed while in probabilistic risk analysis the probability of the event occurring is calculated.
   b. ○ In both probabilistic and deterministic risk analysis a postulated event is assumed, however in the deterministic risk analysis uncertainty associated with the risk is not calculated.
   c. ○ Probabilistic risk analysis is by experts and deterministic risk analysis is used only for advocacy and training purposes.
   d. ○ Probabilistic risk analysis focuses on the hazard, while deterministic risk analysis focuses on the vulnerability component.

2. Which of the following are sources of uncertainty in a risk analysis?
   a. ○ In the acquisition, transformation and representation of exposure databases.
   b. ○ In the spatial, dimensional and temporal estimation of hazard.
   c. ○ In the costs and benefits of various intervention and risk reduction measures.
   d. ⊘ All of the above

3. Which of the following statements are <u>not</u> true about a flood having a 100-year return period?
   a. ○ The probability that the 100-year flood will be exceeded in any one year is 1%
   b. ○ The probability that the 100-year flood will be exceeded in 50 years is 50%
   c. ○ It is possible to have two “100-year floods” in less than two years
   d. ⊘ A 100-year flood occurs regularly once every hundred years.

4. What is the annual probability of exceedance (EP) and the probability of exceedance in 50 years for an earthquake with a return period of 1000 years?
   a. ○ Annual probability of exceedance is 0.001%; probability of exceedance in 50 years is 0.1%.
   b. ○ Annual probability of exceedance is 0.1%; probability of occurrence in 50 years is 10%.
   c. ⊘ Annual probability of exceedance is 0.1%; probability of exceedance in 50 years is 5%
   d. ○ Annual probability of exceedance is 0.001%; probability of exceedance in 50 years is 0.05%.

5. What is the 50-year loss in the exceedance probability (loss frequency curve) shown here?
   a. ○ 20 million USD
   b. ⊘ 65 million USD
   c. ○ 275 million USD
   d. ○ None of the above

6. What does the area under an exceedance probability curve represent?
   a. ⊘ The average annual amount of losses that can be expected to occur.
   b. ○ The total amount of losses that can be expected to occur.
   c. ○ The average amount of losses that can be expected to occur
   d. ○ None of the above

7. What are the uses of a cost benefit analysis?
   a. ○ To evaluate the feasibility of various protective measures.
   b. ○ Enable consensus on strategies and measures to reduce disaster risks.
   c. ○ Provide an comparison of upfront investment costs against benefits of mitigation
   d. ⊘ All of the above

8. When might a participative risk analysis be used?
   a. ○ For public participation of risk mitigation.
   b. ○ For building capacity and promoting self-help.
   c. ○ For integrating subjective perceptions and sensitivities into the risk analysis process
   d. ⊘ All of the above

9. Which of the following statements is <u>not</u> true about the following approaches used risk analysis?
   a. ○ Scenario analysis is very useful tool in emergency management and disaster planning.
   b. ○ Average Annual Loss is a rational way for mapping multiple risks from different hazards.
   c. ⊘ Probabilistic risk analysis is most rigorous risk analysis approach and is the preferred method for all applications.
   d. ○ Risk indexing is a useful tool as it is relatively easy to do and is a good tool for engaging stakeholders in a discussion about risk.

Questions Related to Case Study 1: Megacity Indicators System for Disaster Management

1. What is an impact factor used in the Urban Seismic Risk Index?
   a. ⊘ A factor consisting of a set of indicators describing inherent factors of fragility and resilience in a society.

b. ○ A factor describing the impacts of an earthquake in an urban area.
c. ○ A factor combining direct and indirect damages from an earthquake.
d. ○ A factor describing the economic impact of earthquakes.

2. Which are the two quantitative indices used in the Megacity Indicator System?
   a. ○ Urban Seismic Risk Index and Disaster Risk Management Index
   b. ⊘ Urban Seismic Risk Index and Coping Capacity Index
   c. ○ Disaster Risk Management Index and Coping Capacity Index
   d. ○ All of the above

3. Who is the target audience of the MIS?
   a. ○ Fire Brigade
   b. ○ Government of Turkey
   c. ⊘ Istanbul Metropolitan Municipality
   d. ○ Universities

Questions Related to Case Study 2: Bangladesh Flood Mitigation

1. Which are the "Participatory Learning Tools" used in the Bangladesh Flood Mitigation case study? (More than one answer)
   a. ⊘ Transect walk
   b. ⊘ Social Mapping
   c. ⊘ Mobility Chart
   d. ⊘ Wealth Ranking
   e. ⊘ Seasonal Calendar

2. What was the approach used *in problem identification and prioritization* of the community members?
   a. ⊘ Community members were requested to use jute sticks to indicate more pressing problems for a list provided.
   b. ○ Community members were requested to rank their wealth according to household income and ownership of homestead.
   c. ○ Community members were requested to walk transects in order to learn the history, topographic conditions, and culture in each ward Loss of life and injuries.
   d. ○ All of the above

3. In the conceptual framework of community participation under BUDMP of the Bangladesh Flood Mitigation case study, how is the input of the community integrated into mitigation plans?
    a. ○ Through the participatory identification and prioritization of problems
    b. ○ Through community participation in the seeking of solutions and needs assessment
    c. ○ Through the participatory implementation, monitoring and evaluation of mitigation plans
    d. ☑ All of the above

Questions Related to Reading 1: Mapping Hazards and Risk Hotspots in Sri Lanka

1. What four hazards were combined in the Hotspot analysis for Sri Lanka?
    a. ○ Drought, Earthquake, Flood and Tsunami
    b. ☑ Drought, Flood, Landslide and Cyclone
    c. ○ Drought, Landslide, Cyclone and Tsunami
    d. ○ Drought, Flood, Earthquake and Landslide

2. Which approaches are used in combining hazards in the multi-hazard map of Sri Lanka?
    a. ○ Using weights of each hazard based on the number of occurrences of each hazard
    b. ○ Using weights of each hazard by the disaster relief expenditure of each hazard
    c. ○ Using equal weights for each hazard
    d. ☑ All of the above

3. What are the advantages of comparing risks rather than hazards from different perils?
    a. ○ Hazards parameters for different types of hazards cannot be readily compared, as they often measure different physical quantities, whereas risk parameters (e.g. building damage) can be readily compared.
    b. ☑ Risk parameters are of more interest to the population and stakeholders.
    c. ○ Risk parameters provide more information on the occurrence of the event.
    d. ○ Risk parameters provide more information on the impact of the event.

Questions Related to Reading 2: Community Based Vulnerability Assessment (CVAT)

1. What is a "Relative Priority Matrix" used for?
    a. ○ To initiate thought and discussion about the hazards and their potential impacts.
    b. ○ As a subjective exercises for communities where the score do not have absolute statistical significance.
    c. ○ To provide relative rankings that can guide the vulnerability assessment as well as hazard mitigation priorities.
    d. ☑ All of the above

2. What information are *not* examples of information on the *structural vulnerability* of facilities?
   a. ○ Construction materials used in building.
   b. ○ Wind load capacity of building.
   c. ⊘ Insurance policies available for building.
   d. ○ Number of floors of building.

3. What societal conditions can affect disaster recovery efforts?
   a. ○ Literacy or language can impact disaster recovery efforts.
   b. ○ Poverty and limited access to public assistance income can influence recovery efforts.
   c. ○ Elderly and children may indicate special mobility needs and can impact disaster recovery efforts.
   d. ⊘ All of the above

Questions Related to Reading 3: Visions of Risk

1. Which of the following statements is <u>not</u> true about the Disaster Risk Index (DRI)?
   a. ○ The aim of DRI is to demonstrate the ways in which development influences disaster risk and vulnerability.
   b. ○ DRI has been fully applied to earthquake, cyclone and flooding disasters. Loss of ecosystem amenity values
   c. ○ Relative vulnerability in DRI is calculated by dividing the number of people killed by the number of people exposed to a particular hazard.
   d. ⊘ The socio-economic indicators chosen in DRI were selected by expert judgment and were not used to explain mortality to individual hazard types.

2. Which of the four indices below were not developed under the IDB-IDEA Americas program?
   a. ○ Disaster Deficit Index (DDI)
   b. ⊘ Social Vulnerability Index (SVI)
   c. ○ Local Disaster Index (LDI)
   d. ○ Risk Management Index (RMI)

3. Using measures for mortality risk, which of the following findings is not true of the Hotspot Risk Index?
   a. ⊘ More than four-fifths of world's population was located in areas of relatively high risk from one or more hazards.
   b. ○ Nearly one quarter of total land area and more than three-quarters of the world's population were shown to be at relatively high risk from one or more hazards.

c. ○ Around one twentieth of the total land area and about one in four people were subject to high risk from two or more hazards.
d. ○ About seven per cent of total population lived in areas at high risk from three or more hazards.

Assignment 1

Objective
This assignment is composed of two parts. In part 1, the objective is to discuss the concept of hazard, risk and vulnerability by interpreting a probabilistic earthquake hazard map, and differentiating a hazard map from a risk map. The purpose of part 1 is not to arrive at the "correct answer", but mainly to promote active involvement of students and to foster thinking in terms of "hazard" and "risk" and "probability" and to put these concepts, as they relate to earthquakes, into context with other hazard events. The facilitator's objective should be that participants are better able to answer these questions and form stronger opinions as the course progresses. Please note that while "Answers" for the instructor are provided here, several of the questions are open-ended giving room to variations in responses.

In part 2 of the assignment, the objective is to calculate important variables used in risk analysis such as Average Annual Loss (AAL) and Exceedance Probability (EP). These are difficult concepts to grasp just from the lecture, and the assignment will reinforce these concepts through a learning-by-doing approach. The step-by-step explanations in the assignment information should help the participants calculate the EP and AAL by following the example, however, their knowledge is put to test in interpreting the results from the exceedance probability curve.

Part 1: Questions Regarding the Concept of Probability in Risk

1. What does the map say about the risk of earthquake in the United States? Does the map include any information about vulnerability of buildings and populations? Interpret the information provided in this map in your own words.
2. What level of risk is "acceptable" for the design of constructed facilities and lifelines? How does this level of earthquake probability compare with the risk from other natural disasters (such as damaging floods or) everyday threats such as car wrecks and plane crashes?
3. More people die each year world-wide from floods (i.e., consider Bangladesh), how does this hazard compare with earthquakes?

4. How concerned should we be about the level of earthquake threat given these other threats? How much risk is "acceptable"? What value should be placed on human life? How is risk perceived differently by different people? For instance, not being in control is why people tend to believe that jet travel is inherently riskier than riding in a car, even though we seldom think about the fact that we spend much more time driving than flying.

Part 1: Answers

1. The map is not directly providing information about risk, as it is only showing the earthquake hazard. Risk is a function of hazard and vulnerability, and the map does not include any information about vulnerability. For example, the map does not provide any information on how buildings might perform in California versus Missouri, where similar earthquake hazard can be seen in the New Madrid earthquake zone (center-right of the map). A risk map would integrate this information. According to the map, an earthquake of the intensity shown on the map has a probability of 2% to occur in the next 50 years or a 1-in-2500 probability of occurring annually, a very rare event. The level of shaking is shown in units of gravity. For example, in some parts of California or in the New Madrid area there is a 2% probability in the next 50 years that an earthquake will create vertical accelerations equal to one unit of gravity—imagine the earthquake pushing you up from the floor with the same acceleration that gravity pulls you down.
2. Floods are more likely to occur in most regions in any given year, but earthquakes occur without warning and affect widespread areas. Also, unlike floods, earthquakes cannot be controlled directly, but the effects can be mitigated. Floods can be directly controlled in most cases with appropriate flood control measures (dams, levees, etc.).
3. More people are likely to die from floods in any given year world-wide than from earthquakes although, for floods, warnings exists and the hazard itself can be decreased with mitigation. Earthquakes have higher consequences when they occur, but their occurrence is generally less likely.
4. These questions have no "correct" or "uniform" answers. It is important to emphasize that we should be concerned about earthquakes and other hazards in susceptible regions. An important objective should be to develop tools to better identify, characterize, and mitigate risks (i.e., reliability and risk analysis) to be able to optimize limited resources.

Part 2: Practice Calculations for an Exceedance Probability Curve

1. Calculate the "Return Period" for each of the events in Table 4.1. (hint: the return period is simply the inverse of the annual probability of exceedance)

2. Calculate the Expected Loss, EP(Li), for each event in Table 4.1
3. Calculate the exceedance probability, EP(Li), for each event in Table 4.1
4. Calculate the Average Annual Loss (AAL) of building damages for the city
5. Plot the Exceedance Probability Curve
6. Consider an insurer that wants to limit its Probable Maximum Loss (PML) which it defines as a 1-in-250 year loss to be less than $10million for the portfolio of building losses in this city illustrated in Table 2.1. In other words, the annual probability of exceeding $10million should be less than 0.4% (0.004). Based on the EP curve, determine if this is a suitable portfolio for the insurer. If not, what options might the insurer have to reduce its risk?

Part 2: Answers

1. The Expected Loss for each event is obtained as a product of the loss (Li) and Annual Exceedance Probability (pi) for that event: E[L] =(pi * Li). For an earthquake with a probability of occurrence of 0.002 and loss of 25 million USD, the expected loss in a given year is thus 0.002*25,000,000 = $50,000 (see table 2.1)
2. Assuming that during a given year, only one disaster occurs, the Exceedance Probability for a given level of loss, $EP(L_i)$, can be determined by calculating:

$$EP(L_i) = P(L > L_i) = 1 - P(L \leq L_i)$$

$$EP(L_i) = 1 - \prod_{j=1}^{i} (1 - p_{jsss})$$

3. The resulting exceedance probability is the annual probability that the loss exceeds a given value. As seen in the equation above, this translates into one minus the probability that all the other events below this value have not occurred. This notation can be written out for example for the third event in Table 2.1., E_3, as:
$EP(L_3) = 1 – [(1 – p_1) * (1 – p_2) * (1 – p_3)] = 1 – [(1 – 0.002) * (1 – 0.005) * (1 – 0.010)]$
= 0.0169

4. The Average Annual Loss is the area under the exceedance probability curve, which is equal to the sum of the loss rates for each event. This notation means that AAL is calculated as the sum of all probabilities times their associated losses, and can be written out for the events in Table 2.1., as:
$(p_1 * L_1) + (p_2 * L_2) + ... + (p_{15} * L_{15})$. For all 15 events, the AAL is $760,000 Million.

5. See Table 4.1 and discussion below.

Table 4.1 Expected Loss and Exceedance Probability for Earthquakes

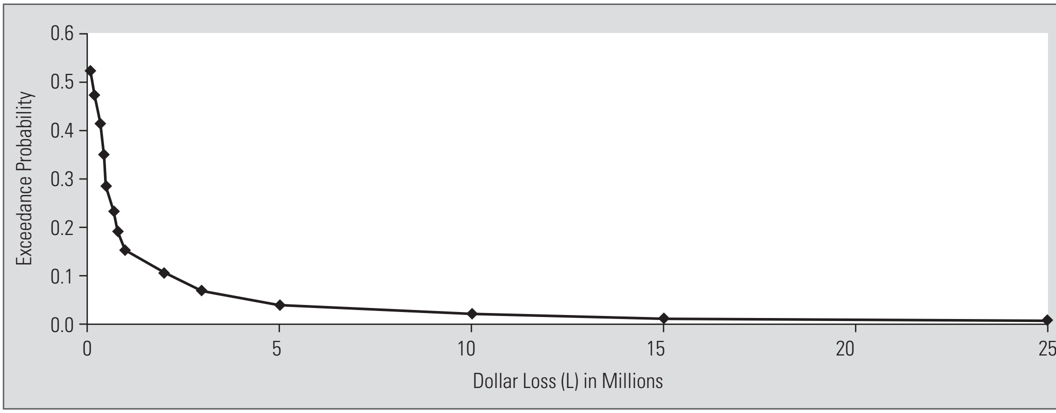
Event (Ei)	Annual Probability of Occurrence (pi)	Loss (Li) USD	Exceedance Probability EP (Li)	E[L]=(pi*Li) USD
1	0.002	25,000,000	0.0020	50,000
2	0.005	15,000,000	0.0070	75,000
3	0.010	10,000,000	0.0169	100,000
4	0.020	5,000,000	0.0366	100,000
5	0.030	3,000,000	0.0655	90,000
6	0.040	2,000,000	0.1029	80,000
7	0.050	1,000,000	0.1477	50,000
8	0.050	800,000	0.1903	40,000
9	0.050	700,000	0.2308	35,000
10	0.070	500,000	0.2847	35,000
11	0.090	500,000	0.3490	45,000
12	0.100	300,000	0.4141	30,000
13	0.100	200,000	0.4727	20,000
14	0.100	100,000	0.5255	10,000
15	0.280	0	0.6597	0
Average Annual Loss (AAL) = $760,000				

6. See Figure 4.1 and discussion below.

Exceedance Probability Curve is constructed as shown in the figure below based on losses associated with cumulative rates of occurrence – $EP(L_i)$

The exceedance probability curve enables an insurer to determine his PML or Probable Maximum Loss for a portfolio of structures in a given time period. The term PML is a subjective risk metric and is associated with a given probability of exceedance specified by the insurer. For example, suppose that an insurer specifies its acceptable risk level as the 0.4% (0.004) probability of exceedance as suggested in the exercise. The insurer can use the EP curve to determine how large a

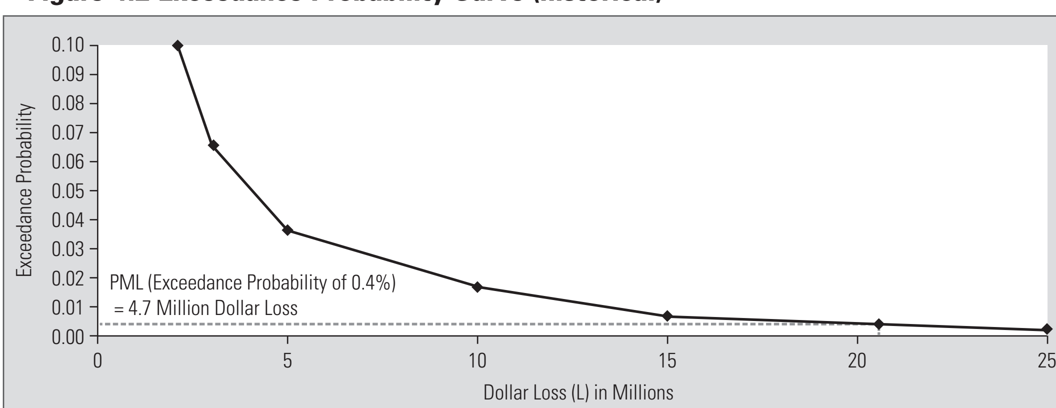
Figure 4.1 The Exceedance Probability Curve



loss will occur at this probability level. Often, PML limits are framed in terms of a return period. The return period is simply the inverse of the annual probability of exceedance.

In the given example, a 1-in-250 year PML is the lower limit on the loss at a 0.4% probability of exceedance on the EP curve. From the EP curve shown in Figure 2.1 above it can be seen that

Figure 4.2 Exceedance Probability Curve (historical)



the PML is approximately $21 million. This is twice greater than the $10million limit the insurer considers as an acceptable PML. Thus the insurer has to reduce its risk. The insurer would need to look for ways to reduce its portfolio, transfer $11 million of loss to a reinsurer, or purchase a catastrophe bond to cover it.

The EP curve is constructed on the basis of historical observations. For low and mid-return period events there has been plentiful data sampled, because these events are more likely and most frequently observed. On the other hand, in the right tail end or extremes of the curve, there have only been a few cases. Sometimes there may have been no cases in a large portion of a tail, and then just a single observation far out in the extreme part of that tail. Whatever the exact configuration of the observations is, the tails are less certain, therefore, conclusions based on the extreme tails of the distribution are particularly dangerous, and should be made with caution. The tails express only an educated guess of the actual extreme value probabilities and should not be taken literally.

The following table provides guidelines for grading the assignment

Module 1 Checklist	Grading Points
Part 1: Discussion of the Concept of Probability in Risk	
There are three parts to this question. Information on risk is not given in this map as vulnerability is not included. Interpretation of the map should include a discussion of the probability of occurrence of the earthquake and what the colors on the map mean.	3 (per item)
Difference between floods and earthquakes in terms of the frequency and intensity of these events should be elaborated (i.e., floods occur much more frequently but cause less damage, whereas earthquakes occur less frequently, but have the potential of creating lots of damage)	1
These questions have no “correct” answer/decision, but the author’s opinion is that we should be concerned about earthquakes and other hazards in susceptible regions. Allocate points depending on the thoughtfulness of the answer.	1
These questions have no “correct” answer/decision, but one important objective might be developing tools to better identify, characterize, and mitigate risks (i.e., reliability and risk analysis) to better optimize limited resources. Allocate points depending on the thoughtfulness of the answer.	1

Module 1 Checklist	Grading Points
Part 2: Exceedance Probability Curve	
Correct calculation of Expected Loss	1
Correct calculation of Exceedance Probability	1
Correct calculation of Average Annual Loss	1
Correct construction of Exceedance Probability curve	2
From Exceedance Probability curve, the student should derive that PML is approximately $21 million. This is twice greater than the $10million limit the insurer considers as an acceptable PML. A discussion on how insurer can reduce risk should also be included.	2
A discussion of why the tail end of the exceedance curve should be interpreted with caution should be included.	2
Sum of grading points	15

Discussion Forum

Points to Emphasize
The discussions should gear towards reinforcing the main messages of Module 1. The following points should be brought out during the discussion:

Mainstreaming Risk Analysis into Disaster Risk Management Processes

- Risk analysis is one of the main pillars of the disaster risk assessment process which also includes risk management and risk communication. When these three components link to each other, a risk reduction strategy can be developed and as an outcome risk reduction can be achieved
- Risk analysis can help disaster managers answer fundamental questions about disasters and their occurrence (e.g., how can people prepare for it, what sort of damage will occur, who will be affected, etc.)
- Mainstreaming risk analysis into disaster risk management processes requires stakeholders to understand how risk analysis as a tool can be useful in their daily operations, and how parameters derived from a risk analysis can be used in various components of disaster risk management (i.e. preparedness, mitigation, response planning and recovery planning)

Better Understanding of the Elements of Risk Analysis: Hazard and Vulnerability

- Hazard analysis can be expressed in terms of a process with spatial, temporal and dimensional components
- Vulnerability is not a well-defined concept, nevertheless in the course, based on the Methods for the Improvement of Vulnerability Estimation (MOVE) framework, vulnerability is regarded as a product of exposure, as an external component, and susceptibility and lack of resilience, as internal components
- Vulnerability is not restricted to physical systems alone which is commonly addressed. It also includes other dimensions such as social, economic, cultural, institutional, etc.
- Vulnerability is dependent on hazard. The concept of fragility curves should be emphasized
- Measuring vulnerability requires a classification to pinpoint that vulnerability is measured with respect to certain target audience, sector, components, consequences and scale

Choice of Tools in Risk Analysis Depends on Scope of Study

- There is no ideal approach in analyzing risk and many tools area available. The choice of instruments and approaches in analyzing risk depends on the aims of the study and available information about hazard and vulnerability
- Understanding concepts such as return period, exceedance probability curves, average annual losses, are important in probabilistic risk analysis
- Probabilistic risk analysis is preferable for mitigation purposes as it includes the impacts of all the potential hazard sources and also the uncertainty in the estimates – providing a more reliable decision-making framework
- Scenario analysis is very useful for emergency preparedness and planning as it allows decision makers to work with a common picture of risk and use risk parameters as inputs for their various planning activities
- Participatory risk analysis uses qualitative methods to include the subjective perception, experience and knowledge of the community and incorporate them into the planning process

Recommended Initial Questions

The following questions are suggested for the first week. Since they are related to the first module of the online course the initial questions can be used as icebreakers:

Discussion Question 1: Recently, increased vulnerabilities, due to development practices, are posing a greater challenge to development practitioners, physical planners, emergency response personnel and disaster risk reduction experts. Briefly explain various processes/factors that make areas more vulnerable to disasters and contribute to an increase of their vulnerability over time.

Discussion Question 2: In your professional capacity how would you envision the usefulness of risk and vulnerability assessment in your current program/project/area?

Discussion Question 3: These days, national governments are pursuing disaster risk mitigation activities very seriously. Under such activities, risk and vulnerability analysis is conducted at various levels. Please share your experiences about the risk analysis and/or vulnerability analysis instruments and approaches applied in your program/project/area.

Recommended Follow-up Questions

The questions should reflect and highlight the main themes in Module 1, which have been described here. Following the first round of exchanges facilitators can start addressing the group stating *"It is nice to note that several of you have started participating in the discussion forum. Several responses have highlighted the important issues regarding ______________"*. The questions below are given as guidelines only, as the follow up questions should reflect and linked to discussions that have taken place.

Follow-up Question 1: What do you see as obstacles in mainstreaming risk analysis into disaster risk management? What role do "risk acceptance" and "risk perception" play in the way the results of a risk analysis is used by decision makers?

Follow-up Question 2: Please identify a dimension of vulnerability relevant to your community/area/sector/exiting hazard. What do you see as the root causes of this dimension of vulnerability that you have identified? Can you think of some indicators that describe the susceptibility as well as lack of resilience of your community with respect to this dimension of vulnerability?

Follow-up Question 3: Please elaborate which of the risk analysis tools introduced in Session 3 you might use in your program/project/area and state your reasons for it.

Follow-up Question 4 (Related to Assignment): The assignment consists of two parts. The questions in the first part of the assignment are suitable for the discussion forum after participants have had a chance to look at the answers for themselves individually. The questions refer to a probabilistic earthquake hazard map of the United States included in the assignment information and are:

- What does the map say about the risk of earthquake in the United States? Does the map include any information about vulnerability of buildings and population? Interpret the information provided in this map in your own words.
- What level of risk is "acceptable" for the design of built facilities and lifelines? How does this level of earthquake probability compare with the risk from other natural disasters (such as damaging floods or) everyday threats such as car wrecks and plane crashes?
- More people die each year world-wide from floods (i.e., consider Bangladesh), how does this hazard compare with earthquakes?
- How concerned should we be about the level of earthquake threat given these other threats? How much risk is "acceptable"? What value should be placed on human life? How is risk perceived differently by different people? For instance, not being in control is why people tend to believe that jet travel is inherently riskier than riding a car, even though we seldom think about the fact that we spend much more time driving than flying.

Guidelines for Preparing Discussion Summary
By the end of the week, the discussion should cover all aspects of the module and highlight the main points described here. All participants should have taken keen participation in the discussion and contributed at least with 2 discussion postings. At the end of the week the facilitator should post a summary of discussions reflecting on the main topics 1–3 described above. The objective of the discussion summary is to have a record of discussions in a concise manner, which is available to everyone. The discussion summary should be to the point and generally no more than one and a half pages. It should highlight the important issues discussed during the week. It is suggested to have a summary according to broad discussion themes outlined in this chapter.

4.6 Suggested Additional References

4.6.1 Reports for Further Reading

Handbook for Estimating the Socio-Economic and Environmental Effects of Disasters, United Nations Economic Commission for Latin America and the Caribbean, 2003

Indicators of Disaster Risk and Risk Management. Inter-American Development Bank. 2005

Natural Disaster Hotspots, A Global Risk Analysis. World Bank, 2005

Natural Disaster Hotspots Case Studies. World Bank, 2006

Vision of Risk, A Review of International Indicators of Disaster Risk and its Management., ISDR/UNDP, 2004

4.6.2 Publications

Adger, W. Neil. 2006. Vulnerability. Global Environmental Change 16 (3):268–281.

Cutter, Susan L., Bryan J. Boruff, and W. Lynn Shirley. 2003. Social vulnerability to environmental hazards. Social Science Quarterly 84 (1):242–261.

Gallopín, Gilberto C. 2006. Linkages between vulnerability, resilience, and adaptive capacity. Global Environmental Change 16 (3):293–303.

Wisner, B., Blaikie, Piers, Terry Cannon, Ian Davis. 2004. At risk: natural hazards, people's vulnerability, and disasters. 2nd ed. London: Routledge.

Birkmann, J. and Wisner, B. 2006. "Measuring the Un-Measurable: The Challenge of Vulnerability". UNU Institute for Environment and Human Security, Bonn, Germany.

Bostrom, French, Gottlieb. 2008. "Risk Assessment, Modeling and Decision Support". Springer-Verlag Berlin Heidelberg.

Mechler, R. 2008. "From Risk to Resilience". *The Cost-Benefit Analysis Methodology*.

V. Module 2: Earthquake Risk Analysis

5.1 Module Description

The module on Earthquake Risk Analysis provides the basic information on all classical aspects of risk assessment. Descriptions of hazard, vulnerability and risk have been included under both deterministic and probabilistic framework. The participants undergoing the course will acquire basic understanding of all these important concepts. Since such concepts are likely to be new to most participants, the level of description has been kept basic.

Earthquake loss models should ideally include all of the possible hazards (e.g. ground shaking as well as earthquake induced events such as landslides, liquefaction, tsunamis and fires) and be able to account for the vulnerability of the exposed elements. This specialized module reviews earthquake loss models and the various components of an earthquake risk analysis and loss estimation process. We start by introducing the earthquake hazard and addressing questions such as what happens when the earth quakes or how earthquake damage can change for different site and soil conditions. This is followed by what steps are involved in vulnerability and exposure analysis and methods for analyzing risk for physical infrastructure such as buildings and lifelines, as well as assessing direct and indirect socio-economic impacts such as business interruption or psycho-social impact. This module also provides an overview of current tools available for earthquake loss estimation and scenario analysis. In the module assignment, we introduce a Microsoft Excel-based loss estimation tool called RADIUS. Participants will use this software in the End-of-Course Project to carry out a simulated risk analysis and answer questions reinforcing the main messages of the course.

5.1 Learning Objective

Module 2 reviews the hazard and vulnerability components for conducting earthquake risk analysis and presents approaches and tools for carrying out earthquake loss estimation.

The aims of this module are:

- Presenting an understanding of what happens when the earth shakes from the seismic source to the site
- Introducing the main earthquake hazard as well as secondary hazards such as landslides, liquefaction, tsunamis, and fire
- Reviewing deterministic and probabilistic approaches to earthquake hazard assessment
- Clarifying how vulnerability is defined for built environment and socio-economic impact in the context of earthquakes
- Presenting approaches and tools to assess the damages caused by earthquakes and how losses are computed

At the end of the module participants will know:

- The essential elements of an earthquake hazard assessment
- How seismic hazard is integrated into earthquake los models
- Understand the difference between probabilistic and deterministic models
- The essential elements of vulnerability analysis for structures and lifelines
- The socio-economic impact of earthquakes and the use of indicators in measuring these impacts
- The basic methods to quantify the damages from earthquakes
- How to apply earthquake loss estimation to a real situation

5.3 Main Terms

Session 1
Plate Tectonics, Seismic Hazards, Seismic Waves, Ground Motion (Duration, Amplitude, Frequency), Peak Ground Acceleration, Spectral Acceleration, Ground Motion Amplification, Ground Motion Attenuation, Secondary Hazards, Earthquake Sequences, Hazard Catalogues, Ground Motion Prediction Equations (GMPEs), Deterministic Seismic Hazard Assessment (DSHA), Probabilistic Seismic Hazard Assessment (PSHA).

Session 2
Elements at risk, Exposure data, Critical Infrastructure, Microzonation, Vulnerability Methods (Empirical, Analytical and Hybrid Methods), Damage Classes, Capacity Spectrum Method, Fragility (Vulnerability) Curves.

Session 3:
Asset Value, Cost-Benefit Analysis, Loss Estimation, Exposure, Damage-Loss Conversion, Direct vs. Indirect Impact (Losses), Economic Loss Conversion, Social Loss Conversion, Earthquake Loss Consequences, Earthquake Mitigation.

5.4 Key Points to Emphasize

- *Estimating earthquake hazard and its uncertainties is the first step in earthquake risk analysis and loss estimation:* Earthquake hazard can be analyzed from its beginning at the source, to the production of waves traveling through the earth, to the site on the Earth's surface where damage occurs. The shaking felt at the site is a function of the duration, amplitude and frequency of the ground motion the distance away from the fault and the rupture length of the fault as well as the local site conditions (i.e., soft soils can amplify the ground motion). A ground motion prediction equation (GMPE) or attenuation relationship can be used to predict the ground motion at certain locations, given the site conditions, magnitude and location, and fault mechanisms of a scenario earthquake. Depending on the study and availability of data, a probabilistic or a deterministic analysis of earthquake hazard can be carried out. A probabilistic seismic hazard analysis calculates the probability of exceeding all levels of ground shaking from all potential seismic sources in the area, rather than just a single postulated event in the case of a deterministic analysis.
- *Estimating vulnerability is not a precise science:* Determining vulnerability to earthquakes is complex, yet there are some key concepts that can be used to relate the earthquake hazard to the vulnerability of physical infrastructure and built environment. Fragility or vulnerability curves are important tools that allow engineers to group buildings in different classes and estimate (based on analytical models, physical experiments and past earthquake behaviour) how the building will react to earthquake forces. However, even with respect to the more traditional methods of estimating vulnerability of physical structures, it is very difficult to obtain precise estimates of vulnerability. There are many uncertainties in vulnerability estimation due to the way that buildings are designed, contracted and built. Estimating social and economic consequences is even more difficult as the indirect and intangible consequences of earthquakes on society are very difficult to model. While economic models are available that account for direct and indirect impacts such as the effects of business disruption or production losses after an event, the link between social vulnerability and earthquakes is less understood.

- *Earthquake Loss Estimation is a powerful tool for disaster risk management planning and earthquake risk reduction:* Earthquake Loss Estimation has many uncertainties, yet by knowing the basics of exposure, vulnerability and hazard, it is possible to construct a simple earthquake loss estimation for any region in the world. There is no ideal approach in analyzing earthquake losses and many tools are available—depending on the level of information you have, certain earthquake loss estimation procedures will be better than others.

5.5 Learning Material and Activities

5.5.1 Presentations

Session 1: Earthquake Hazard

Objective
The objective of the first session is to provide an overview of fundamental concepts to calculate the earthquake hazard, as well as key terminology. The additional presentation with animations can be used to help in understanding and visualizing key earthquake hazard processes.

Key Points:

- Basic earthquake processes: what, where, how and why of earthquakes, from their beginnings at the source, the production of waves travelling through the earth, to the site on the Earth's surface where damage occurs
- Seismic principles such as waves and other concepts in terms of hazard
- Ground motion and the impact of site effects on ground motion
- Integration of seismic hazard into loss models
- The difference between deterministic and probabilistic hazard assessment
- Applying hazard assessment to a real location

Session 2: Earthquake Vulnerability and Exposure Analysis

Objective
The second session presents the necessary tools for creating an exposure database for a certain region and then to determine the vulnerability of that region. The case study related to this session gives an overview of a vulnerability assessment done for a fictional town and illustrates that the given information governs the method of vulnerability analysis.

Key Points:

- Inventory elements are exposed to hazard
- Data needs for exposure analysis and for calculating potential damage
- Class of methods to calculate potential damage: empirical and analytical
- Vulnerability scales for buildings and infrastructure across two classes of vulnerability: physical and socio-economic
- Socio-economic vulnerability assessment and its role in decision-making processes
- Vulnerability assessment application in a real situation

Session 3: Earthquake Loss Estimation

Objective
In the final session the objective is to present, in a systematic way, how to calculate risk and loss for an earthquake scenario or real-time event. Several tools are listed among the resources of the course including open-source software packages from around the world, and participants should be able to use them to undertake their own loss assessments.

Key Points:

- The basics of earthquake loss estimation
- How to convolve the hazard, exposure and vulnerability using damage loss conversion and uncertainties
- The socio-economic loss components from the Earthquake Loss Estimation
- What global software tools are available to undertake an Earthquake Loss Estimation
- Developing an earthquake loss estimate for any location

5.5.2 Case Studies

Overview
The two case studies included in this module complement each other. One is a town-based earthquake loss assessment which goes through a simplified procedure based on the RADIUS software, and the other is for the city of Delhi based on advanced loss estimation methods. Reading both case studies will reveal the differences and the parallels between the RADIUS methodology and other loss estimation methods.

The two case studies have been chosen to illustrate earthquake loss estimation on different scales. Earthquake loss estimation ties together all sessions within this module, as hazard, exposure, vulnerability and damage-loss conversion is required in order to undertake such an assessment. These two cases allow participants to understand the key concepts of damage-loss conversion. Both case studies also include discussion of direct and indirect impacts including social and economic losses. Case study 1 allows readers to understand the theoretical background while case study 2 showcases the application of these fundamentals of earthquake risk analysis.

Case 1: An Earthquake Loss Assessment Procedure for a Fictional Town

This case study provides an overview of the key elements needed in earthquake loss estimation on a regional or settlement-based scale. It summarizes the process of obtaining a simple estimate of building damage, economic and social losses for a test case. The case study takes participants through the main steps needed in undertaking a simplified deterministic seismic hazard assessment which can then be used to apply to various open source software packages. It complements the learning from presentations as it can be considered as an introduction to the assignment in RADIUS.

Key Points

- Explains Earthquake Loss Estimation Procedure and its elements
- Hazard, vulnerability and exposure information retrieval methods
- An earthquake loss estimation process
- Calculation of socio-economic outcome, based on mean damage ratio and a simplified social loss conversion

Case 2: Risk Analysis for a Postulated Earthquake in Delhi

This case study presents the risk assessment of Delhi for a postulated earthquake. The risk assessment methodology and results illustrate a typical implementation of risk analysis for urban areas and the nature of results. The results of the risk assessment are particularly important for city officials in understanding the potential hot-spots in the city. The assessment is also useful in preparation of disaster risk management plans by illustrating the importance of various factors in the final risk in terms of casualties and economic losses.

Key Points:

- Implementation of earthquake risk analysis methodology in the context of an urban area
- Determination of socio-economic impacts based on damage-loss conversions
- Linking results of risk analysis to policy and disaster risk management planning
- Stakeholders need to understand the results of risk assessment to appreciate the underlying causes of risk and to undertake disaster risk management measures

5.5.3 Readings

Overview

The readings' role is to reinforce the key concepts of hazard, vulnerability, exposure, and earthquake loss estimation, as well as to tie together the analysis section with actual implementation. They will also serve to illustrate the actions taken worldwide to mitigate the effects of earthquakes. The first two readings provide the technical basis and the third reading provides a more social and political overview of the earthquake risk analysis procedure.

Reading 1 reinforces the key concepts of hazard, vulnerability, exposure and earthquake loss estimation for a generalized case and explains the key concepts of the RADIUS software package. The intention is that the use of animation contributes to the understanding of the earthquake hazard concepts.

Reading 2 underlines the key concepts of hazard and vulnerability on a city scale. The reading illustrates building loss calculation on the example of Istanbul and explains the benefit/cost and insurance implications of the earthquake loss estimation. This adds to some of the lesser explained points of sessions 2 and 3.

Reading 3 then puts the entire earthquake loss estimation process in perspective by simplifying all of the key outcomes and tying them to the earthquake cycle presented in Session 3.

Readings 1, 2 and 3 are required course readings. Three optional readings included in Module 3, Reading 4 links to the earthquake hazard session and goes into further depth on a topic difficult to present in just a few slides. It also elaborates the uses, advantages and disadvantages of the probabilistic analysis versus deterministic analysis of risk and hazards introduced in Module 1. Reading 5 reflects on the uses and applications of loss estimation software using earthquakes as an application example. This reading reinforces the concepts presented in Session 3, but also links to Module 1, Session 3. The final optional reading, reading 6, provides an overview of various open source earthquake loss estimation software for those participants interested in pursuing this further. The RADIUS software used in the course is a simplified loss estimation methodology; this reading, however, presents some of the state-of-the-art software in earthquake loss estimation and the advantages and disadvantages of each.

Reading 1: Simplified Earthquake Loss Estimation through use of RADIUS
Risk Assessment tool for DIagnosis of Urban areas against Seismic disasters (RADIUS) tool was developed for International Decade for Natural Disaster Reduction (IDNDR) by the Japanese OYO Corporation and RMSI to enable city administrators to do quick assessment of earthquake risk to a city. The objective of this tool is to aid users in understanding the seismic hazard and vulnerability of their cities and to guide them in starting preparedness programs against future earthquakes. Designed in Microsoft Excel to provide a simple and very familiar interface, the tool is user friendly, and provides risk-mapping functionality. The area of a city and probable loss to infrastructure and life is displayed as a mesh of rectangular cells that allows the user to get a graphical view of the data. Outputs are seismic intensity, building damage, lifeline damage, and causalities, which are presented in tabular as well as map forms.

Key Points

- Reinforces the key concepts of hazard, vulnerability, exposure and earthquake loss estimation for a generalized case
- Explains the key concepts behind the RADIUS software package
- Explains simplified concepts introduced in Module 2 and recur in the entire course
- Provides an important background reading to the assignment in Module 2 and the ECP

Reading 2: Earthquake Vulnerability of Buildings and a Mitigation Strategy
In recent decades, earthquake risk for Turkey's urban centers has increased, mainly due to high rates of urbanization, faulty land-use planning and construction, inadequate infrastructure and services, and environmental degradation. This reading first summarizes an assessment of building losses in Istanbul in the event of a major earthquake. The study was conducted by the Department of Earthquake Engineering, Bogaziçi University, with support from the American Red Cross (BU-EQE, 2002). The second part of the reading proposes a cost-effective mitigation strategy based on retrofitting.

Key Points

- Building loss calculation from earthquake loss assessment can be used in benefit/cost analysis and insurance industry
- Covers some of the lesser explained points of sessions 2 and 3

Reading 3: Building Technical and Political Capacity for Earthquake Risk Reduction
This reading introduces a framework for building a culture for seismic risk reduction. There is an urgent need to build a culture of prevention, mitigation, preparedness and to increase the capacity to prevent potential losses in countries prone to earthquakes, regardless of their size, population, and assets exposed. To accomplish this goal, scientists and engineers must work together with other stakeholders and policy makers and commit intellectual and political capital to a long-term process that will institutionalize earthquake risk reduction (i.e., prevention, mitigation, and preparedness) as a public value.

Key Points

- Links the earthquake cycle presented in Session 3 to all aspects of earthquake risk analysis
- Focuses on earthquake risk mitigation and involvement of stakeholders to mainstream results of risk analysis

Reading 4: Deterministic Versus Probabilistic Earthquake Hazards and Risks
This reading reviews deterministic and probabilistic approaches to assessing earthquake hazards and risks and presents the differences, advantages, and disadvantages that often make the use of one preferable over the other. Both probabilistic and deterministic methods have a role in decision-making. They complement one another in providing additional insights to the seismic hazard or risk problem. The selection of the method depends on the seismic environment, the scope of the project (single site or a region) and the necessity of numerical results for decisions. In many applications a recursive analysis, where deterministic interpretations are triggered by probabilistic results and vice versa, will give the greatest insight and allow the most informed decisions to be made.

Key Points

- Overview of deterministic seismic hazard and risk analysis
- Overview of probabilistic seismic hazard and risk analysis

- Links Session 1 and 3 of Module 1 to a more in-depth discussion of these two key approaches in earthquake risk analysis

Reading 5: Loss Estimation: A Powerful Tool for Risk Assessment and Mitigation
Today, loss estimation techniques are translated into efficient software applications that are accessible by a large constituency of end-users. These techniques offer a high level of sophistication and enable users to perform various '"if / then" scenarios to study the sensitivity of the results, to develop a better understanding of the outcomes and to gain insight on the consequences of the findings and decisions. Functionality of loss estimation models has improved significantly due to advances in information technology such as Geographical Information Systems (GIS). GIS allows easy display of input and output (in standard reports and maps) providing a critical functionality for communication of outcomes to emergency-planners and decision-makers.

Key Points

- Loss estimation tools can be used by urban planners, emergency managers, risk managers, and public policy/decision-makers to understand the impact of earthquakes, study the effect of mitigation techniques and incorporate the results into preparedness programs and urban development plans
- Links to Session 3 on loss estimation models as well as Module 1, Session 3 to the reading which introduces this topic. The reading, however, treats the topic in more depth than as introduced in Module 1 and uses the example of earthquake loss estimation to illustrate the application of loss estimation models

Reading 6: OPAL Procedure for Earthquake Loss Estimation
The OPAL procedure has been developed to provide a framework for optimization of a global earthquake modeling process. It gives an overview of available state-of-the-art open-source software tools.

Key Points

- Many Earthquake Loss Estimation (ELE) software packages have been created globally, allowing for reasonably accurate damage, social and economic loss estimates of scenario earthquakes

- Using the OPAL procedure, ELE can be undertaken for a desired test case anywhere in the world
- Links to the last slide of Session 3 and provides further reading for those interested in exploring the use and suitability of different ELE software

5.5.4 Activities

Knowledge Checks

The list of questions in the knowledge checks underlines the key points of the earthquake risk module. Nine questions form each session. The knowledge checks also include questions from the readings and case studies. The topics of all questions cover the theoretical foundations, methods, and approaches in earthquake risk analysis, as well as specific aspects from the selected case studies.

Questions Related to Session 1: Earthquake Hazard

1. Which areas of India are expected to have buildings designed to withstand an Intensity 9 earthquake?
   a. ⊘ Jaipur (Rajasthan)
   b. ○ Mumbai (Maharashta)
   c. ○ Assam (near Arunachal Pradesh)
   d. ○ Pondicherry (Tamil Nadu)

2. Which area has the lowest predicted hazard by the makers of the zone map?
   a. ○ Zone V
   b. ○ Zone IV
   c. ⊘ Zone III
   d. ○ Zone III

3. Why and where do earthquakes occur? (There can be more than 1 answer correct)
   a. ⊘ Plate tectonics; on faults.
   b. ⊘ To release built up energy and stress in the earth; on faults.
   c. ○ Because of landslides; on mountains.
   d. ○ Because of directivity; on faults.

4. What is the most common depth of an earthquake around the world?
   a. ☑ 0–70km, shallow
   b. ○ 70–300km, intermediate
   c. ○ 300–700km, deep

5. What is the correct earthquake process?
   a. ○ An earthquake occurs at the epicenter producing P, S and surface waves which travel through the earth to the site where the ground motion is felt.
   b. ☑ An earthquake occurs at the hypocenter producing P, S and surface waves which travel through the earth to the site where the ground motion is felt.
   c. ○ An earthquake occurs at the site producing ground motion which propagates waves towards the source.

6. Which of these are secondary hazards to earthquake shaking?
   a. ☑ Tsunami
   b. ☑ Fire
   c. ○ Cyclones
   d. ☑ Liquefaction
   e. ☑ Landslides
   f. ☑ Fault Rupture

7. What are the 2 best ways to measure the size of earthquake ground motion at a site?
   a. ☑ Using only Human Impact Indices (Intensity).
   b. ○ Using only duration.
   c. ☑ Using only accelerometers (Acceleration).

8. Where does the most amplification of soils occur?
   a. ○ Rock sites
   b. ○ In water
   c. ○ Far away from a fault
   d. ☑ In loose soils or valleys

9. Calculate what the following acceleration will be using the following GMPE for a site which is 100km away from the hypocenter where a magnitude 7.0 earthquake occurs?
   a. ○ 10g
   b. ○ 2.5g
   c. ☑ 0.25g
   d. ○ 0.1g

Questions Related to Session 2: Vulnerability and Exposure Analysis

1. Which of the following are important exposure elements to characterize if you were doing an earthquake vulnerability assessment on a city scale?
   a. ☑ Residential, Commercial, Industrial Infrastructure.
   b. ○ Low-loss facilities.
   c. ○ Parks
   d. ☑ Large Loss Facilities
   e. ☑ Transportation networks
   f. ☑ Utilities and Lifelines
   g. ☑ High Risk facilities
   h. ○ Rivers

2. What are 5 main contributors to the vulnerability of buildings?
   a. ☑ Design of the building.
   b. ☑ Construction Material
   c. ○ Number of Doors
   d. ☑ Age of the building
   e. ☑ Irregularities in the building
   f. ☑ Location of the building
   g. ○ Rate of Construction.

3. Refer back to the Indian Earthquake Zone Map from the Earthquake Hazard Knowledge Checks. Which areas should have the buildings seismically designed?
   a. ☑ Zone V
   b. ☑ Zone IV
   c. ☑ Zone III
   d. ☑ Zone II

4. Which vulnerability method is analytical?
   a. ○ One that calculates vulnerability from historic earthquake damage loss ratios and assessment.
   b. ☑ One that calculates vulnerability via mathematical and mechanical formulae to characterize the given damage per ground motion.

5. What does 0.85 mean as a damage ratio value in a Damage Probability matrix for a group of buildings of a certain material? Is it a high or low value of damage?
   a. ○ 85% of buildings will be destroyed; Low.
   b. ○ 85% of buildings will be destroyed; High.
   c. ○ Each of the buildings will have 85% damage; Low.
   d. ⊘ Each of the buildings will have 85% damage; High.

6. There is a 5-storey building and the peak acceleration occurs at 0.5 seconds. Would the building be expected to vibrate strongly?
   a. ⊘ Yes
   b. ○ No

7. The capacity spectrum method has been undertaken and it has been found that a group of certain buildings has a high spectral displacement = strong shaking, on the following diagram. What are the percentages of buildings in certain damage states?
   a. ○ 50% slight, 50% moderate.
   b. ○ 10% none, 90% complete.
   c. ○ 100% moderate, 80% extensive, 20% complete.
   d. ⊘ 20% moderate, 60% extensive, 20% complete.

8. What is the order of vulnerability methods from least data to most data required i.e. least complex to most complex?
   a. ⊘ Qualitative, Damage Probability Matrix, Capacity Spectrum Method.
   b. ○ Damage Probability Matrix, Capacity Spectrum Method, Qualitative.
   c. ○ Capacity Spectrum Method, Qualitative, Damage Probability Matrix.

9. Why is socio-economic vulnerability so important to quantify?
   a. ○ Because earthquakes only occur in rich countries.
   b. ○ It is not important.
   c. ⊘ Because it can multiply the direct physical vulnerability many times in terms of an aggravating factor.

Questions Related to Session 3: Earthquake Loss Estimation

1. What are the key tools for earthquake loss estimation?
   a. ○ Exposure, Hazard, Mitigation, Mediation.
   b. ○ Preparedness, Direct Risk, Vulnerability.
   c. ⊘ Exposure, Vulnerability, Hazard and Damage-Loss Conversion.

2. What is the difference between risk and hazard for earthquakes?
   a. ○ There is no difference, they are the same.
   b. ○ Hazard is the amount of losses or damage that could occur at a certain location and risk is the probability of occurrence of ground shaking in time.
   c. ⊘ Risk is the amount of losses or damage that could occur at a certain location and hazard is the probability of occurrence of ground shaking in time.
   d. ○ I know there is a difference, but I need to reread the notes.

3. What is a mean damage ratio?
   a. ○ The damage that has occurred in a location which is very mean.
   b. ○ The mean ratio of replacement to repair for a certain location.
   c. ⊘ The mean ratio of repair to replacement for a certain location.

4. Which color geocells have the highest average economic loss?
   a. ○ White
   b. ⊘ Black
   c. ○ Light Grey
   d. ○ Dark Grey

5. Why does each geocell have a different MDR value?
   a. ⊘ Because each geocell has different building types, distance from the fault and soil types.
   b. ○ Only because of the distance from the fault.
   c. ○ Because each geocell has different social losses.

6. What are components of direct socio-economic effects?
   a. ⊘ Deaths, injuries, repair and reconstruction costs.
   b. ○ Temporary shelter, follow-on effects, downtime of utilities.

7. Which of the following indirect socio-economic effects are hazard independent?
   a. ○ Business interruption
   b. ○ Flow-on lifeline problems
   c. ⊘ Economic vulnerability
   d. ⊘ Coping capacity

8. What are the key components in the earthquake cycle?
   a. ○ Awareness, Policy, Preparedness, Flow-on effects, Reconstruction.
   b. ○ Repair and Reconstruction.

c. ⊘ Response & Recovery, Earthquake Loss Analysis, Policy, Mediation, Mitigation, Preparedness
d. ○ Coping capacity, Economic vulnerability, business interruption.

9. Why is earthquake loss analysis important?
   a. ○ Because it provides results that policymakers can employ to improve earthquake design.
   b. ⊘ It provides a social and economic result that policy makers can understand and eventually use for mitigation and mediation purposes.
   c. ⊘ It can be used for response and recovery as a first order estimate where similar scenarios have been undertaken previously.

Questions Related to Case Study 1: An Earthquake Loss Assessment Procedure for a Fictional Town

1. What are some components of hazard that need to be taken into account?
   a. ○ Characterization of infrastructure stock, population density, variability of infrastructure.
   b. ○ Damage Probability Matrices, capacity spectrum, displacement-based methods.
   c. ○ Loss assessment via economic means (direct and indirect).
   d. ⊘ Path and site effects, tectonic regimes, GMPEs, distance from fault, NEHRP site classification.

2. For the following types, rank the following in terms of expected vulnerability for Xa where post-1970 buildings are engineered and built to seismic codes? (Highest to lowest)
   a. ⊘ C-->A-->D-->B
   b. ○ A-->D-->B-->C
   c. ○ D-->C-->B-->A
   d. ○ A-->D-->C-->B

3. In the Cauzzi and Faccioli (2008) GMPE which of the two options would be expected to have higher ground motions at the site, given all other factors staying the same? Distance:
   a. ○ 200km from a strike-slip fault
   b. ⊘ 50km from a strike-slip fault

4. In the Cauzzi and Faccioli (2008) GMPE which of the two options would be expected to have higher ground motions at the site, given all other factors staying the same? Site Velocity ($V_{s,30}$):
   a. ⊘ Vs,30 = 150m/s
   b. ○ Vs,30 = 760m/s

5. In the Cauzzi and Faccioli (2008) GMPE which of the two options would be expected to have higher ground motions at the site, given all other factors staying the same? Magnitude (Mw)
   a. ⊘ Mw=7.8
   b. ○ Mw=6.8

6. In the Cauzzi and Faccioli (2008) GMPE which of the two options would be expected to have higher ground motions at the site, given all other factors staying the same? Depth of hypocentre (km)
   a. ○ 150km
   b. ⊘ 20km

7. In the Cauzzi and Faccioli (2008) GMPE which of the two options would be expected to have higher ground motions at the site, given all other factors staying the same?
   a. ○ 1.00
   b. ○ 0.03
   c. ⊘ 0.70
   d. ○ 0.67

Questions Related to Reading 1: Simplified Earthquake Loss Estimation through use of RADIUS

1. What was the reason for most of the damage in the 1985 Mexico City earthquake given that the distance was approximately 400km from the source to the site?
   a. ⊘ Longer period (high-rise) buildings collapsed due to wave action in the soft clay surface, amplifying the ground motion.
   b. ○ All buildings collapsed due to the proximity to the fault and the high ground motion attenuation.

2. When lifelines are affected by earthquakes, what other considerations must be made?
   a. ○ Delays that may occur to emergency response and recovery activity.
   b. ○ The improvement to emergency response and recovery activity that may occur.
   c. ○ The impact on daily life.
   d. ○ The cost impact on business interruption.

3. Rank the following in order of expected physical vulnerability where there was the proportion of earthquake energy occurring at longer periods – Most vulnerable first, to least vulnerable last.
   a. ○ B-->C-->A-->D
   b. ○ A-->D-->C-->B

c. ⊘ D-->C-->A-->B
d. ○ A-->B-->D-->C

Questions Related to Reading 2: Earthquake Vulnerability of Buildings and a Mitigation Strategy

1. What method is proposed to retrofit the existing building stock of 800000 buildings?
   a. ○ Undertake a non-linear static procedure on each building to determine the capacity.
   b. ⊘ A screening method with prioritization for risk.
   c. ○ An engineering capacity assessment looking at recovery of buildings.

2. According to the 6000 damaging earthquakes that there is data for around the world in the last 110 years in CATDAT, approximately what percentage of social losses and economic losses are from secondary hazards, as distinct from earthquake shaking?
   a. ○ Social – 25%, Economic – 10%
   b. ○ Social – 50%, Economic – 50%
   c. ⊘ Social – 75%, Economic – 90%
   d. ○ Social – 88%, Economic – 88%

3. What type of accepted mitigation techniques can be done pre-disaster?
   a. ⊘ Prediction
   b. ○ Rehabilitation
   c. ○ Demolition techniques
   d. ○ Recovery plans
   e. ○ Relief operations
   f. ⊘ Preparedness
   g. ⊘ Awareness
   h. ⊘ Building code and Policy changes

4. At what periods is the HAZUS response spectrum generally constructed from?
   a. ○ No periods, it is intensity-based.
   b. ○ No periods, it is response spectrum based
   c. ○ Periods = 0.3 and 1.0sec
   d. ⊘ Periods = 0, 0.3 and 1.0sec

Questions Related to Reading 3: Building Technical and Political Capacity for Earthquake Risk Reduction

1. What makes a community vulnerable to earthquakes?
    a. ○ Seismically resistant construction
    b. ⊘ Low construction standards without lateral resistance
    c. ⊘ Siting of certain construction types
    d. ⊘ Building in coastal low lying areas near active fault systems
    e. ⊘ Communication and emergency control centers that are concentrated in a high-hazard location
    f. ○ Hospital facilities that are adequately built and prepared for large numbers of casualties.
    g. ⊘ Flaws in planning

2. What is the 3-step process for new construction to make it seismically (in order)?
    a. ⊘ Determine the temporal and spatial characteristics of the ground shaking and ground failure hazards the structure will be exposed to during its useful life.
    b. ○ Implement repair and strengthening program.
    c. ⊘ Adopt and implement state-of-the-art guidelines, siting criteria, standards, and regulations that set seismic safety policies, acceptable risk, and professional practices for the new development.
    d. ○ Identify the locations that are susceptible to potential flooding from tsunami flood wave run up.
    e. ○ Characterize each fault in terms of its earthquake potential, using geologic, geophysical, and geodetic and paleoseismology methods.
    f. ○ Identify the type of building or infrastructure being constructed, its uses, the characteristics of the proposed construction site, and the construction materials.

3. Which of the following is true of the performance of engineered buildings in earthquakes?
    a. ○ The poor, elderly, and disadvantaged are less likely to live in the most vulnerable buildings.
    b. ⊘ The performance of specific building types in an earthquake can be used as a guide for improving risk assessments and risk management.
    c. ○ Engineered buildings are likely to collapse in a major earthquake.
    d. ⊘ Buildings constructed in accordance with modern building codes perform well in earthquakes.
    e. ⊘ Unreinforced masonry buildings are more vulnerable to collapse than buildings constructed from other types of building materials like reinforced concrete and timber.

Assignment 2

Objective

The objective of the assignment is to provide a greater understanding of earthquake loss estimation, by requiring participants to undertake a simplified earthquake loss estimation procedure using RADIUS. Participants will need to follow the steps outlined in the assignment information. By completing this exercise they will have a better understanding of seismic vulnerability, hazard and exposure and will be able to apply the tool to the hypothetical case in the End-of-Course Project and undertake a full earthquake loss assessment.

Solution Template

The assignment information gives a step-by-step solution with screenshots, and therefore both participants and course facilitators can simply follow the instructions in RADIUS. By going through the steps and answering the questions, participants will understand the key concepts within the activity, yet will not get lost in the software.

While the entire exercise is self-contained and the solution can be easily followed in the course, the detailed description below will give facilitators a quick and simple solution key. This description should be used together with the step-by-step outline in the assignment information. Each step is illustrated in a screenshot. The end of this section has the answers to assignment questions.

Please note that the approach for solving the assignment can have 2 possible answers: one involves two geocells, and the other involves using eight geocells. Both are equally valid and shown below. The manual shows 8 geocells.

Make sure users have clicked "2.2 Generate Mesh". Notice that the mesh spacing must be 1 km to have the same area as indicated in the assignment manual. It should be recommended to people to use 0.5 km spacing and eight geocells, as more accurate answers occur as the distance in the GMPE will change accordingly, slightly varying the hazard at each geocell.

Basic Input Data

Epart is where the E type soils are and Beeville is where the B type soils are. We assume a mesh weight of 2 as the population density is expected to be average. It does not matter if users use other mesh weights. The local soil type is extremely important however—a value of 4 indicates Landfill/reclaimed land, and we can assume that our S-wave velocities are around this value. A

Figure 5.1 RADIUS Main Menu Screen

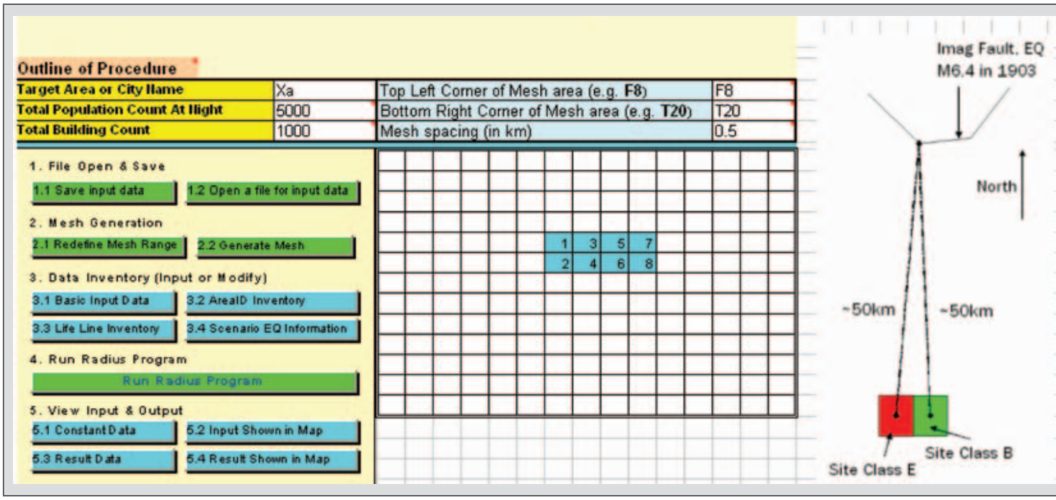


Figure 5.2 Main Menu Screen (shown here with two geocells)

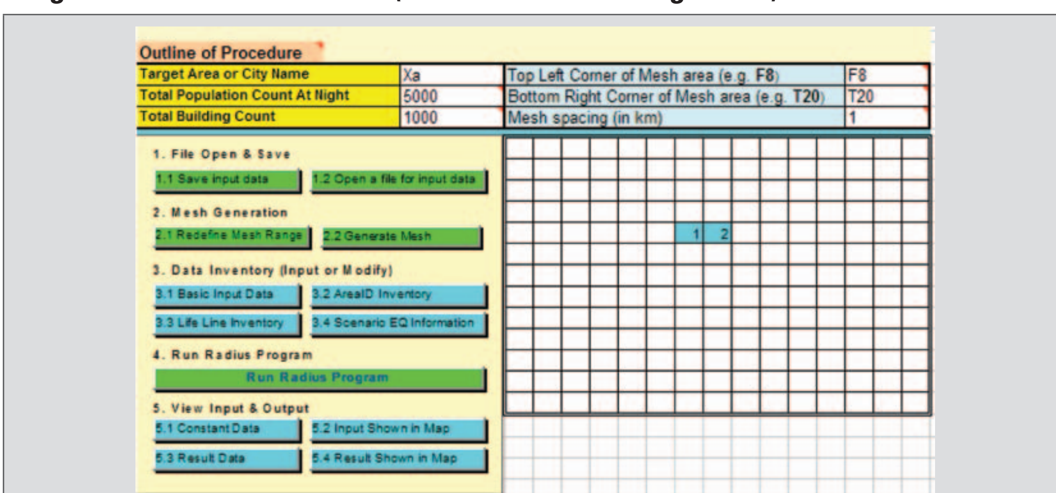
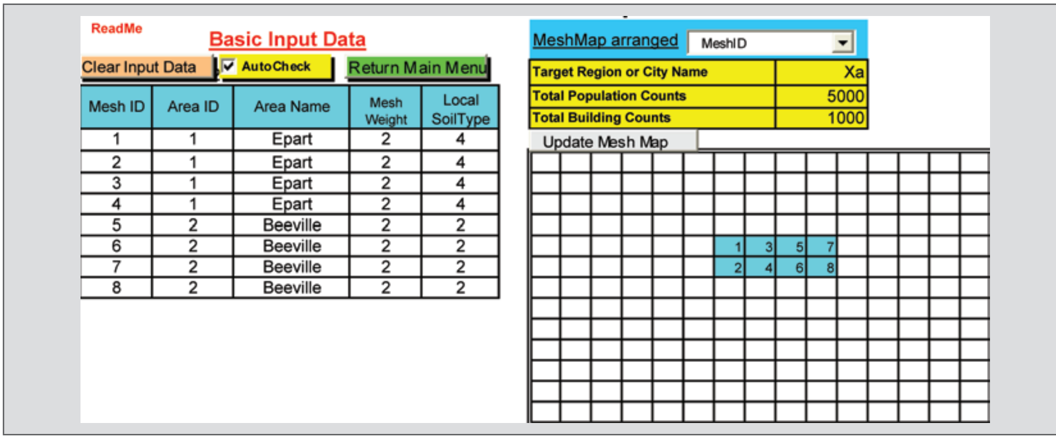
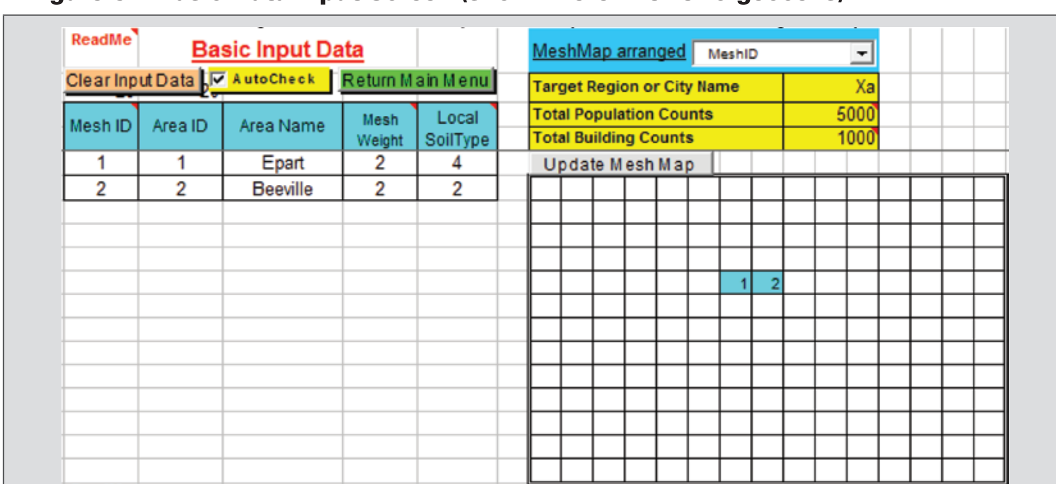


Figure 5.3 Basic Data Input Screen



value of 2 indicates soft rock—NEHRP B type. If users give a value of 3 and explain why, then they should not be penalised.

Figure 5.4 Basic Data Input Screen (shown here with two geocells)



Area ID Inventory

The area ID inventory will be the same for both two and eight geocell solutions. It is assumed that 50% of the buildings are pre-code, and 50% are engineered (post-code)

Figure 5.5 Area ID Inventory Screen

Inventory by Area

Read Me First | Clear Input Data | ☑ AutoCheck | Return Main Menu

Area ID	Area Name	RES1 (%)	RES2 (%)	RES3 (%)	RES4 (%)	EDU1 (%)	EDU2 (%)	MED1 (%)	MED2 (%)	COM (%)	IND (%)	Sum (%)
1	Epart	0.00	50.00	0.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
2	Beetown	0.00	50.00	0.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00

For our town there is no differentiation between timber and RC structures in RADIUS.

We define Post-1970 buildings as Res4 as they are designed under the latest code provisions.

We define Pre-1970 buildings as Res2 as they do not comply with local code provisions and <3 storeys

Lifeline Inventory

The lifeline inventory will be the same for both two and eight geocell solutions. These are assumed values using council data, if users put in other values they should not be penalized – it will not impact on the social losses.

Scenario Earthquake

The scenario earthquake will be the same for both two and eight geocell solutions. We put 0 for the depth, as we neglect it here for simplicity, assuming instead a shallow earthquake.

Then once everything has been checked, the user will run the program.

Part 1: Questions Regarding Earthquake Hazards

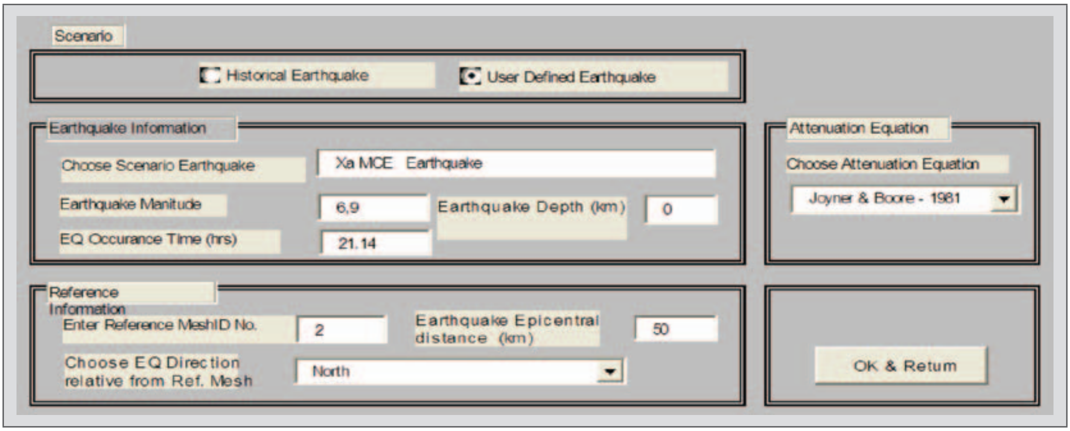
1. Where will there be higher ground motions? In Epart or Beeville? Why?
2. What are some of the secondary hazards that this location could be susceptible to given an earthquake of this magnitude?

Figure 5.6 Lifeline Inventory

Read Me First | Data Clear | Return Main Menu | AutoCheck

LifeLine	Total Count	Unit	Definition
Road1	8	km	Length of Local Roads (in km), for the concerned city or target region.
Road2	5	km	Length of major roads such as Freeways/ Highways (in km).
Bridge	1	Count	Number of major Transportation Bridges (road and railway).
Tunnels	1	Count	Number of major Transportation Tunnels, for the concerned city or target region.
Electric1	5	Count	Number of major Electrical & Telecommunication transmission towers.
Electric2	1	Site	Number of Electrical & Telecommunication sub-stations.
Water1	15	km	Length of major Water & Sewage trunk and distribution lines (km).
Water2	1	Site	Number of Water & Sewage pumping stations.
Water3	0	Site	Number of Water & Sewage treatment plants.
Reservoir1	0	Count	Number of Storage Reservoirs or Dams.
Reservoir2	1	Count	Number of Terminal Reservoirs or Elevated Storage Tanks.
Gasoline	1	Count	Number of Gasoline stations.

Figure 5.7 Scenario Earthquake Inventory Screen



3. Study the list of historical earthquakes below and answer the following:
   a) Which of these events do you think would have the highest ground motion at each city? (See Table 5.1.)
   b) Which of these events do you think would have the highest casualties at each city? (See Table 5.2.)
   c) Which of these events do you think would have the highest economic losses at each city? (See Table 5.3.)

Table 5.1 Question 3a

Highest Ground Motion	Earthquake	MMI	Moment Magnitude (Mw)
1	Tangshan	11	7.6
2	Nantou	10	7.6
3	Golcuk	10	7.6
4	Manjil	9	7.4
5	Baguio	9	7.7
6	Spitak	10	6.7
7	El Asnam	10	7.1
8	Kobe	11	6.9
9	Northridge	9	6.7

Table 5.2 Question 3b

Rank	Earthquake	HDI Value	Deaths	Injured	Homeless	Time of Day
1	Tangshan EQ, China	0.772	242,419	528,200	2,000,000	Night
2	Manjil EQ, Iran	0.782	45,000	60,000	50,000	Night
3	Spitak EQ, Armenia	0.798	25,004	82,000	517,000	Day
4	Kocaeli EQ, Turkey	0.806	17,439	43,953	675,000	Night
5	Kobe EQ, Japan	0.96	6,048	34,900	300,000	Night
6	El Asnam EQ, Algeria	0.754	2,633	23,369	443,000	Day
7	Luzon EQ, Philippines	0.751	2,430	3,513	1,193,716	Day
8	ChiChi EQ, Taiwan	0.943	2,416	11,443	600,000	Night
9	Northridge EQ, USA	0.956	72	9,138	20,000	Night

Table 5.3 Question 3c

Highest Economic Losses	Earthquake	2010 USD in Millions
1	Kobe EQ, Japan	178,473.5
2	Northridge EQ, USA	63,505.8
3	Tangshan EQ, China	41,375.0
4	Spitak EQ, Armenia	27,928.1
5	Kocaeli EQ, Turkey	21,810.1
6	ChiChi EQ, Taiwan	17,961.2
7	El Asnam EQ, Algeria	13,482.0
8	Manjil EQ, Iran	13,087.3
9	Luzon EQ, Philippines	2,453.9

There can be some variation around this list. If they rank it by MMI that can also be correct. The table above is based on Shakemaps from USGS.

Part 1: Answers

1. There will be higher ground motions in Epart due to the softer soils. This means that there will be ground motion amplification as the waves have a higher amplitude.
2.
   a) Landslides: there is a mountain nearby which could result in rock falls or landslides as a result of earthquake shaking.
   b) Liquefaction: the earthquake is of sufficient magnitude, and the sandy soils could be saturated. Geotechnical investigation should be undertaken.
   c) Fire: There is a possibility of fire, depending on if people are cooking, gas, oil or electricity problems occur or other earthquake related fire hazards. Tsunami and fault rupture are incorrect answers.

Part 2: Questions Regarding Vulnerability and Earthquake Loss Estimation

1. What are the social losses (deaths and injuries) and what is the mean damage ratio?
2. Where was more damage—in Epart or Beeville? Why?
3. Calculate the probable repair cost for the imaginary city given this earthquake and the results data you have at 100000 dollars replacement cost per building. Hint: Use the MDR, and the building cost given.
4. How could the secondary hazards, identified in Activity 1, impact on these loss estimates?

Part 2: Answers

1. The main check for facilitators is the deaths, injuries and damaged buildings calculation.

For two geocells, the following results are created:

Return to Main Menu | Six Tables included in this sheet

Table 1 --- Main Results

Max MeshID 2 | Total Building Count is 1000 | Total Population Count (night) is 5000

Mesh ID	Area ID	Area Name	Mesh Weight	Soil Type	Distance(km)	PGA (g)	MMI	Bldg Count	Dmg Bldg Count	MDR (%)	Pop Day	Pop Night	Injury (Severe &	Death
1	1	Epart	2	4	1.0	0.8	9.7	500	189	37.8	1250	2500	238	29
2	2	Beeville	2	2	0.0	0.5	8.8	500	134	26.7	1250	2500	163	17
					Average	Average	Averag	Total	Total	Averag	Total	Total	Total	Total
					Distance	PGA	MMI	Building	Dmg Bldg	MDR	Pop Day	Pop Night	Injury	Death
					0.5	0.7	9.3	1000	323	32.3	2500	5000	402	46

Deaths – 46, Injuries – 402, MDR average is 32.3%

For eight geocells, the following results are created:

Table 1 --- Main Results

Max MeshID 8 | Total Building Count is 1000 | Total Population Count (night) is 5000

Mesh ID	Area ID	Area Name	Mesh Weight	Soil Type	Distance(km)	PGA (g)	MMI	Bldg Count	Dmg Bldg Count	MDR (%)	Pop Day	Pop Night	Injury (Severe &	Death
1	1	Epart	2	4	0.5	0.8	9.7	125	47	38.0	313	625	60	7
2	1	Epart	2	4	0.0	0.9	9.7	125	48	38.0	313	625	60	7
3	1	Epart	2	4	0.7	0.8	9.7	125	47	37.9	313	625	60	7
4	1	Epart	2	4	0.5	0.8	9.7	125	47	38.0	313	625	60	7
5	2	Beeville	2	2	1.1	0.5	8.8	125	33	26.5	313	625	40	4
6	2	Beeville	2	2	1.0	0.5	8.8	125	33	26.6	313	625	40	4
7	2	Beeville	2	2	1.6	0.4	8.8	125	33	26.4	313	625	40	4
8	2	Beeville	2	2	1.5	0.4	8.8	125	33	26.4	313	625	40	4
					Average	Average	Averag	Total	Total	Averag	Total	Total	Total	Total
					Distance	PGA	MMI	Building	Dmg Bldg	MDR	Pop Day	Pop Night	Injury	Death
					0.9	0.7	9.3	1000	322	32.2	2500	5000	400	45

Deaths – 45, Injuries – 400, MDR average is 32.2%

2. In RADIUS, the vulnerability method is a vulnerability curve based on MMI (a fragility function). 46 deaths (29 in soft soil, 17 in soft rock) and 403 injuries and a mean damage ratio of 0.38 in the soft soil (Epart) and 0.267 in the soft rock (Beeville). Thus there was more damage in Epart.

3. Probable repair cost = 0.322*1000 buildings*$100000 = $32.2 million
4. Landslides could significantly increase loss. Liquefaction is probably not as damaging depending on conditions as it could only affect half of the town. Fire is a major concern due to the large amount of timber housing and close proximity of the town—1000 buildings in 2 square kilometres.

Module 2 Checklist	Grading points
Part 1: Earthquake Hazard	
Where will the highest ground motions be – in Epart or Beeville? Why? 1/2 point for correct answer (Epart), 1/2 point for explanation	1
What are some of the secondary hazards that this location could be susceptible to given an earthquake of this magnitude? Allocate point if one of the secondary hazards were identified.	1
Study the list of Historical earthquakes in Figure 8 (Part 1), and answer the following: Which of these events do you think would have the highest ground motion at each city? Which of these events do you think would have the highest casualties at each city? Which of these events do you think would have the highest economic losses at each city?	3 (per item)
Part 2: Vulnerability and Loss Estimation	
What are the deaths and injuries, and what was the mean damage ratio?	3 (per item)
Where was more damage – in Epart or Beeville? Why?	2
Calculate the probable repair cost for Xa given this earthquake and the results data you have. (Hint: Use the MDR, and the building cost given).	2
How could the secondary hazards identified in Activity 1 impact on these loss estimates?	2
Sum of grading points	15

Discussion Forum

Points to Emphasize
The discussions should emphasize the main messages of Module 2 with the following points:

Estimating the earthquake hazard and its uncertainties is the first step in an earthquake risk analysis and loss estimation

- The earthquake hazard can be analyzed from their beginning at the source, to the production of waves traveling through the earth, to the site on the earth's surface where damage occurs
- The shaking which is felt at the site is a function of the duration, amplitude and frequency of the ground motion; the distance away from the fault and the rupture length of the fault; as well as the local site conditions (i.e., soft soils can amplify the ground motion)
- Ground motion prediction equations are not exact because each earthquake has different source processes. Thus, the ground motion can never be 100% accurately represented. There are two types of uncertainty: randomness, and a second type due to a lack of knowledge
- Earthquake hazard analysis can be conducted using deterministic or probabilistic analysis, each of which has their particular uses

Estimating vulnerability is not a precise science. Fragility curves are important for estimating vulnerability of structures.

- Estimating vulnerability of the infrastructure to earthquakes is complex, yet there are some key characteristics that make one infrastructure type more vulnerable than others
- Even with respect to the more traditional methods of estimating vulnerability of physical structures, it is very difficult to obtain precise estimates of vulnerability. How do we know for certain the way a building was built? Even if we know that the building is a concrete building built from a certain strength of concrete—say 30 MPa concrete, there is still variability due to the way that the concrete is poured, and also because the concrete could be 35MPa or 28MPa in terms of strength
- There are many uncertainties in vulnerability estimation due to the differences in design, construction, etc.
- Fragility curves are important tools allowing engineers to group buildings in different classes and estimate (based on analytical models, physical experiments and past earthquake behaviour) building reaction to earthquake forces
- Exposure to earthquakes is increasing, and by accurately quantifying the critical infrastructure types for earthquake loss estimation, the better the result
- Social loss functions in earthquake loss estimation derive casualties as a function of building collapse based on empirical studies of past earthquakes. Evidence of past earthquake may have limited applicability to collapses of buildings in parts of the world where no data has been collected and casualty rates based on past data can be very misleading
- Human reactions will also be different in every case, and buildings will collapse differently every time

- The time of day is also an extremely important factor in loss estimation. Note it is impossible to know exactly where people are at certain point in time as there are changes from day to day due to traffic patterns, appointments and meetings, and other changes
- Similarly it is very difficult to calculate economic effects exactly, as there are subjective factors related to housing and repair costs. The best proxies to estimate use insurance data and house valuations etc.

Earthquake Loss Estimation is a powerful tool for disaster risk management planning and earthquake risk reduction.

- Earthquake Loss Estimation has many uncertainties yet by knowing the basics of exposure, vulnerability and hazard, it is possible to construct a simple earthquake loss estimation result for any region in the world
- There is no ideal approach in analyzing earthquake losses and many tools area available. Depending on the level of information and data, certain earthquake loss estimation procedures will be better than others

Recommended Initial Questions

In the beginning of the second week, facilitators can start the discussion with reference to the previous week, for example*, "I hope all of you had a very good weekend. During the last week discussion we were able to identify different aspects of vulnerability and recognize specific risk analysis approaches and instruments that can be useful in your areas. This week, we are going to focus on the application of these techniques to analyze earthquake risk."* The following are suggested questions for the second week:

Discussion Question 1: Do you expect an earthquake to occur in your area in your lifetime? What is the general level of perception of earthquake risk in your community? What program and measures have been employed in your community to mitigate the threat of earthquakes? Also, if you have experienced an earthquake please explain when this was, what you felt and what impacts this has had on you.

Discussion Question 2: Earthquakes can result in huge devastations of built environment and large number of deaths especially in developing and underdeveloped countries. To mitigate the impending earthquake risk, one of the prerequisite is the earthquake risk analysis. Please discuss the availability of various tools and techniques to assess the earthquake risk at national and international level.

Discussion Question 3: What are the attributes of people, society, infrastructure and cultures that make them vulnerable to earthquakes? In what way earthquake hazards as low probability events with severe consequences different from other more frequently occurring natural disasters?

Recommended Follow-up Questions

The questions should reflect and underline the main themes in Module 2, which have been described earlier. At the end of week 2, facilitators can start to make references to assignments and ECP: *"It is nice to note that several of you have discussed tools and techniques available to assess the earthquake risk. In the assignment included in this module and for the End of Course Project we will use the RADIUS loss estimation software. Hopefully, you have already had a chance to get started the assignment. Reflecting on the material of the three sessions in Module 2 and the use of the RADIUS in carrying out earthquake loss estimation, please discuss the following:"*

Follow-up Question 1 (Earthquake Hazard): Why are ground motion prediction equations are not exact?

Follow-up Question 2 (Earthquake Vulnerability): Why can't we calculate vulnerability exactly? What are the differences in exposure?

Follow-up Question 3 (Earthquake Loss Estimation): What are the sources of uncertainties in earthquake loss estimation? Why can't we know exactly how many people will die in an earthquake?

Follow-up Question 4 (Related to RADIUS Assignment): The following are examples of some possible follow-up questions with respect to the RADIUS assignment:

Put yourself in the perspective of a decision-maker responsible for the future of the city for which you have just completed the risk analysis assignment with RADIUS. Having just seen the earthquake loss estimation results—46 deaths, 400 injuries and mean damage ratio is 0.323 for a town of 5000—what can be done if the town is expected to grow to the size of 50000 people within 10 years due to some mining discoveries. How would the expected death toll be affected then? How does this change your decision?

Discussion Question 4 can be organized as a role playing exercise, and you may ask participants to take the following roles and answer the questions from the perspective of their roles:

- Experts (having the knowledge now from this course)
- Local government officials (what do they want to get out of earthquake policy change?)
- Local homeowners (are they interested in earthquakes?)
- National government officials
- Local business owners (or industrial chamber)
- Disaster management specialists

The following questions should be helpful:

- Is there a solution that would be in the interest of every stakeholder?
- Now that you know about DSHA and PSHA, and using your new roles, what do you think will be your strategic interest?
- What could be the possible mitigation and mediation strategy? How will that affect your way of life?
- Which values do you trust more; RADIUS, or the case study method? Or should you do a PSHA and an analytical method?
- Given that the uncertainty in such analyses is usually quite high, how does this affect your decision-making?
- What finding would result in an expert opinion that the earthquake policy should change?
- What are the consequences for a town of 50,000 people with rapid construction?
- Where would be the best place to site a hospital to ensure that it can service a large number of injuries from such earthquake?

During the role-play facilitators should consider the following:

- There is usually no solution that is in every stakeholder's interest.
- Local homeowners in Epart may be very worried as they have a much larger chance of destruction given their soil type. Also with a rapidly growing population it has to be looked at which part of the town is expanding, Epart or Beeville.
- National government officials will always be worried about the amount of money that they need to invest in earthquake preparedness and policy change. As the next election is only four years away, they may be reluctant to do anything.
- Local business owners will be more interested in any effect that increases insurance rates and new mine owners would worry about the impact of earthquake policy on their business.

Please note there is no right or wrong answer here, and that the questions serve to initiate open discussions on some of the key points addressed in the presentations, and readings of Module 2. The discussions should also be based on the detailed results from the RADIUS and Case Study 1.

Guidelines for Preparing Discussion Summary
By the end of week two, the facilitator should cover all aspects of the module and highlight the main points described above during discussions. At the end of the week the facilitator should post a summary of discussions reflecting on the main topics 1–3 described above. The objective of the discussion summary is to have a record of discussions in a concise manner available to everyone. It should highlight the important issues discussed during the week and follow the broad discussion themes outlined in this chapter. It is important to emphasize that an experienced earthquake loss estimation engineer is always required to do a thorough analysis, but RADIUS does give a simplified view of the situation.

5.6 Suggested Additional References

5.6.1 Reports for further reading

ALNAP: Learning from earthquake recovery. South Asia.

FEMA, HAZUS-MH Technical Manual. 2010. Federal Emergency Management Agency, Washington D.C., USA

Natural Disaster Hotspots Case Studies—Multi-risk in Caracas. World Bank

5.6.2 Online Resources

Earthquakes Explained: http://pubs.usgs.gov/gip/2006/21/ – Earthquake Science Explained is a series of 10 short articles for students, teachers, and parents that were originally published as weekly features in the San Francisco Chronicle. The U.S. Geological Survey created the series to present new understandings gained and scientific advances made in the century since the 1906 San Francisco earthquake.

GeoHazards International – RADIUS Project: http://www.geohaz.org/index.htmlIncluded are a description and outline of the RADIUS project, case studies from around the world, guidelines for developing local RADIUS-type risk management projects, a description of a

"Tool for Earthquake Damage Estimation" developed for RADIUS and available on CD, a comparative study of the RADIUS initiative around the world, and a project evaluation

Seismosurfing – http://www.geophys.washington.edu/seismosurfing.html – "Seismosurfing" is an index of known Internet connections where seismic data or seismic research information are available. It also offers instructions for persons without access to the World Wide Web about obtaining seismic data.

Earthquake Animations: http://earthquake.usgs.gov/learn/animations/ – Users can find learning tools related to earthquake concepts

CAPRA www.ecapra.org – An online earthquake loss estimation tool for Central America providing some good examples.

EERI – http://www.world-housing.net – World housing encyclopaedia showing some of the different housing types around the world and their response to earthquakes.

PEER – http://peer.berkeley.edu – Pacific Earthquake Engineering Research Center provides many useful tools and reports on earthquakes.

FEMA – http://www.fema.gov/hazard/earthquake/ – Earthquake Publications and Tools

5.6.3 Publications

Applied Technology Council. Earthquake Damage Evaluation Data for California. ATC-13. Applied Technology Council, Redwood City, CA, 1985.

Bostrom, A., Turago, R.M.R., Ponomariov, B. (2006). "Earthquake Mitigation Decisions and Consequences," Earthquake Spectra, Vol. 22, No. 2, pp. 313–327, May.

Carreno, M.L., Cardona, O.D., Barbat, A. 2007. Urban Seismic Risk Evaluation: A Holistic Approach. Natural Hazards Journal. 40 (1):137–172.

Chen, W-F., Scawthorn, C. 2003. Earthquake Engineering Handbook, CRC Press, Japan

Coburn, A., Spence, R. 2002. Earthquake Protection. John Wiley, Chichester, U.K.

Davidson, R. 1997. An Urban Earthquake Disaster Risk Index. The John A. Blume Earthquake Engineering Center. Report No. 121. Stanford, California.

Grünthal, G. 1998. European Macroseismic Scale 1998. Cahier du Centre Europeén de Géodynamique et de Séismologie, Vol. 15, Luxembourg, Luxembourg.

Kramer, S.L. 1996. Geotechnical Earthquake Engineering, Prentice-Hall, New Jersey, USA.

Shaw R. K. 2000. RADIUS Evaluation for Asian Cities: Bandung, Tashkent and Zigong in United Nations International Strategy for Disaster Reduction (UN-ISDR) RADIUS Year-later Evaluation, Geneva, Switzerland.

Wyss, M. 2004a. Earthquake loss estimates in real-time begin to assist rescue teams worldwide. EOS. Vol. 85. p. 567.

VI. Module 3: Flood Risk Analysis

6.1 Module Description

With economic growth, urbanization and the subsequent concentration of population and property, in many countries people who have never experienced flood earlier are moving in increasing numbers to flood-prone areas. In regions where flood control facilities have been improved and the frequency and magnitude of inundation are reduced, residents are less aware of the threat of floods. In such cases, the population is hardly prepared for floods and by no means capable of taking proper actions, consequently suffering more serious damage once a flood occurs.

It can be time-consuming and costly to build flood control facilities to lower the risk of flood damage. Therefore, it is recommended to enhance local residents' awareness of the importance of flood protection efforts and, in parallel, develop flood control facilities to mitigate flood damage. Flood risk analysis has a crucial role in achieving this objective. It makes local residents aware of the vulnerability of their living space, the roles they can play in disaster prevention activities and in evacuation in the event of floods. The combination of these private measures with centrally planned flood mitigation leads to an increased societal resilience to floods—the overall aim of flood risk management.

The module structure follows the fundamental definition of risk as a combination of hazard and vulnerability. The first session, "Flood Hazard Analysis," introduces concepts of estimating flood hazards defined by several intensity parameters and a probability of occurrence. The second session introduces the principles of flood vulnerability analysis by explaining exposure mapping and estimation of flood susceptibility. And finally, the third session combines hazard and vulnerability analysis into a flood risk analysis. It also introduces the flood risk management procedure.

6.2 Learning Objective

The following part of the course reviews the hazard and vulnerability components of flood risk analysis and presents approaches and tools for conducting flood loss estimation.

This module aims to:

- Presenting an understanding of characteristics of flood-prone areas and the factors affecting and determining the scale (force) of the flooding (hazard factors)
- Explaining flood causes (precipitation, current land use, soil infiltration capacity, retention capacity, etc.)
- Reviewing the procedures to estimate the scale (force, magnitude) and probability of occurrence of the expected flooding
- Introducing methods to estimate vulnerability of infrastructure, people and their livelihoods to floods

At the end of the module participants will know:

- How flood-prone areas are delineated
- How flood intensities are mapped
- The essential elements of a flood vulnerability analysis
- What factors affect flooding and how the scale and frequency of a future flood event is estimated.
- How to combine hazard and vulnerability analysis to a flood risk analysis
- How the analysis of flood risk can be visualized and used for flood risk management

6.3 Main Terms

Session 1
Flood Hazard, Hydrological Cycle, Flood Intensity Index, River Floods, Coastal Floods, Urban Floods, Rainfall Runoff Modeling, Frequency Analysis, Discharge Time Series, Hydrographs, Hydraulic Modeling, Inundation Depth, Inundation Extent , Inundation Timing, Inundation Duration, Flow Velocities, Flood Simulation (1D, 2D), Climate Change And Floods

Session 2
Vulnerability Analysis, Elements at Risk (Societal, Economic, Cultural, Environmental), Exposure Databases, Susceptibility, Flood Plains, Flood Impacts (Losses), Flood Awareness, Flood Preparedness, Micro-and-MesoScale of Analysis, Flood Loss Assessment (Buildings, Agriculture, Life)

Session 3
Flood Risk, Flood Risk Management Cycle, Risk Identification, Scenario Definition, Risk Curves, Risk Maps, Uncertainties, Flood Risk Appraisal, Flood Risk Mitigation, Early Warning System, Flood Forecasting, Residual Flood Risk Management, Flood Risk Communication

6.4 Key Points to Emphasize

The main messages related to risk analysis are grouped according to the three components of this module: flood hazard analysis, flood vulnerability analysis and flood risk management. The key points reflect the essence described in the presentations, readings and case studies of this module.

- *Flood hazard analysis:* determines the locations and areas potentially threatened by flooding, the time, frequency (i.e. seasons, cycles, frequency), and the intensity and duration (scale, force) of expected future floods. Depending on the scope of the analysis, flood hazard analysis requires different type of information. The analysis often includes information on flood extent and inundation depths, inundation timing and duration, flow velocities and intensity index, and the product of depth and velocity. The information generated by hydraulic modeling, i.e. the simulation of the water flow on the land surface and displayed in hazard maps. Hydraulic modeling takes the anticipated flood events as input and simulates the propagation of water on the land surface. The simulation results provide the basis for mapping the information. Geographic Information Systems (GIS) are the standard tools for spatial visualization of these data. Working with GIS is a basic requirement in flood risk analysis.
- *Flood vulnerability analysis:* addresses questions related to vulnerability of people, asset and environment, and the way these elements are affected by flood. Flood losses are determined by the combined effect of impact and resistance. Vulnerability is a dynamic concept, as both exposure and susceptibility change constantly. River trainings, extended use of floodplains due to population and urban growth, accumulation of valuable goods

in flood prone areas and the decrease in flood awareness and preparedness are responsible for increasing losses from floods. From this follows that flood risk management should aim not only at the hazard mitigation, but should also address vulnerabilities and flood awareness and preparedness.

- *Flood management and risk communication:* Flood risk management involves dialogue and requires communication: communication of the risk itself to all stakeholders; from the relevant levels of government to the individual citizens as well as communication among the concerned. The success of communication depends on various factors, one of them is the integration of a communication component in each phase of the risk management cycle, from risk identification though the planning and implementation of risk mitigation measures to disaster management. It should be noted that public acceptance of structural flood mitigation measures are a necessary precondition to risk reduction. Additional requirements include raised flood awareness, public participation in developing sustainable mitigation solutions, and incentives for individual action and responsibility. All these can be promoted by well well-designed flood risk communication. Communication also contributes to establishment of effective flood warning systems and communication channels.

6.5. Learning Material and Activities

6.5.1 Presentations

Session 1: Flood Hazard Analysis

Objective

This session introduces flood hazard assessment through definitions, key concepts, methods and tools. It reviews the basics of hydrology, explains the hydrological cycle and highlights the causes of floods. This session also introduces additional flood categories according to their sources and characteristics. The fundamental elements of flood and the methods to estimate flood magnitudes for varying probabilities of occurrence are also discussed with emphasis on statistical methods. This session introduces hydraulic modeling for converting estimated flood magnitudes into inundation areas taking into consideration dike failures as well. Finally, this session discusses the impact of climate change impact on flood hazard.

Key Points:

- How to determine which areas are flood prone
- How to determine magnitudes of different floods and the probabilities of their occurrence
- How to estimate inundation extents, depths, and other flood impact factors
- How flood defenses are integrated into hazard assessment
- The impact of climate change on flood patterns and frequency

Session 2: Flood Vulnerability Analysis

Objective
This session introduces flood vulnerability analysis, including key concepts and methods. As in previous modules, flood vulnerability is defined in broad terms. First, it describes the elements at risk and their exposure. Following the exposure analysis, the susceptibility analysis is explained with methods for their quantification for buildings, humans and agriculture. This session also introduces different effects of flood impact and resistance. Because susceptibility analysis and damage estimation are typically done regionally the session reviews ways of damage data collection and development of damage models.

Key Points:

- What and who is at risk of flooding
- What and who is exposed to floods
- The susceptibility of exposed elements at risk and how to calculate it
- Identification and quantification of resilience to floods

Session 3: Flood Risk Management

Objective
In this last session we guide participants through the actual flood risk assessment by combining flood hazards and vulnerability to a quantitative risk analysis. We illustrate the procedure schematically with a flow chart and describe how to demonstrate and interpret flood risk. We discuss scale considerations and data requirements for the analysis as well. The session goes beyond the flood risk analysis by embedding it into the flood risk management cycle, the basic concept of flood risk management. In order to establish reasonable, adaptable and sustainable flood risk

management strategy, the overall objective of flood risk management for increased societal resilience, the session reviews the steps to be taken following the quantitative flood risk analysis.

Key Points:

- How hazard and vulnerability analysis is combined in risk analysis
- How risk estimates are presented and displayed
- How risk analysis results serve flood risk management
- The general principle of flood risk management
- The objective of flood risk management and the elements of related procedures

6.5.2 Case studies

Overview

The flood risk module is accompanied by two case studies highlighting different aspects of flood risk analysis. Both studies cover risk analysis elements, hazard and vulnerability, and therefore closely linked to Session 3 of the module. However, select aspects of case studies refer to the first two sessions so it is recommended that participants review the first two sessions before starting to work on the case studies.

The first case study elaborates on the different models used in flood risk assessments on both the hazard and vulnerability side and assesses their appropriateness to the given problem and data. The object of the study is the city of Eilenburg in Eastern Germany. The city suffered extraordinary damages in the century flood of 2002. In the aftermath of the event, a large dataset was created on inundation extent, depths and actual damages. Models of different complexity in terms of data requirements, objective, and hardware were applied and tested on the collected data. This method determined the best compromise between necessary model complexity and tolerable simplification. The study also allows a deeper view into the applied models: whereas the results can serve as a guideline for selecting models in similar settings.

The second case study presents a first approach on estimating potential flood risks on a continental scale. The objective of the study was to estimate the damage potential with a probability of 1 into 100 years for riverine flood events for the whole European Union, and to show the spatial distribution of potential damage. The resulting map supports the implementation of the European strategy to mitigate flood risks as defined in the European Flood Directive. It also guides the allocation of disaster relief funds in case of trans-national flood events. In the context of the course, the study intends to serve as a reference for the applicability, advantages, limitations and data needs for large large-scale risk assessments.

Case 1: Model Comparison in Flood Risk Assessment at Eilenburg, Germany

This case study describes the different models used in flood risk assessments on both the hazard and vulnerability side. It also evaluates the appropriateness of the models to the given problem and data. The study object is the city of Eilenburg in Eastern Germany, which suffered extraordinary damages in the century flood of 2002.

Key Points:

- Trade-offs between model complexity and simplicity as a key criteria for flood model selection
- Comparative hazard model assessment
- Comparative loss model assessment
- Evaluation of risk analysis

Case 2: Flood Damage Potential at European Scale

This case study presents a flood exposure map on the continental scale. It is based on the project implemented in the European Union. The objective was to calculate the damage potential for riverine flood events with a probability of 1 into 100 years, and to show the spatial distribution of potential damage across Europe. The case highlights the importance of baseline data and geographical information such as records of disaster losses, flood damage potential and flood risk maps as fundamental aspects of decision decision-making and effectiveness of public policies designed to reduce losses from natural hazards.

Key Points:

- In the context of the course the study serves as a reference for the applicability, advantages, limitations and data needs for large large-scale risk assessments
- Approach on estimating potential flood risks on a continental scale is illustrated
- Spatial distribution of damage potential for 100-year floods for all of Europe
- Large-scale hazard analysis

- Comparable inter-country damage analysis
- Large-scale cumulated risk analysis and presentation

6.5.3 Readings

Overview

The readings included in this module provide additional guidance on the application of flood risk mapping based on hazard mapping experience in Europe. The readings are based on the "Handbook on Good Practices for Flood Mapping in Europe, published by the European Union. The information from this handbook was amended with practical guidance on damage data collection and on developing damage models.

Reading 1: Flood Hazard Analysis

In this reading the core aspect of hazard assessment, the development of flood hazard maps, is described including data collection, scale issues, flood modeling, and graphical presentation in maps.

Key Points:

- Production and visualization of flood hazard maps
- Data collection and scale issues

Reading 2: Flood Vulnerability Analysis

This reading deals with the most important steps in vulnerability analysis, the process of collecting data on the elements at risk (i.e., their exposure), their mapping, the development of loss models (i.e. estimation of the susceptibility of elements at risk). As in Reading 1, this paper intends to deepen the understanding of conceptual issues while giving practical guidance as well.

Key Points:

- Process of flood vulnerability analysis
- Steps in establishing a flood loss model
- Data collection on the elements at risk and their mapping

Reading 3: Flood Risk Management
The reading gives additional details on how to develop risk maps. Different types of maps can be created depending on the purpose of the exercise: planning, insurance, emergency response. Maps also differ according to the layout, map design, the type of risk visualized and meta-data compilation. It is important to design user-specific dissemination strategies for risk maps and risk information.

Key Points:

- Process of flood risk management
- Development of flood risk maps and how they are used
- Visualization and presentation of flood risk maps

6.5.4 Activities

Knowledge Checks
The topics of the questions cover the theoretical foundations, methods, practical aspects of flood risk analysis and the communication aspect of flood risk assessment.

Questions Related to Session 1: Flood Hazard Analysis

1. What are the causes of floods?
   a. ○ Excessive rainfall
   b. ○ Exceedance of retention capacity of the catchment (i.e. infiltration capacity of soils, surface storage)
   c. ○ Exceedance of conveyance capacity of river channels
   d. ☑ All of the above

2. What flood cause is specific for urban areas?
   a. ○ Overland flow
   b. ☑ Sewer blockage
   c. ○ Dam breach
   d. ○ Alluvial river flooding

3. What inland flood type has the shortest lead time and highest flow velocity?
   a. ○ Tsunamis.
   b. ○ River floods

c. ⊘ Flash floods
d. ○ Groundwater floods

4. What additional hazard is caused by coastal storm surges?
   a. ⊘ Wave impact
   b. ○ Mud flow
   c. ○ Gravel transport
   d. ○ High rainfall

5. How is the magnitude of a flood defined?
   a. ○ By maximum discharge.
   b. ○ By flood volume
   c. ○ By flood volume
   d. ⊘ By either one or a combination of the above*

6. How is the flood intensity index defined?
   a. ○ Flow velocity divided by water level.
   b. ⊘ Flow velocity multiplied by water level
   c. ○ Flood velocity multiplied by flood volume
   d. ○ Water level + lead time

7. What characterizes a one-dimensional hydraulic model?
   a. ⊘ That the flow is simulated in one spatial dimension parallel to the river course.
   b. ○ That the flow is simulated in the time domain only.
   c. ○ That only one river reach can be simulated at a time.
   d. ○ That the flow is simulated over a rectangular grid

8. Why are dike failures important for riverine flood risk assessments?
   a. ○ This is a misunderstanding, they are not important at all. Dikes are always safe.
   b. ○ Because they are hard to predict.
   c. ⊘ Because they cause severe inundations and alter the flood magnitude in the downstream river reaches.
   d. ○ Because they are hardly monitored.

9. What are the general expected impacts of climate change on floods?
   a. ○ Generally floods will not change with climate change.
   b. ○ With raised temperatures evaporation will increase, thus floods will decrease.
   c. ○ A warmer climate cause less rainfall and thus less floods.

d. ⊘ An increased energy content of the atmosphere, both sensible and latent, will cause more frequent and more intense rainfall events, thus floods have to be expected to increase in frequency and magnitude in general.

Questions Related to Session 2: Flood Vulnerability Analysis

1. What is not the purpose of flood vulnerability analysis?
   a. ○ As a basis for cost-effective planning of flood mitigation
   b. ○ As a basis for cost-effective planning of flood mitigation
   c. ⊘ Determining the extend of a 100-year flood
   d. ○ Supporting emergency planning for flood catastrophes

2. On which sector focuses an encompassing flood vulnerability analysis?
   a. ○ Environment
   b. ○ Economy
   c. ○ Society
   d. ⊘ All of the above

3. What is the recommended tool for flood exposure mapping?
   a. ○ Analog maps
   b. ○ Photographs
   c. ⊘ GeoInformation Systems GIS
   d. ○ Remote sensing images

4. What are the causes of the increasing flood losses in the past decades worldwide, besides increasing number of flood events?
   a. ○ River training
   b. ○ Increasing use of flood plains for urban development
   c. ○ Decreasing awareness of flood risk
   d. ⊘ All of the above

5. What factors have to be considered when assessing the susceptibility to flooding of elements at risk?
   a. ○ The flood impact
   b. ○ The resistance to floods
   c. ⊘ Both flood impact and resistance to floods
   d. ○ The exposure of the elements

6. What characterizes micro-scale loss estimations?
   a. ○ Regional risk analysis
   b. ○ Cumulated loss estimation
   c. ☑ Object specific loss estimation
   d. ○ Aggregated data input

7. Why are flood loss data important?
   a. ☑ Because they enable loss model development
   b. ○ Because they enable loss model validation
   c. ○ Because they enable regional loss model adaptation
   d. ○ All of the above

8. What is the advantage of relative flood loss assessment models over absolute loss models?
   a. ○ They can include uncertainty estimates.
   b. ☑ They can be adapted to different regions and economic developments
   c. ○ They allow the inclusion of expert knowledge.
   d. ○ They establish a correlation of flood impact factor to damage.

9. What has to be specifically considered when estimating agricultural losses?
   a. ○ The market value of the crop
   b. ○ The type of harvesting
   c. ○ The geographical region
   d. ☑ The phenological state of the crop and the season of the year

Questions Related to Session 3: Flood Risk Management

1. Why do we have to live with risks?
   a. ○ Because disasters are naturally occurring phenomena
   b. ○ Risks are a consequence of our vulnerability to natural disasters
   c. ○ We can by no means guarantee absolute safety
   d. ☑ All of the above

2. What is the overall aim of the flood risk management cycle?
   a. ○ An encompassing set of flood scenarios and damages associated with probabilities of occurrence
   b. ○ Minimizing risks by technical flood defense

   c. ⊘ An open dialog between all stakeholders on all societal levels to increase societal resilience to floods
   d. ○ Appropriate disaster management

3. What is the basis of flood risk analysis?
   a. ⊘ An encompassing set of flood scenarios and damages associated with probabilities of occurrence
   b. ○ A profound analysis of the hazards
   c. ○ A profound analysis of the vulnerabilities

4. What is the correct process chain of a flood risk analysis?
   a. ○ Estimation of flood magnitude —> exposure mapping of elements at risk —> derivation of inundation area and depths —> flood loss estimation
   b. ○ Exposure mapping of elements at risk —> estimation of flood magnitude —> exposure mapping of elements at risk —> derivation of inundation area and depths —> flood loss estimation
   c. ○ Derivation of inundation area and depths —> exposure mapping of elements at risk —> estimation of flood magnitude —> exposure mapping of elements at risk —> flood loss estimation
   d. ⊘ Estimation of flood magnitude —> derivation of inundation area and depths —> exposure mapping of elements at risk —> flood loss estimation

5. How can the results of a flood risk analysis be presented?
   a. ○ By flood risk curves
   b. ○ By discrete flood risk maps
   c. ○ By integral flood risk maps
   d. ⊘ All of the above

6. How can uncertainty analysis help in flood risk analysis?
   a. ⊘ Uncertainty analysis supports the credibility of flood risk analysis as well as the inte pretation of the results
   b. ○ Not at all, because it undermines the credibility of science
   c. ○ It helps only in cases where data quality is good.
   d. ○ It gives only qualitative results, thus it is of limited use.

7. What means ALARP in the context of flood risk appraisal?
    a. ○ Always Lower As Recently Perceived
    b. ⊘ As Low As Reasonably Practicable
    c. ○ Another Low Alarm Risk Perception
    d. ○ As Left As Right Policy

8. How can the resilience to floods in flood risk mitigation plans be increased?
    a. ○ Flood adapted construction
    b. ○ Flood adapted building and land use
    c. ○ Behavioral risk prevention in combination with flood warnings
    d. ⊘ All of the above

9. What is not an aim of flood risk communication?
    a. ○ Raising public awareness
    b. ⊘ Increase use of flood plains
    c. ○ Public participation of flood risk mitigation
    d. ○ Individual flood preparation

Questions Related to Case Study 1: Comparative Risk Analysis

1. Order the inundation modeling approaches by increasing complexity.
    a. ○ Interpolation, 2D hydraulics, 1D/2D hydraulics
    b. ○ 1D/2D hydraulics, interpolation, 2D hydraulics
    c. ⊘ Interpolation, 1D/2D hydraulics, 2D hydraulics
    d. ○ 2d hydraulics, 1D/2D hydraulics, interpolation

2. What is the specific feature of the damage model FLEMOps+?
    a. ○ It is a relative damage function
    b. ⊘ It considers precautionary measure and contamination in the damage estimation.
    c. ○ It resembles a step-function
    d. ○ It takes the inundation depth as the dominant damage influencing factor.

3 In this case study, what model combination proved to be the most successful and the best compromise between data requirements and modeling efforts?
    a. ○ Interpolation and FLEMOps+ micro
    b. ○ 2D model and FLEMOSps+ meso
    c. ○ 1D/2D model and HYDROTEC damage function
    d. ⊘ 1D/2D model and FLEMOps+ meso

Questions Related to Case Study 2: Flood Risk Potential Europe

1. How are the flood defenses considered in this large-scale study?
   a. ○ Very detailed with high resolution
   b. ⊘ They were neglected to show the damage potential without the protection by dikes.
   c. ○ They were considered on large rivers only
   d. ○ They were considered on flash flood prone rivers only

2. What is Purchasing Power Parities (PPP)?
   a. ○ PPP are absolute figures of flood damages in different countries.
   b. ○ PPP compare flood damages recorded in different currencies.
   c. ⊘ PPP are indicators of price level differences across countries, thus enabling inter-country comparison of flood damages
   d. ○ PPP indicate what an individual could by with the amount of the flood damage suffered

3. What is the purpose of this large-scale flood risk analysis?
   a. ○ Supporting implementation of the European Union Floods Directive
   b. ○ Evaluating EU Solidarity Fund applications after flood disasters
   c. ○ Estimating pan-European Climate Change effects on the water cycle
   d. ⊘ All of the above

Questions Related to Reading 1: Flood Hazard Analysis

1. What is the most basic flood hazard map?
   a. ○ Flood velocity map.
   b. ○ Flood depth map
   c. ⊘ Flood extend map
   d. ○ Flood duration map

2. Flow velocity maps are of particular importance for
   a. ○ River floods
   b. ⊘ Groundwater floods
   c. ○ Coastal floods
   d. ○ Flash floods

3. Digital elevation models (DEM) are a basis requirement for flood hazard mapping. What is the most accurate method to derive DEM's?
   a. ○ Radar altimetry.
   b. ☑ LiDAR (airborne laser based altimetry)
   c. ○ Digitized topographical maps
   d. ○ Ortho-maps derived from satellite or airborne optical imagery

4. By what models can the magnitude of floods be estimated?
   a. ○ Rainfall-storage models.
   b. ○ Hydraulic models
   c. ☑ Rainfall-runoff models
   d. ○ Ecological models

Questions Related to Reading 2: Flood Vulnerability Analysis

1. What categories should be mapped in flood exposure analysis?
   a. ○ Population
   b. ○ Assets and economic activities
   c. ○ Critical infrastructure and pollution sources
   d. ☑ All of the above

2. What can be neglected when collecting flood loss data?
   a. ○ Information on the event
   b. ○ Information on the damage and the object
   c. ☑ Information on water temperature
   d. ○ Information on damage reducing measures

3. How can the important damage influencing factors be identified from the collected loss data?
   a. ☑ By correlation analysis
   b. ○ By damage modeling
   c. ○ By absolute damage functions
   d. ○ By the damage value

Questions Related to Reading 3: Flood Risk Management

1. How can risk be quantified?
   a. ☑ As the product of exposure, susceptibility, value of the object at risk, and the probability of occurrence of the causing event

b. ○ As the product of exposure, susceptibility, and value of the object at risk
c. ○ As the product of exposure, susceptibility, and value of the object at risk, divided by the probability of occurrence of the causing event
d. ○ As the probability of occurrence of the causing event

2. What is the most precise but also most difficult method to consider flood defenses in flood risk analysis?
   a. ○ The inundation modeling with and without defenses
   b. ⊘ The probabilistic modeling of defense failures
   c. ○ A pre-determined set of breach locations
   d. ○ All of the above

3. In risk maps, how are integral expected annual damage quantified?
   a. ○ In value/ m^2
   b. ○ In value/year
   c. ○ In value/m^2*year
   d. ⊘ In value/m^2/year

4. Another output of risk analysis are emergency maps. What is their purpose?
   a. ○ Support insurance companies for calculating replacement costs
   b. ⊘ Support crisis management and rescue services
   c. ○ Inform policy makers about the current disaster extent
   d. ○ Serve as a basis for land use planning

Assignment 3

Objective

The assignment takes participants through the steps of flood risk analysis from hazard analysis through vulnerability analysis to the final risk analysis. It is based on a fictional city of Xa, where the flood risk analysis should lead to a decision on resource allocation for flood risk management and mitigation.

Part 1: Questions Regarding Flood Hazard Analysis

1. What kind of data must be collected to create a flood hazard map?
2. Name the two options for estimating flood magnitude.
3. Name the two elements for developing hypothetical flood scenarios.

4. Name the method of developing inundation scenarios/hazard maps from the hypothetical flood events and explain which approach you would use.
5. Please list at least three parameters that can be illustrated in a flood hazard map.

Part 1: Answers

1. Hydrometry (discharge time series of gauging station and tidal range), Digital elevation model (DEM, best quality as possible), Information on catchment (area, flood characteristics), Bathymetry (cross sections of river channel, i.e. depths and widths), Information on dikes (location, height, age, construction), Land use
2. One option is hydrological modeling of the whole catchment area which may not be feasible because of time and data constraints. The second option is the extreme value statistics using discharge time series of the gauging station. Extreme value statistics can be used to estimate the magnitude, i.e. the peak discharge associated to the return periods. Using these peak discharges hypothetical hydrographs for the selected return periods can be constructed.

   Participants should come up with the idea of using extreme value statistics for estimation of discharge for the selected return periods (i.e. probability of occurrences) and mention the construction of hypothetical hydrographs scaled to the magnitude determined by extreme value statistics as input for the modeling.

3. Extreme value statistics and normalized representative hydrographs.
4. Hydraulic modeling. If a very detailed and high resolution DEM is available, the reach area selected is sufficiently small, and expected flows in the floodplain substantially two-dimensional, a two-dimensional modeling approach should be used. As there are dikes in the location, this should be taken into consideration in the model setup.
5. Inundation extend, Inundation depth, Inundation duration, Flow velocity, Flood impact (depth x velocity). This is the full set of impact factors. However, the first two are the most common and important. The participants need to list at least these two.

Part 2: Questions Regarding Flood Vulnerability Analysis

1. What are four elements at risk for Xa?
2. How would you map elements at risk using exposure analysis?
3. What are the six steps involved in developing a loss model?

Part 2: Answers

1. The following list gives the most common elements at risk. The participants should come up with the basic categories and some of the elements within the categories:
   a) Buildings
      1. The nuclear power plant as the major risk element
      2. The fire station as the major emergency response unit
      3. The hospital
   b) Critical infrastructure
      1. The airport, the highway, the national road and the bridge over the river as the most important life lines and emergency aid connections of the city
   c) Pollution sources
      1. The chemical factory in the industrial area as the chief potential source of environmental pollution
   d) Cultural assets
      1. The museum as the most important cultural heritage of Xa

   The importance of the elements should be recognized and discussed in the final risk analysis. The allocation of resources should be based on that discussion.

2. Locate and display the selected elements at risk in a GIS. Slide 2.1 illustrates the type and location of the elements at risk of Xa. This includes a number of critical infrastructures like the nuclear power plant, the fire station, the river bridge and the airport. It also shows the different land-use categories describing the building structure of Xa and the surrounding area. The city is divided into the old city center which is the commercial heart of the city, a dominantly one-family house upper class area surrounding the city, a multi-story dominated suburban area on both sides of the river and an industrial area. The old city center is located on a small hill stretching from the bend of the river to the coasts.
3. As no appropriate damage model is available, it has to be developed. This involves six steps:
   a) Estimate the asset value of elements at risk (Slide 3.1 (Additional Instructions on page 3) shows the hypothetical asset values for land use area in Xa $/m
   b) Collect damage data (Data on flood damage from past events for the region, Documented damages from direct surveys, Questionnaires)
   c) Develop damage model
   d) Analyze the correlation among the damage degree and various factors influencing damage
   e) Define the model in functional or rule based forms

f) Calculate damage degree with damage model and hazard maps

The participants should come up with these six steps in their answer. If vulnerability estimation in monetary term is not feasible or wanted, the risk needs to be categorized by qualitative susceptibility and the severity of flood consequences. E.g. the risk imposed by a flooded nuclear power plant is immensely high so its flooding has to be prevented at any cost.

Part 3: Questions Regarding Flood Risk Analysis

1. How is a flood risk map created?
2. What are the two different ways of presenting risk maps?
3. How would you perform a risk appraisal (i.e., prioritize objects at risk) for each of the three inundation scenarios (i.e., 20, 100, and 500 year events) based on the following three criteria?
   a) Losses (100 and 500-year event)
   b) Critical infrastructure to be protected
   c) Threats that have to be avoided at any cost
4. What are the most important risks in the 100-year event?
5. Name and explain two criteria for flood mitigation planning.

Part 3: Answers

1. This is the straightforward process of combining the hazard maps of Step 1 with the asset values and damage functions of Part 2. The damage degree is calculated for every grid cell of the land use map by applying the damage model developed on the flood intensity, e.g. the maximum inundation depth from the hazard maps. The relative damage degree is then multiplied by the asset values for every grid cell given in the asset value map. This leads to the discrete risk map for every inundation scenario, i.e. the 20, 100, and 500 year event. The damages per grid cell can be further aggregated to land use classes and the overall damage value determined for each scenario as seen in the slides above and found in the additional instruction materials.
2. Integral and discrete.
3.
   a) The ranking according to the last two criteria can be done using the maps of the critical and important elements at risk in Xa for the 20, 100 and 500 year event respectively. The 20-year event doesn't show any damage, because the flood is

well contained within the dike lines. Only the uncontrolled urban settlement within the dikes lines has to be seen as critical. In the 100-year event, the chemical factory is causing the most severe threat to population and environment. The unplanned settlement within the dike lines deserves special attention also as it is severely affected similarly to the highway and the national road. The fire station is nearly affected and given the inherent uncertainties of risk assessments, some action should be taken.

b) The 500-year event is catastrophic. All critical elements at risk are affected, even the nuclear power plant.
c) Chemical factories, unplanned settlement, roads, fire brigade.

4. Decisions on allocating resources for flood risk mitigation can be based on:
   a) Cost-benefit analysis
   b) Critical decisions, priority actions

5. The management options listed on the last slide of the Module 3, Session 3 should be linked to these approaches. Because a real cost benefit calculation cannot be performed, we assume that for the 100-year flood, structural protection measures payoff such as improvement of the weak dike section, protection of the highway and national road. The costs for permanent structural measures for flood protection in case of a 500-year flood are extremely high and the low probability of the event does not necessitate these expenses. Only the nuclear power plant has to be protected at any cost. However, disaster management plans should be developed for the 500-year scenario. The following structural and non-structural measures can be included:

   Structural

   a) Protect nuclear power plant, e.g. ring dike
   b) Protect industrial site, e.g. by raising weak dike section
   c) Develop mobile emergency flood protection for station, hospital, museum
   d) Protect exit ways and connections between vital infrastructure

   Non-structural

   a) Move people from unplanned urban area (if socially acceptable and sustainable)
   b) Develop disaster management plans for extreme event
   c) Invest in flood forecasting system

Module 3 Checklist	Grading points
Part 1: Flood Hazard Analysis	
Compilation of the required data sets given in Step 1	3 (1/2 per item)
List two options of deriving estimates of flood magnitude (hydrological modeling and extreme value statistics)	1 (1/4 per item)
Name the two elements for construction of hypothetical flood scenarios (extreme value statistics and normalized representative hydrographs)	1 (1/2 per item)
Name the method of deriving inundation scenarios/hazard maps from the hypothetical flood events (hydraulic modeling)	1
Name the flood indicators in the hazard maps given in Step 4	1 (1/4 per item)
Part 2: Vulnerability Analysis	
List the basic categories of elements at risk (buildings, critical infrastructure, pollution sources, cultural assets)	1 (1/4 per item)
Exposure analysis using GIS mapping	1
Name the 4 steps involved in developing a loss model given in Step 3	1 (1/4 per item)
Part 3: Risk Analysis	
Explain the procedure as calculating risk estimates from the hazard maps, asset values and loss model (Step 1)	1
Name the two different ways of presenting risk maps (discrete or integral)	1
Performing the risk appraisal based on the three criteria listed in Step 2 (losses, critical infrastructure and extraordinary threats)	3 (1 per item)
Total Score	15

Discussion Forum

Points to Emphasize

The following points should be brought out in the third week discussions:

- Flood hazard is defined by a given magnitude and associated probability of occurrence.
- The magnitude and frequency of floods can be estimated using statistics (probabilities) or computational hydraulics.
- Uncertainties are inherent in estimating extreme events.

- Dikes and dike failures as an important aspect of flood hazard analysis.
- In flood hazard analysis various data are is needed depending on the scope of the analysis. In addition to standard information the following can be included in the analysis: flood extend and inundation depths, inundation timing and duration, flow velocities and intensity index (the product of depth and velocity).
- Climate change and floods.
- Region specific susceptibility analysis.
- Importance of preparedness to reduce susceptibility.
- Flood losses are determined by the combined effect of impact and resistance, an important aspect of vulnerability analysis.
- Vulnerability is not a static phenomenon. In fact, both exposure and susceptibility change constantly due to river trainings, increased use of floodplains from population and urban growth, accumulation of valuable goods in flood prone buildings, and the decrease in flood awareness and preparedness.
- Consideration of uncertainties in the risk analysis.
- Risk analysis as the basis of flood risk mitigation and part of the flood risk management cycle.
- Importance of flood risk communication, stakeholder involvement in the flood risk management process.
- The notion of "living with risks" is the underlying social agreement and reflected in the principles and different components of the flood risk management cycle.
- Flood risk communication should utilize all available media in all phases of the flood risk management cycle: from the risk identification though the planning and implementation of the risk mitigation measures to disaster management.

Recommended Discussion Questions

In the beginning of the third week, facilitators can reflect on the summary of second week discussions and start with the following: *"We had a very good discussion during the last two weeks. Several of you have participated in the discussion forum with insightful points. This week we are going to learn about the flood risk assessment tools and techniques."*

The suggested questions for the third week:

Discussion Questions 1:

- Do you expect a flood to occur in your area?

- What is the general level of perception of flood risk in your community?
- What program and measures have been used in your community for flood mitigation?
- Also, if you have experienced a flood please explain when this was, and what impacts this has had on you.

Discussion Question 2: Floods are one of the most common natural hazards. The flood risk mitigation starts with its risk assessment. There are several tools and techniques available to assess the risk.

- Please elaborate on tools and techniques to assess flood risk
- What is the most valuable information you can get from a flood risk analysis for your purpose/expertise/background?

Discussion Question 3: List some of the attributes of people, society, infrastructure and cultures that make them vulnerable to floods? How do you think climate change can influence the occurrence of floods in the future? Can you think of some demographic trends and other factors that can lead to increased vulnerability to floods in the future?

Recommended Follow-up questions

These follow-up questions should encourage participants to discuss their flood risk analysis experiences in the context of their own professions, environments and envisaged application. The facilitators will not be able to comment all the questions raised but the discussion should help participants to recognize problems and think of possible solutions. It should also encourage sharing good practices and lessons learned by those who already were involved in flood risk analysis.

Follow-up Question Set 1 (Flood Hazard):

- What defines a flood hazard?
- How can the magnitude and probability of a flood scenario be determined?
- What is the problem in estimating extreme events?
- Why is it necessary to pay attention to dikes in flood hazard analysis?
- What is a hydrological cycle and the main causes of floods?
- What are the general tendencies of climate change impacts on floods? How can climate change impacts estimated? Is there a global tendency of climate change impact on floods?

Follow-up Question Set 2 (Flood Vulnerability):

- What does climate change and susceptibility have in common?
- Why is susceptibility analysis region-specific?
- What reduces susceptibility? Why is preparedness so efficient in reducing susceptibility?
- Who and what is at risk from flooding? Who and what is exposed to floods? How susceptible the exposed elements at risk to floods are and how to calculate this? Identification and quantification of resilience to floods.

Follow-up Question Set 3 (Flood Risk Management):

- What are the sources of uncertainties in flood loss estimation?
- How reliable is flood risk analyses and how can we increase confidence in flood risk analysis results?
- How do we get from flood risk analysis to flood risk management?
- What is the prerequisite of efficient and sustainable flood risk management?

Follow-up Question Set 4 (Open answers and reflection):

- Do you see some open questions in the context of your profession?
- Which part of the whole procedure do you regard most critical for an application in your environment?
- Are there any special elements at risk in your environment that were not covered in the course? And how would you analyze their vulnerability?
- Do you live in a multi-hazard environment and how would you perform a risk assessment for your location?

Follow-up Question Set 5 (Related to Assignment):

Put yourself in the perspective of a decision-maker in Xa for which you have just completed the flood risk analysis. Having seen the 20, 100 and 500-year flood risk maps for the town of Xa, please discuss the questions below:

- Please explain how you would perform a risk appraisal (i.e., prioritize objects at risk) for each of the three inundation scenarios (i.e., 20, 100, and 500 year events) based on the following three tasks.
    - Identify the most important risks in the 100-year event

- Name and explain two criteria for flood mitigation planning
- What can be done if the town is expected to grow to the size of 50,000 people within 10 years due to some mining discoveries? How would the critical infrastructure and assets be protected? These questions can be used in a role-playing exercise during week 4 and 5 and participants can be grouped. Participants need to take on the following roles and answer the questions from the perspective of these roles:
    - Experts (Having the knowledge now from this course)
    - Local government officials (What do they want to get out of earthquake policy change?)
    - Local homeowners (Are they interested in earthquakes?)
    - National government officials
    - Local business owners (or industrial chamber)
    - Disaster management specialists

Please note there is no right or wrong answer here, and that the questions serve to initiate open discussions on some of the key points addressed in the presentations, and readings of Module 3. The discussions should also be based on the detailed results from the Assignment.

6.6 Suggested Additional References

6.6.1 Reports for Further Reading

ISDR (2009) Guidelines for reducing flood losses, UNESCO International Strategy for Disaster Reduction, Geneva.

Johnson, C., Tunstall, S. and Penning-Rowsell, E. Crisis as catalysts for adaptation: human response to major floods, Flood Hazard Research Centre, Middlesex, UK.

6.6.2 Online Resources

Handbook of good practices for flood mapping in Europe: http://ec.europa.eu/environment/water/flood_risk/flood_atlas/

Results and guidance to various flood risk aspects developed in the EU FP6 funded project FloodSITE: http://www.floodsite.net/

The Flood Estimation Handbook of HR Wallingford; standard reference to statistical flood analysis: http://www.ceh.ac.uk/feh2/fehintro.html

FEMA flood hazard maps of USA – Online and interactive web platform: https://hazards.fema.gov/femaportal/wps/portal

6.6.3 Publications

Apel, H., Aronica, G., Kreibich, H. and Thieken, A. (2009) Flood risk analyses—how detailed do we need to be? Natural Hazards, 49(1): 79–98.

Apel, H., Merz, B. and Thieken, A.H. (2008) Quantification of uncertainties in flood risk assessments. International Journal of River Basin Management (JRBM), 6(2): 149–162.

Büchele, B., H. Kreibich, A. Kron, A. Thieken, J. Ihringer, P. Oberle, B. Merz, F. Nestmann (2006) Flood-risk mapping: contributions towards an enhanced assessment of extreme events and associated risks. Natural Hazards and Earth System Sciences, 6: 485–503.

Grünthal, G. et al. (2006) Comparative risk assessments for the city of Cologne – Storms, floods, earthquakes. Natural Hazards, 38(1–2): 21–44, DOI 10.1007/s11069-005-8598-0.

Kaplan, S. and Garrick, B.J. (1981) On The Quantitative Definition of Risk. Risk Analysis, 1(1): 11–27.

Lind, N.C., Nathwani, J.S. and Siddall, E. (1991) Management of Risk in the Public-Interest. Canadian Journal of Civil Engineering, 18(3): 446–453.

MunichRe (2009) Topics Geo: Natural catastrophes 2008 – Analyses, assessments, positions, Münchener Rückversicherungs-Gesellschaft (Munich Re Group), Munich.

Penning-Rowsell, E., Johnson, C. and Tunstall, S. (2005) The benefits of flood and coastal risk management—a handbook of assessment techniques. ISBN 1-904750-51-6, Flood Hazard Research Centre, Middlesex Univ. Press, London.

Smith, K. and Ward, R. (1998) Floods: physical processes and human impacts. John Wiley & Sons Ltd, Chichester, UK, 394 pp.

VII. Week 4–5

7.1 End of Course Project

Objective
The objective of the project at the end of the course is to conduct a multi-risk analysis (earthquake and flood) for the imaginary city of Xa. The analysis covers the socio-economic impacts as well. The participants will prepare an End-of-Course Project report (5–10 pages) where, they provide a summary and discussion of the results with respect to:

- Analysis of the city's seismic risk and development of an earthquake scenario that describes the impacts of a probable earthquake on the city
- Analysis of the city's flood risk and description of the impacts of a 100-year flood on the city
- Analysis of the social vulnerability of Xa
- Preparation of an action plan describing activities that, if implemented, would reduce the city's seismic and flood risk. The action plan should be prepared based on the results of the risk analysis

The end-of-course project instructions include all the necessary background information to complete the project. The End-of-Course Handout is structured in two parts. Part 1 provides all the parameters and background data needed to complete the analysis. This includes general information on the city of Xa, its population make-up and socio-economic conditions of different administrative regions in the city. Information on the vulnerability of buildings and critical infrastructure has been provided in both tabular and map format. Finally, the first part includes the needed information to carry out a Maximum Credible Earthquake (MCE) scenario in RADIUS, as well as a 100-year flood hazard map and information on vulnerability and damage due to this event.

Part 2 of the end-of-course project handout is composed of guidance notes to take the participants through the various steps in completing the project. Unlike the module assignments, the end of course instructions do not provide a step-by-step solution template, as participants need to demonstrate their understanding of the learning materials. However, a general outline needed to carry out the analysis and many hints are given throughout part 2 which the participants can refer to. The End-of-Course Project also builds on the assignments in the 3 modules which the participants can always refer to (this is especially necessary to complete the analysis in RADIUS). Thus, a participant who has understood the concepts presented in the module and successfully completed the assignments should also be able to successfully complete the End-of-Course Project as well.

The RADIUS software will be used in the End-of-Course Project to estimate the losses in the imaginary city of Xa for a scenario earthquake which has been provided (6.9 Magnitude on Xa fault, 10km away from city at 21:00). A 100-year flood map has also been given in the End-of-Course Project instructions. The 100-year flood hazard map has been overlaid on maps of critical infrastructure, land-use/land-cover and administrative regions of Xa. Given the tables on flood damage for each of the exposed elements, the participants should be able to calculate economic losses associated with the 100-year flood event. There are additional questions within the assignment which reinforce the key concepts of the course but still tie into the RADIUS exercise. Maps of the 20-year and 500-year flood hazard for Xa are provided in the End-of-Course Project handout and have to be referenced in order to answer the questions, but need not to be used in the risk analysis.

7.1.1 Step-by-Step Guide for Completing the Exercise

Earthquake Risk Analysis

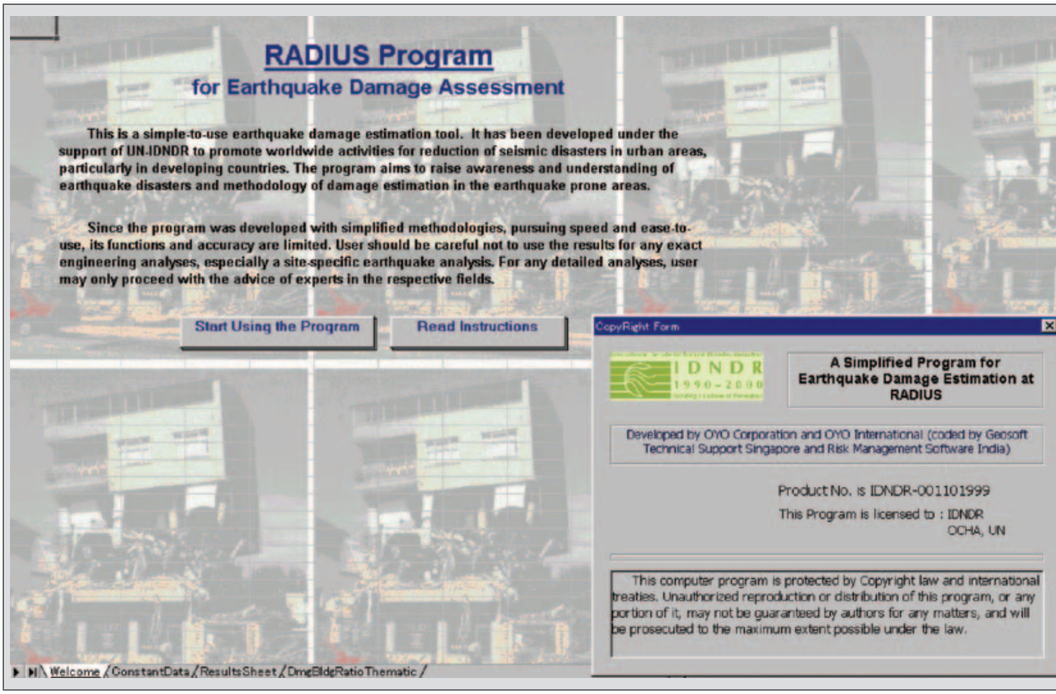
To conduct the earthquake risk analysis, participants will the Radius Tool, which is available to download from the course website. The user must have a Windows operating system, with Microsoft Excel installed on it. In case the RADIUS program does not show up automatically when participants start it in Microsoft Excel, advise them to "enable macros" to run the program. More information on this can be found on the Microsoft helpsite.[1] After entry of basic data, the user can obtain preliminary results that help to understand what an earthquake is and how vulnerable a city is. If you are having any problems with the terminology, please refer to the Course Glossary. More background information on the RADIUS tools is uploaded to the course platform.

[1] http://office.microsoft.com/en-us/excel/HA100310711033.aspx

1. Opening Radius Tool

The opening/welcome screen (Figure 7.1) shows the title and copyright. Clicking on introduces the main menu, or the user can read the instructions by clicking on "Read Instructions".

Figure 7.1 Opening/Welcome Screen



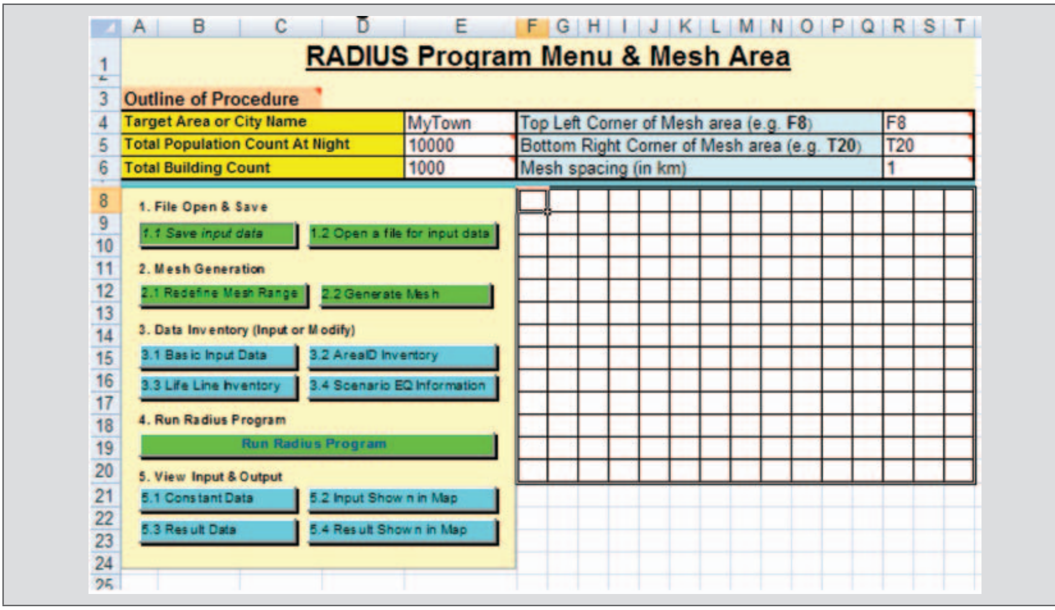
2. Main menu

The main menu screen (Figure 7.2) consists of three parts: target area information, mesh area generation and numbered functionality menus.

3. Outline of Procedure: (see top of Figure 7.2 and Figure 7.3)

The target area is defined by filling out the tables in the "Outline of Procedure" area. This includes defining, in order, the Target Area or City Name" and "Population Count at Night",

Figure 7.2 Main Menu in RADIUS



"Total Building Count", and "Top Left Corner of Mesh area (e.g. F8)", "Bottom Right Corner of Mesh area (e.g. T20)", "Mesh spacing (in km)".

Figure 7.3 Target Region Definition Screen

Outline of Procedure			
Target Area or City Name	Xa	Top Left Corner of Mesh area (e.g. **F8**)	F8
Total Population Count At Night	260500	Bottom Right Corner of Mesh area (e.g. **T20**)	Y18
Total Building Count	30250	Mesh spacing (in km)	1

All of this information can be entered by reading the background information on Xa, in the end-of-course project handout and instructions. The following guide explains how this information is entered. The result is shown in Figure 3.

Target Area or City Name: **Xa**

Population Count at Night: **260,500** night time population (from 1.1 General Information of City of Xa in the handout)

Total Building Count: **30,500** buildings (from 1.2 Vulnerability-Building Information in the handout)

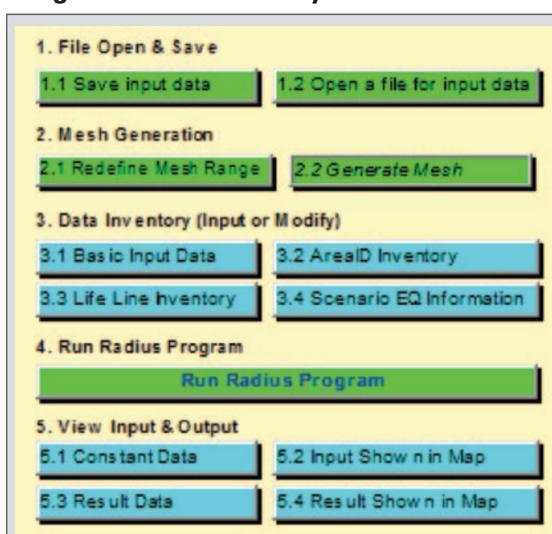
Top Left Corner of Mesh area (e.g. F8): The cell in excel where the top left corner of our region is defined is given as **F8**

Bottom Right Corner of Mesh area (e.g. T20): Referring to the maps of Xa in the handout, we can see the grids for the region and note that the mesh area is 11 cells wide and 20 long. Starting at F8, the bottom right corner to define the rectangle is **Y18**

Mesh Spacing: **1km,** looking at the scale of the Xa map, we see that each grid is 1km. We use the same mesh spacing here.

The following will step through the numbered functionality menu describing the tasks in each step:

Figure 7.4 Functionality Menu



4. File Open & Save

If the user wants to save the result file or input existing file, the 1.1 Save input data or 1.2 Open a file for input data buttons can be used for inputting data. This will avoid duplication of effort for data input each time the program is run. Please note, that before generating a mesh you cannot save a file.

5. Mesh Generation

The first step in the analysis is to subdivide the Xa region into smaller even-sized blocks (geocells) which represent the geology well. The mesh/grid is a set of Excel cells, which define the target region. In RADIUS Program, the user needs to create a uniformly spaced grid or mesh over the target region. The user manually creates the mesh, and then enters the data manually into the RADIUS Program, in a specified format. The user is free to adopt any mesh spacing value, depending on the resolution of available data. A uniform mesh spacing of 1 km corresponds to the grid size in the Map of Xa used here.

The user defines the target region as wanted—for the Xa region. Note that the mesh area is 11 cells wide and 20 long. Starting at F8, the bottom right corner to define the rectangle is **Y18.** The target region is represented by small squares, which are in turn represented by marked spreadsheet cells called meshes.

The user can generate a mesh by:

1. Define Top Left Corner cell No. (i.e., F8),
2. Bottom Right Corner cell No. (i.e., Y18), and
3. Mesh Spacing (1km) in the outline of Procedure box.
4. The default mesh has to be Refined for the new dimensions to take effect. This is achieved by clicking 2.1 Redefine Mesh Range. Now a rectangle with for the dimensions of the Xa region is created.
5. The user manually defines the meshes on the RADIUS Program interface. The user has the freedom to number the meshes using integers, alphabets or a combination of the two. It is important for the user to enter something in a mesh to help the program identify that a mesh has been selected as users target region. Here we choose to label cells with numbers from top to bottom and left to right (see Figure 7.5).
6. Clicking on 2.2 Generate Mesh button codes the meshes and each mesh is given a Mesh ID (see Figure 7.6).

The mesh generated by clicking on the tab "2 Mesh Generation" should look like the one in Figure 7.6.

Basic input data:

The user clicks on the 3.1 Basic Input Data button to enter the basic input screen of the target study area. According to the Mesh ID, which automatically appears in the table when the "1.3 Mesh Generation" button is clicked, AreaID and Area Name (which means that the user can decide or input which group or district a particular mesh belongs to), the soil type for each mesh

Figure 7.5 Indexing the Mesh

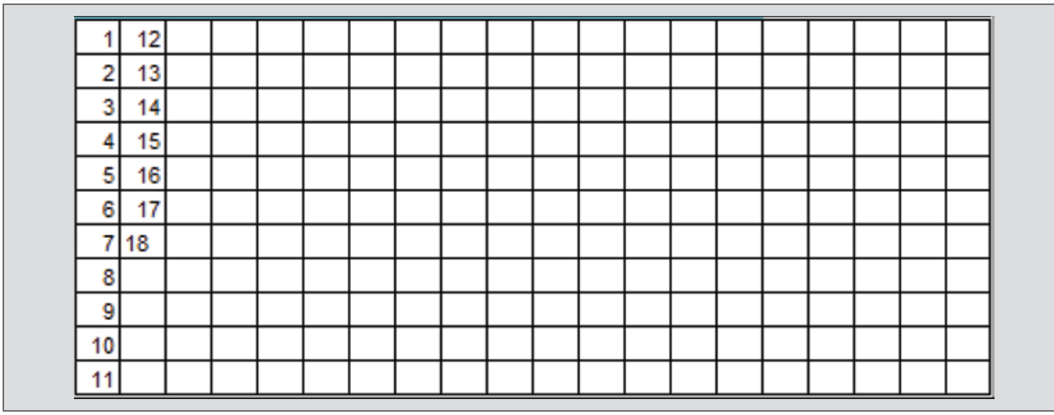
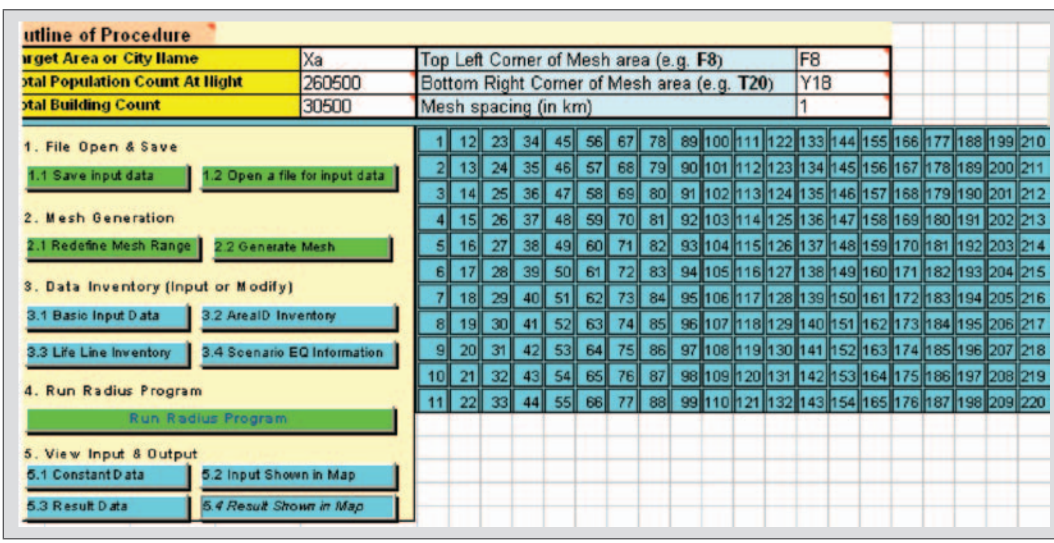


Figure 7.6 Meshed Area Screen



and the mesh weight (relative building density) for each mesh should be entered. The mesh distribution map for each item is shown on the right side for assisting the user to enter data. When all the data has been entered, clicking on "Return Main Menu" validates the data entered and returns to the main menu if no mistake is found. The online help will assist when a problem occurs.

Figure 7.7 Data Inventory (to Input or Modify)

ReadMe

Basic Input Data

Clear Input Data | AutoCheck | Return Main Menu

Mesh ID	Area ID	Area Name	Mesh Weight	Local SoilType
1	5	Beetown	2	2
2	1	Westville	1	3
3	1	Westville	1	3
4	1	Westville	1	3
5	6	Newxa	2	3
6	5	Beetown	2	3
7	1	Westville	1	3
8	1	Westville	1	3
9	1	Westville	1	3
10	6	Newxa	2	3
11	6	Newxa	2	2
12	6	Newxa	2	2
13	6	Newxa	2	2

6. MeshID

It is the unique identification number (ID) given to a mesh, in the target region. The RADIUS Program automatically assigns MeshID values to meshes from left to right and top to bottom, after the user input is complete. This eliminates the burden on the user to correctly number the meshes.

7. AreaID

Several meshes comprise an area in the RADIUS Program. AreaID is the unique identification number (ID) given to an area, in the RADIUS Program. Imagine a block or district or area made up of several meshes. Of course, the user may choose to have as many AreaID's, as equal to the MeshID's. In addition, the user could also enter the name of the AreaID in the AreaName field, as the user would be able to identify easily with a name rather than a number. Such a classification system would ease the user in defining the building inventory. It is assumed that the building inventory distribution is same for all meshes falling in an AreaID. The user provides the MeshID-AreaID mapping in the Basic Input Data sheet. The user cannot leave a cell entry blank for AreaID.

The AreaID in our case is of course the 6 administrative regions from the Xa map that include: Westville, Xaravi, City Center, Epart, Beetown, and Newpart.

8. Mesh Weight

Mesh Weights are relative importance factors, based on user's view of what should be the relative building-density for the city or target region, under consideration. The Mesh weights are given in Table 1 on page 4 of the end of project handout corresponding to the population density of each administrative region. These rates are used for distribution calculation of building counts in each Mesh and Area.

The density of building types as described in mesh weights is:

1= Industrial.
4= Downtown, Xaravi = 4 times as many buildings as type 1 in each geocell.
2= Rest of Xa.

9. Local Soil Type

To enter the local soil type data, carefully study the Geology Map of Xa provided in Figure 3 (page 5) of the end of project handout. The following table shows show how the different soil types from Xa can be coded in RADIUS, based on definition of soil types from the Radius Glossary of Terms. This soil type is used for determining the dynamic amplification in the ground shaking.

Figure 7.8 Mesh Map by Local Soil Type

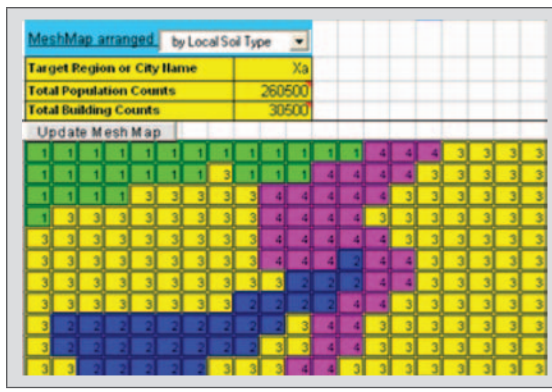


Table 7.1 Xa Geology and RADIUS Soil Categorization

Map of Xa Geology	RADIUS Soil Categories	
Hard Rock	1	Hard Rock/Bedrock
Soft Rock	2	Soft Rock
Medium Stiff Soil	3	Sedimentary Rock/Average Stuff Soil (standard amplification factor is 1.0)
Soft Soil	4	Soft Soil/ Land Fill/ Reclaimed Land
N/A	0	Unknown

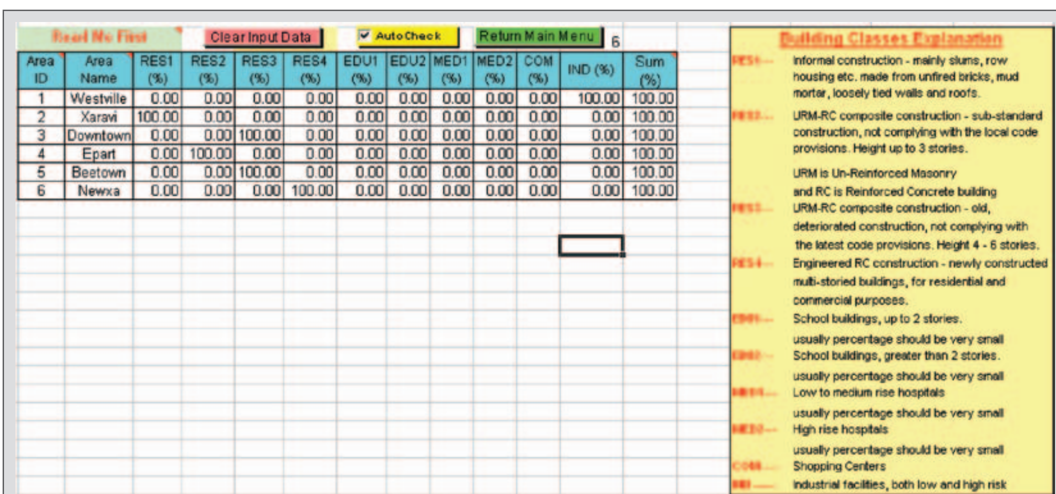
10. Area ID Inventory

The user feeds into the program data on the types of buildings that exist in each area (district) of the city and their percentage. Information on Building Types in Xa and their corresponding Building Class in RADIUS is given in Table 1 on page 4 of the end of project handout. The program will calculate the number of buildings in each mesh on the basis of the mesh weight data provided by the user. The percentage of each building type will then be used for calculating the numbers of each type of building in each mesh. An explanation of building types or classes and instructions on how to input percentage data will be given by the online help for each item. After this input, click on "Return Main Menu", and the program will check whether the total percentage for each mesh is 100 per cent and, if found correct, it will return to the main menu. If a user wants to reenter data, click on the "Clear Input Data" button, all the area data will be cleared. The "Auto Check" button will check the validity of the data as it is being keyed in and prevent the user from entering unacceptable data. This check can also be made by clicking on the "Return Main Menu" button.

11. Lifeline Inventory

The user can specify lifeline facilities for analysis, such as roads, bridges, tunnels, electrical towers or substations, water pipes, sewage pumping stations/treatment plants, reservoirs, and gas stations. Since the detailed estimation of damage to lifeline facilities at each site, point or line

Figure 7.9 Area ID Inventory Screen



Area ID	Area Name	RES1 (%)	RES2 (%)	RES3 (%)	RES4 (%)	EDU1 (%)	EDU2 (%)	MED1 (%)	MED2 (%)	COM (%)	IND (%)	Sum (%)
1	Westville	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00	100.00
2	Xaravi	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
3	Downtown	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
4	Epart	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
5	Beetown	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00
6	Newxa	0.00	0.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	100.00

Figure 7.10 Lifeline Inventory Screen

Read Me First | Data Clear | Return Main Menu | ☑ AutoCheck

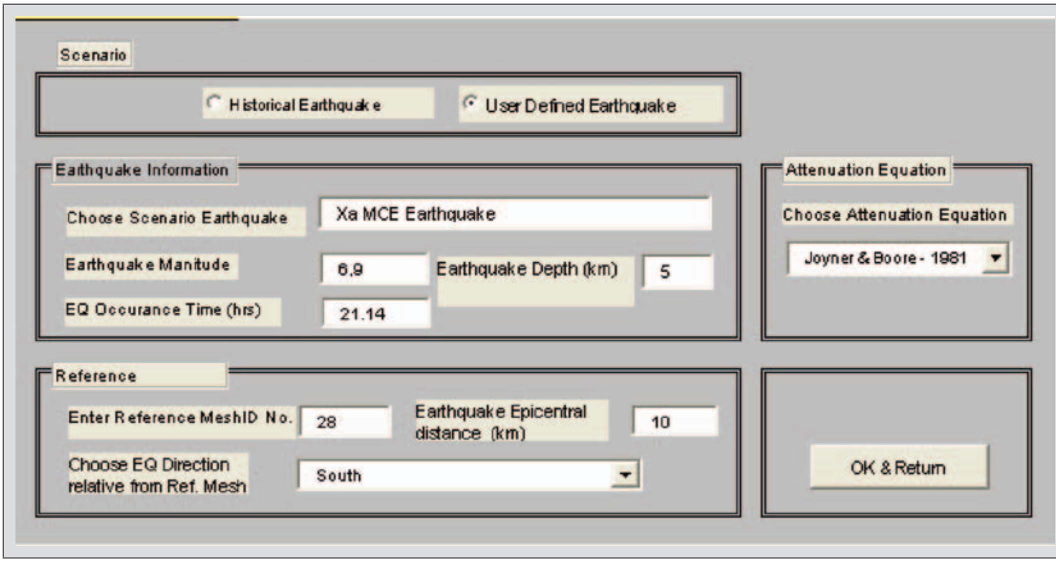
LifeLine	Total Count	Unit	Definition
Road1	50	km	Length of Local Roads (in km), for the concerned city or target region.
Road2	30	km	Length of major roads such as Freeways/ Highways (in km).
Bridge	1	Count	Number of major Transportation Bridges (road and railway).
Tunnels	0	Count	Number of major Transportation Tunnels, for the concerned city or target region.
Electric1	300	Count	Number of major Electrical & Telecommunication transmission towers.
Electric2	10	Site	Number of Electrical & Telecommunication sub-stations.
Water1	100	km	Length of major Water & Sewage trunk and distribution lines (km).
Water2	5	Site	Number of Water & Sewage pumping stations.
Water3	1	Site	Number of Water & Sewage treatment plants.
Reservoir1	1	Count	Number of Storage Reservoirs or Dams.
Reservoir2	0	Count	Number of Terminal Reservoirs or Elevated Storage Tanks.
Gasoline	25	Count	Number of Gasoline stations.

needs extensive data input, for instance, materials, radius of pipes and varied depth, this program calculates only the total damage by a simplified method. The user needs only the total count of each facility but no information about exact location. After entering the data and clicking on the "Return Main Menu" button, the program will check the data and, if no mistake is found, return to the main menu. The lifeline inventory for Xa is given in Table 2 (page 4) of the End-of-Course Project handout

12. Scenario Earthquake Information

The scenario earthquake dialog box contains information on the scenario earthquake for which losses are to be analyzed. The user may use a famous historical earthquake from the table or a user-defined earthquake for analysis. In the case of a historical earthquake, user should enter reference mesh number and choose direction of epicenter (earthquake center) relative to the reference mesh. In the case of user defined earthquake, the user will enter earthquake name, magnitude, and time of occurrence of the earthquake, attenuation equation to be used (for a description of this term, refer to the glossary), epicentral distance, reference mesh number and direction relative to the reference mesh. When the user clicks on the "OK & Return" button after finishing the input, the program checks the data and, if no mistake is found, returns to the main menu.

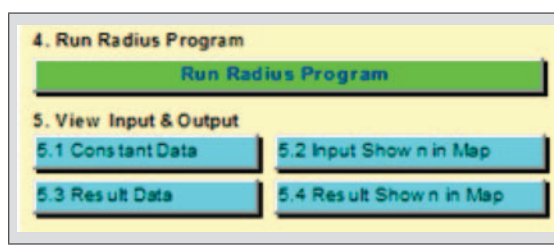
Figure 7.11 Scenario Earthquake Inventory Screen



In the end of project course handout, you find that the Maximum Credible Earthquake is a M6.9 earthquake 10km from the Xa fault and 5km depth at 21:00. You also find that the GMPE of Joyner and Boore (1981) is the one that best represents the ground motion for the tectonic regime of the Xa region.

13. Run RADIUS Program

After entry of the data and checking, losses can be analyzed by clicking on the "Run RADIUS Program" and "Go" buttons. The time needed for calculations depends on the number of meshes/areas and the speed of the user's personal computer. In the case of meshes lower than 100, the user can obtain results within a couple of minutes. After calculation, the program returns to the main menu.



14. View Input & Output

The constant data used for estimation, input data distribution, tables and maps for the calculated results, can be viewed in this part.

15. Constant Data

Thirteen tables present constant data used for analysis. They are mesh weight rates, soil type amplification factors in Figure 7.12, a, attenuation equations with relation between PGA and MMI (see Figure 7.12, b), vulnerability values for casualty estimation, vulnerability values for building types, lifeline facilities (see Figure 7.13), the difference between daytime and nighttime populations for each building type and the definition of daytime and nighttime (see Figure 7.14 below).

Figure 7.12 Constant Data Screen: Mesh Weight, Soil Type, Attenuation and MMI-PGA Conversion

Table 1 --- Mesh Weight

Code	Description	Rate
0	NONE	0.0
1	LOW	0.5
2	AVERAGE	1.0
3	HIGH	1.5
4	VERY HIGH	3.0

Table 2 --- Soil Type

Code	Description	Amplification Factor
0	Unknown	1.00
1	Hard Rock	0.55
2	Soft Rock	0.70
3	Medium Soil	1.00
4	Soft Soil	1.30

Table 3 --- Attenuation Equations

[illegible]	Source	Attenuation Equation
1	Joyner & Boore - 1981	PGA=10^(0.249*M-Log(D)-0.00255*D-1.02, D=(E^2+7.3^2)^0.5
2	Campbell - 1981	PGA=0.0185*EXP(1.28*M)*D^(-1.75), D=E+0.147*EXP(0.732*M)
3	Fukushima & Tanaka - 1990	PGA=(10^(0.41*M - LOG10 (R + 0.032 * 10^(0.41*M)) - 0.0034*R + 1.30))/980
	Note:	E-----Epicentral distance R----Hypocentral distance

The MMI will be calculated by the formula:

log(PGA*980)=0.30*MMI+0.014

or MMI=1/0.3*(log10(PGA*980)-0.014)

by Trifunac & Brady (1975). PGA unit is G.

Figure 7.13 Constant Data Screen (3): Vulnerabilities of Lifeline Facilities

Table 12 --- LifeLine Damage Curve Data (%)

MMI	Road1	Road2	Bridge	Tunnels	Electric1	Electric2	Water1	Water2	Water3	Reservoir1	Reservoir2	Gasoline
4	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.00	0.00
5	0.01	0.01	0.03	0.01	0.01	0.20	0.01	0.30	0.15	0.10	0.00	0.01
6	0.25	0.03	0.49	0.02	0.03	4.93	0.03	2.35	1.09	1.10	0.04	0.60
7	1.95	1.29	4.35	0.04	1.39	10.10	0.69	5.85	3.33	4.10	1.52	8.00
8	5.39	3.00	9.37	1.76	2.62	20.37	2.00	11.73	6.67	6.45	4.50	20.00
9	13.55	5.80	27.23	3.81	4.71	33.75	5.21	20.74	13.38	10.63	9.00	32.00
10	22.12	11.05	50.60	6.43	9.07	44.22	9.13	30.77	20.59	24.11	20.65	40.00
11	28.00	13.50	60.00	8.00	11.00	53.00	12.00	37.00	24.00	32.00	27.00	47.00
12	30.00	15.00	70.00	9.00	12.00	60.00	15.00	40.00	28.00	35.00	30.00	50.00

The user can modify part of this data according to local conditions. However, for most of the analysis the same data may be used. It should be changed only if the user is familiar with the engineering modalities and terms and has an understanding of the figures he/she is changing. The users, who have little or no idea about these terms and the implications of the numbers on the program, should not change it.

Figure 7.14 Constant Data Screen: Night/Day Ratio and Time Band for Occurrence Time

Table 13 --- Habitant Parameter for Day/Night difference (Night of RES1 & 2 are 1.0)										
	RES1	RES2	RES3	RES4	EDU1	EDU2	MED1	MED2	COM	IND
Night	1.0	1.0	4.0	10.0	0.2	0.2	2.0	4.0	0.2	0.2
Day	0.5	0.5	2.0	5.0	10.0	25.0	6.0	12.0	4.0	4.0
Night Time Definition (hrs)		18.00	6.00							
Day Time Definition (hrs)		6.00	18.00							

16. Input Data Shown in Maps

Maps representing input data such as mesh weight, with mesh table data and Area ID in the map, building counts, and population counts with area table data are included here. These maps and tables can be used for checking the data input and for presentation and discussion.

17. Result Data

Six tables with the calculated results and inventory data for all the meshes are presented in this section. They are: building counts, damage to buildings with counts, MDR (mean damage ratio) of buildings, casualties such as deaths and injuries and lifeline facilities damage ratio. Each of these tables has been prepared for each mesh and gives information about the mesh weight, Area ID and name. The soil type, PGA and MMI values and the daytime and nighttime population values have also been included.

18. Result Data Shown in Maps

Estimated results of mesh damage with maps and tables for damage ratio of buildings with table of counts, casualties (deaths and injuries) are presented in this section. The maps present the results in a format that is easier to understand. Also they are useful for directly presenting the results for discussion and planning and formulating plans for earthquake disaster management.

19. Results of Earthquake Risk Analysis

After following the steps above and successfully running the RADIUS tool, you should have obtained for each geocell: a PGA value, damaged building count, Mean Damage Ratio (%), injury (sever and moderate) and death. Furthermore, you should have obtained a damage number and damage ratio (%) for the lifeline inventory. Using the replacement and repair values in Table 1, Table 2 and Table 3 of the end of project handout, it is possible to compute direct losses for:

Replacement cost for Building Damage (sum for each of the 6 administrative areas in Xa), where:

*Replacement Cost of Damaged Buildings = MDR * Replacement Value * Total Number of Buildings*

Table 7.2 Replacement Cost of Damaged Buildings

Administrative Area	MDR (%)	Replacement Value (Xa $/bldg)	Total Number of Buildings	Total Replacement Cost of Damaged Buildings (Million Xa $)
Westville	0.27	2 million	1,210	653
Xaravi	0.494	10,000	3,227	16
City Center	0.420	750,000	7,260	2,287
Epart	0.332	150,000	10,890	542
Beetown	0.508	200,000	4,437	451
Newpart	0.114	500,000	3,227	184
				Total Cost = Xa $4,133M

Replacement/Repair costs for all lifelines

*Replacement Cost of Damaged Lifelines = DR (%) * Replacement Value * Total Count of Lifelines*

Replacement/Repair costs for all critical facilities: We can assume that critical infrastructure will have to be repaired/replaced if PGA values experienced at the site of these facilities are greater than **0.400g**, based on the suggestions in the end of project packet. Thus we have to first examine what PGA levels each of the sites (grids) where critical facilities are located experience.

Table 7.3 Replacement Cost of Damaged Lifelines

LifeLine	Total Count	Damage Number	Unit	Damage Ratio (%)	Cost of Replacement (Xa $/Unit)	Total Replacement Cost of Damaged Lifelines (Xa $)
National Road	50	4.6	km	9.1	50,000	227,500
Highway	30	1.3	km	4.3	30,000	3,870,000
Bridge	1	0.2	Count	17.6	5,000,000	88,000,000
Electric1	300	10.7	Count	3.6	50,000	54,000,000
Electric2	10	2.6	Site	26.4	50,000	13,200,000
Water1	100	3.5	km	3.5	50,000	17,500,000
Water2	5	0.8	Site	15.8	500,000	39,500,000
Water3	1	0.1	Site	9.7	5,000,000	48,500,000
Reservoir 1	1	0.1	Count	8.4	50,000,000	420,000,000
Gasoline	25	6.3	Count	25.4	50,000	31,750,000
						Total Damage to Xa: **$716,547,500**

Thus, we can assume damage to the harbor, central train station, museum and bridge. We will calculate the direct repair and replacement cost, based on Table 3 (page 54) of the end of project handout.

While the direct damages to critical infrastructure and lifelines have been calculated, these calculations do not account for any of the indirect damages. For example, we know from the end of project handout a main railway line runs from the Xa harbor through the industrial zone, connecting Xa to the global and national economy. As the main bridge over which the railway crosses,

Table 7.4 PGA Levels by Critical Facility

Critical Facility	Geocell Location	MMI	PGA
Airport	Geocell 53	7.9	0.243g
Hospital	Geocell 129	8.1	0.273g
Harbor	Geocell 154	8.8	0.453g
Central Train Station	Geocell 152	8.6	0.407g
Museum	Geocell 148	8.7	0.418g
Bridge	Geocell 148	8.7	0.418g
Fire Station	Geocell 159	8.3	0.318g
Nuclear Power Plant	Geocell 189	8.0	0.255g

the central train station and the harbor will be damaged, the indirect damages as a result to disruption in the delivery of goods and services will also incur and may exceed the cost of direct damages by far. Also, while the direct loss to the museum building is estimated at Xa 60 million, the loss of cultural heritage and historic monuments are intangible and cannot be estimated.

Table 7.5 Replacement Costs of Critical Infrastructure

Critical Infrastructure	Cost of Repair and Replacement (Xa $M)
Central Train Station	15
Harbor	80
Museum	60
Bridge	50
	Total = Xa $205M

Flood Risk Analysis

Overlay Analysis

The first step is to count the grids that are inundated by the 100-year flood hazard maps given in Figure 1–4 and Figure 1–5, for land-use types and critical infrastructure respectively in Xa. The cost of replacement/repair for damaged land-use types and critical infrastructure are given in Table 4 and Table 5. The next step is the straightforward combination of the hazard maps with the damaged asset values. The damages per grid cell can be further aggregated to land use classes and the overall damage value per scenario. As each square grid in the flood hazard maps is $1km^2$, the cost of flood damage for each inundated grid can be determined by converting the replacement/repair cost per m^2 for each of the affected grids (make sure you convert the costs in m^2 to km^2). For ease of calculation, approximations (¼, half, ¾, etc.) can be made when counting grids that are partially inundated. For critical infrastructure, locate the grids where each of the facilities are located and determine if the grid is inundated or not according to the 100-year flood hazard map. If yes, use the replacement/repair costs to compute the direct monetary losses. Looking at the 100-year flood inundation map, one can also immediately see that all of Westville, the industrial zone of Xa, will be inundated.

Results

After successfully completing the overlay analysis, participants should have for each geocell:

Replacement cost for Building Damage (sum for each of the 6 administrative areas in Xa)

Table 7.6 Replacement Costs for Damaged Buildings

Area	Flood Damage (Cost of Replacement) Xa $/m^2	100-year Flood Inundation (km^2)	Total Flood Damage Replacement Costs (Xa $M)
Westville	5,000	6	3,000
Xaravi	500	4	200
City Center	3,000	2.5	750
Epart	1,500	6.5	975
Beetown	2,000	4	800
Newpart	2,500	2	500
			Total Damage = Xa $6,225M

Replacement/Repair costs for critical facilities (if they are contained in the grid)

Table 7.7 Replacement Costs by Flood Severity

Critical Infrastructure	Flood Damage (Cost of Repair and Replacement of Content)	20-year Flood (Xa $M)	100-year Flood (Xa $M)	500-year Flood (Xa $M)
Hospital	50			50
Central Train Station	15		15	15
Airport	200			200
Harbor	80		80	80
Nuclear Power Plant[1]	100			100
Museum[1]	6			6
Fire Station	1			1
Totals			95	452

It can be seen immediately that the flood damage costs are enormously high for Xa, for a 100-year event which is actually not an extreme event. For an even less frequent event, such as a 500-year flood, all the critical infrastructure of Xa including the Nuclear Power Plant will be inundated which is a catastrophic scenario. Even for a 100-year event, as in the case of the earthquake the harbor and the central train station which are vital to the flow of the regional economy in Xa will be out of service.

In the flood risk analysis the following elements deserve special attention:

- The nuclear power plant as the major risk element
- The fire station as the major emergency response unit
- The chemical factory in the industrial area as the chief potential source of environmental pollution
- The hospital
- The airport, the highway, the national road and the bridge over the river as the most important life lines and emergency aid connections of the city
- The museum as the most important cultural heritage of Xa

The importance of the elements should be recognized and discussed in the risk analysis report prepared by the participants. Also, monetary vulnerability estimation in some cases is not feasible (e.g. museum and nuclear power plant). Thus participants should categorize the risk by qualitative susceptibility and the severity of consequences of flooding. E.g. the risk imposed by a flooded nuclear power plant is immensely high therefore the flooding of the plant has to be prevented at any cost. The discussion should also include identification of a prioritization scheme for mitigation based on the 100-year flood event, but also the 20-year and 500-year event included in the Appendix.

Socio-economic Impacts Analysis

An approach to compute Socio-economic Impact is to use the Urban Seismic Risk Index, which was discussed in Module 2, session 2 and given as a case study in Module 1. In this approach, physical losses are aggravated by an impact factor, to capture a total risk score. This approach requires the calculation of total direct physical losses, and the calculation of an impact factor

Total Direct Physical Losses

Direct physical losses should be determined in terms of Xa$ values and include the cost of replacement of buildings, lifelines and critical infrastructure. Participants had already calculated this for both earthquakes and floods in section 2.1 and 2.2

In order to obtain a relative ranking of the administrative regions in Xa in terms of their total direct physical losses, first the direct physical losses from building damage have to be summed up for each administrative region. If these regions include critical facilities, also include their contribution. As lifeline losses in RADIUS are given over the entire target area and are not spatially explicit, and because we did not calculate these in the flood risk analysis, we will not include the damage to lifelines here to keep calculations simple.

Once the direct physical losses from the scenario earthquake and 100-year flood have been obtained for each administrative region, these values have to be transformed into indicators ranging between 0 and 1. Thus the values have to be normalized. This can be done by dividing all values in a column by the highest value in that column (see Tables 7.8, 7.9 and 7.10).

Finally, the total direct physical loss for Xa is obtained as a weighted average of the direct losses from the MCE earthquake scenario and direct losses from the 100-year flood for each administrative region in Xa. In other words:

Total Direct Physical Losses = (0.5 x Earthquake Loss Indicator) + (0.5 x Flood Loss Indicator)

Table 7.8 Direct Physical Losses from Earthquake Damage

Location	Direct Losses from Building Damage	Direct Losses from Damage to Critical Infrastructure	Total Direct Losses	Direct Loss Indicator
Westville	653		653	0.28
Xaravi	16		16	0.01
City Center	2,287	56	2343	1.00
Epart	542	95	637	0.27
Beetown	451		451	0.19
Newpart	184		184	0.08

Table 7.9 Direct Physical Losses from 100-year Flood Damage

Location	Direct Losses[1] from Building Damage	Direct Losses[1] from Damage to Critical Infrastructure	Total Direct Losses	Direct Loss Indicator
Westville	3,000		3,000	1.00
Xaravi	200		200	0.07
City Center	750		750	0.25
Epart	975	95	1,070	0.36
Beetown	800		800	0.27
Newpart	500		500	0.17

Table 7.10 Direct Loss Indicators

Direct Loss Indicator for Earthquake Damage (6.9 Magnitude Scenario)	Direct Loss Indicator for Flood Damage (100-year Flood)	Total Direct Loss Indicator (Equally Weighted Average of Flood and Earthquake Losses) = (0.5 x Earthquake Loss Indicator) + (0.5 x Flood Loss Indicator)
0.28	1	0.64
0.01	0.07	0.04
1	0.25	0.63
0.27	0.36	0.32
0.19	0.27	0.23
0.08	0.17	0.13

Impact Factor

Socially vulnerable populations could be most dependent on public resources after a disaster and thus could be good investment areas for hazard mitigation activities. In Table 7.11, below, the fragilities and coping capacities of each of the six urban regions in Xa have been evaluated. Four fragility indicators and four indicators of coping capacity have been provided. For ease of calculation these indicators have also been normalized. Participants will need to calculate the Fragility Index and Coping Capacity Index as a weighted average of the indicators, according to the formula shown below.

Importance Weights: Not all of the indicators shown above have to be equally important. This is a subjective matter and some of the indicators in the table may perceive as more important than others. In the suggested formula all indicators have been equally weighted (weight = 0.25), however, you may find some indicators more important than others and give them a higher weight. Make sure the weights add up to 1.0 in the end. Make sure that all the weights add up to 100% in the end.

Table 7.11 Fragility Index and Coping Capacity Index

Social Fragilities in Xa					
Location	Population Density (PD)	Minority Populations (MP)	Households below poverty (HP)	Population over Age 65 (AGE)	Fragility Index
Westville	0.01	0.02	0.00	0.20	0.06
Xaravi	0.10	0.55	0.85	0.10	0.40
City Center	0.46	0.15	0.10	0.15	0.22
Epart	0.08	0.03	0.02	0.35	0.12
Beetown	0.20	0.20	0.03	0.10	0.13
Newpart	0.15	0.05	0.00	0.10	0.08

Table 7.12 Coping Capacity Index

Coping Capacities in Xa					
Location	Medical Services (MS)	Risk Perception (RP)	Insurance (INS)	Emergency Response Resources (ERR)	Coping Capacities Index
Westville	0.30	0.30	0.95	0.45	0.50
Xaravi	0.05	0.25	0.00	0.05	0.09
City Center	0.70	0.30	0.55	0.55	0.53
Epart	0.25	0.40	0.25	0.35	0.31
Beetown	0.20	0.15	0.15	0.10	0.15
Newpart	0.15	0.05	0.45	0.10	0.19

Impact Factor: This can be obtained as (1 + F), where

Coping Capacity Index = (0.25xMS) + (0.25xRP) + (0.25xINS) + (0.25xERR)
Fragility Index = (0.25xPD) + (0.25xMP) + (0.25xHP) + (0.25xAGE)
F =Fragility Index/Coping Capacity Index
Total Risk = Total Direct Losses x (Impact Factor) = Total Direct Losses x (1 + F)

Table 7.13 Total Risk Index

Location	Total Direct Loss Indicator (floods and earthquakes)	F = Fragility Index /Coping Capacity Index	Impact Factor (1 + F)	Total Risk Index
Westville	0.64	0.12	1.12	0.71
Xaravi	0.04	4.57	5.57	0.22
City Center	0.63	0.41	1.41	0.89
Epart	0.32	0.38	1.38	0.44
Beetown	0.23	0.88	1.88	0.43
Newpart	0.13	0.40	1.40	0.18

As discussed in depth in the Megacity Indicator System case study of Module 1, this approach provides a holistic look at risk that accounts not just for damage, but also how damage may be aggravated by social vulnerability conditions. The high population density in the City Center and high flood and earthquake risk indexes make this the riskiest place to be in Xa. However, it is interesting that the industrial area of Westville is also ranked very high. Perhaps the most interesting observation is that even though the losses in Xaravi are lower than in Newpart, the social vulnerability conditions in Xaravi create for an overall higher risk score than Newpart. The districts can also be ranked and the results can be shown in bar charts.

Figure 7.15 Coping Capacity

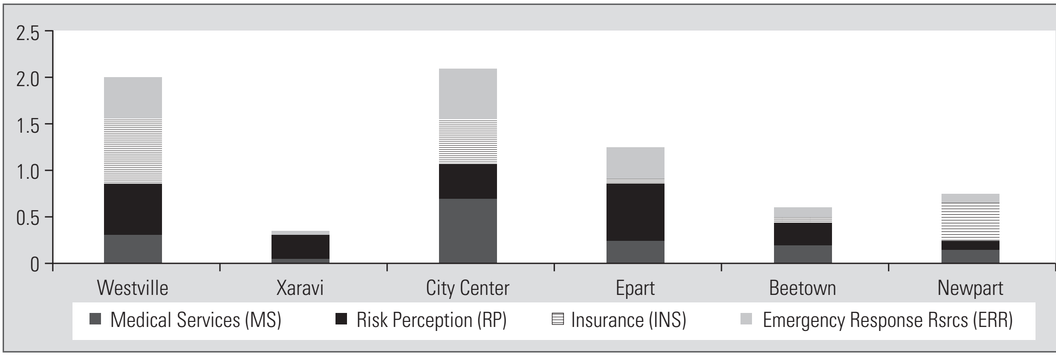


Figure 7.16 Social Fragility

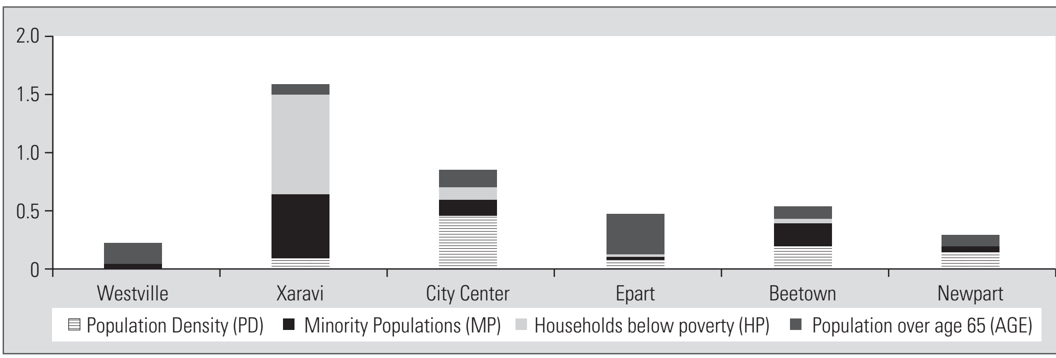


Figure 7.17 Direct Loss (Flood and Earthquake)

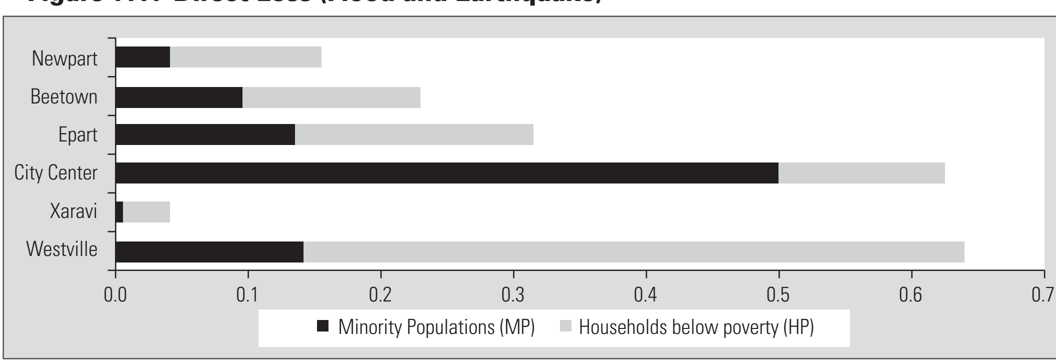
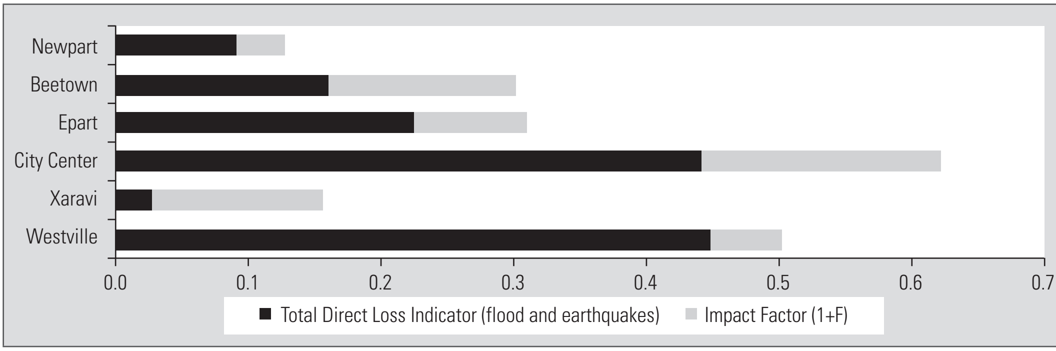


Figure 7.18 Total Risk Index



Action Plan

In the action plan, participants should interpret their findings in obtaining earthquake and flood risk parameters and socio-economic impacts in Xa in developing thoughtful approaches to mitigating these threats.

Flood Risk: The 20 year event doesn't show any damage, because the flood is well contained within the dike lines. Only the uncontrolled urban settlement within the dikes lines has to be seen critical. In the 100 year event the chemical factory is causing the most severe threat to population and environment. Special attention deserves also the unplanned settlement within the dike lines which is severely affected as well as the highway and the national road, which both will be flooded. The fire station is closely affected and given the inherent uncertainties of risk assessments, some action should be taken here. The 500 year event is catastrophic. All special elements at risk are affected, even the nuclear power plant. Based on this, the management options listed on the last slide of the presentation (found in module 3, session 3) should be discussed and worked out. Because an actual cost benefit analysis cannot be performed, we assume that for the 100 year flood structural protection measures, i.e. the improvement of the weak dike section and the protection of the highway and national road, will pay off. The costs for permanent structural measures for flood protection in case of a 500 year flood are extraordinary high and the low probability of the event does not justify them. Only the nuclear power plant has to be protected at any cost. However, disaster management plans should be developed for this scenario.

Earthquake Risk: In the earthquake scenario, Newpart suffers the least damage (MDR = 0.1 or approx. 10%). The other areas vary depending on soil type and construction type. Especially vulnerable to earthquake damage is the city center, which by itself is almost 3 times as high as the vulnerability of the area ranked just below it, the industrial zone of Westville. Given the large losses associated with damage to the city center, and the importance of this area to the economy and welfare of Xa (e.g., location of museum, hospital, etc.), a more detailed study should be made on the vulnerability of building types and a cost benefit analysis should be carried out with considerations of retrofitting the old structures. A possible alternative scheme may be an urban renovation/renewal program where the most vulnerable areas are demolished and a new zone contributing to the economic growth of Xa can be developed. However, the implications of such plans must be studied carefully in displacing the residents of Xa and affecting their livelihoods. Another vulnerable area is the industrial area. This area, as well as the lifelines connected to it (e.g., harbors, train stations, railways, or bridges) are all expected to experience high levels of ground motion during the scenario earthquake and have to be secured to minimize the cascading impacts of indirect economic losses.

Socio-economic Impact: The perception of risk and level of preparedness is not equal throughout Xa. Newly developed areas such as Newpart and Beetown have little perception of risk. Perception of risk and the level of preparedness are also very low in the Xaravi slums. Given the social fragility in this area more active risk communication and preparedness programs can help with flood warning and evacuation programs. The participants should suggest several areas of potential mitigation based on obtained results in reducing the socio-economic impacts to the most vulnerable populations.

Part 4 of the ECP report is more open-ended and includes discussions of action plans for mitigating the risks. This should be a thoughtful reflection of the situation and special attention should be given to the following elements:

- Discussion of possible mitigation and mediation strategies for the city of Xa that, if implemented, would reduce the city's seismic and flood risk. The action plan should be prepared based on the results of the risk analysis.
- What are some of the indirect impacts of the scenario earthquake and 100-year flood that were not considered in the analysis?
- Review the 20-year and 500-year flood hazard map in Appendix I of the ECP handout, and explain how you would prioritize mitigation for a flood event based on this additional information.

The EPC report should be summarized in 5–10 pages. Part of the project is the calculation of losses and socio-economic impacts. The report should include the following calculations:

- Direct physical losses from earthquake scenario
- Direct physical losses from 100-year flood
- Total direct physical loss indicator for earthquake and flood combined
- Fragility Index
- Coping Capacity Index
- Impact Factor
- Total Risk Index

Checklist for Review/Grading Points

The End-of-Course Project and the test should be completed within two weeks of finishing the review of basic training materials. The evaluation of the End-of-Course are based on the following criteria: (i) Use of and references to course content, (ii) Significance of the case and lessons learned, (iii) Focus, substance and depth of the analysis, including data and illustrations.

Week 4–5 Checklist	Grading Points
Part 1: Earthquake Risk Analysis (10 points)	
Creation of a mesh for Xa and input of basic data in RADIUS	3
Correct Calculation of Results in RADIUS	2
Calculation of direct losses from building damage based on MDR	1
Calculation of direct losses from lifelines based on damage ratio	1
Calculation of direct losses from critical infrastructure	1
Focus, substance and depth of the analysis, including data and illustrations.	2
Part 2: Flood Risk Analysis (5 points)	
Deriving loss estimates of 100-year flood for building damage	1
Deriving loss estimates of 100-year flood for critical infrastructure	1
Reference to 20-year or 500-year flood map in comparison to 100-year event	1
Focus, substance and depth of the analysis, including data and illustrations	2
Part 3: Socio-economic Impacts (5 points)	
Calculation to total direct (flood and earthquake) loss indicator	1
Calculation of Impact Factor	1
Calculation of Total Risk Index	1
Focus, substance and depth of the analysis, including data and illustrations (bar charts)	2
Part 4: Action Plan (10 points)	
Discussion of mitigation and mediation strategies to reduce seismic risk	3
Discussion of mitigation and mediation strategies to flood risk	3
Discussion of direct vs. indirect impacts	2
Focus, substance and depth of the analysis, including data and illustrations (bar charts)	2
Total Score	30

Final Exam

Questions Related to Module 1: Fundamentals of Risk Analysis

1. Which of the following questions does risk analysis try to answer?
   a. ○ Probability of a hazard event occurring?
   b. ○ Consequences or impacts of the hazard event?
   c. ☑ Both a. and b.
   d. ○ None of the above.

2. What is an "Acceptable Risk"?
   a. ○ Risk associated with an event with low probability of occurrences.
   b. ○ Risk with insignificant consequences.
   c. ○ Risk with b enefits that compensate for potential negative consequences.
   d. ☑ All of the above

3. An element/asset is considered **vulnerable**, if it is:
   a. ○ Exposed to the hazard
   b. ○ Fragile or susceptible to the hazard event
   c. ○ Does not have the capabilities or resources to withstand the negative impacts of the hazard event
   d. ☑ All of the above

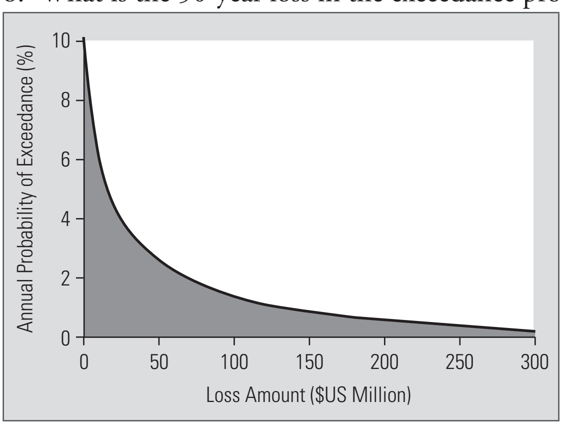
4. What is the goal of a hazard analysis? (Maybe more than one answer)
   a. ☑ To determine where and over which extent a hazard will occur
   b. ☑ To determine how big a hazard will be in different locations over an affected area
   c. ☑ To determine how often will a certain event of a particular size occur
   d. ○ To determine the impacts of an event, given that it occurs

5. What information can be obtained from a "Fragility Curve"?
   a. ○ The degree of hazard intensity
   b. ○ The geographic region affected by the hazard
   c. ☑ The degree of the damage as a function of the level of hazard experiences
   d. ○ All of the above

6. What is the difference between deterministic and probabilistic risk analysis?
   a. ⊘ In the deterministic risk analysis a postulated event is assumed while in probabilistic risk analysis the probability of the event occurring is calculated
   b. ○ In both probabilistic and deterministic risk analysis a postulated event is assumed, however in the deterministic risk analysis uncertainty associated with the risk is not calculated
   c. ○ Probabilistic risk analysis is by experts and deterministic risk analysis is used only for advocacy and training purposes
   d. ○ Probabilistic risk analysis focuses on the hazard, while deterministic risk analysis focuses on the vulnerability component.

7. Which of the following statements are **not** true about a flood having a 100-year return period?
   a. ○ The probability that the 100-year flood will be exceeded in any one year is 1%
   b. ○ The probability that the 100-year flood will be exceeded in 50 years is 50%
   c. ○ It is possible to have two “100-year floods” in less than two years
   d. ⊘ A 100-year flood occurs regularly once every hundred years

8. What is the 50-year loss in the exceedance probability (loss frequency curve) shown here?



   a. ○ 20 million USD
   b. ⊘ 65 million USD
   c. ○ 275 million USD
   d. ○ None of the above

9. What does the area under an exceedance probability curve represent?
   a. ○ The maximum amount of losses that can be expected to occur
   b. ○ The total amount of losses that can be expected to occur
   c. ⊘ The average amount of losses that can be expected to occur in one year
   d. ○ None of the above

10. Which approaches are used in combining hazards in the multi-hazard map of Sri Lanka?
    a. ○ Using weights of each hazard based on the number of occurrences of each hazard
    b. ○ Using weights of each hazard by the disaster relief expenditure of each hazard
    c. ○ Using equal weights for each hazard
    d. ⊘ All of the above

11. Which of the four indices below were not developed under the IDB-IDEA Americas program?
    a. ○ Disaster Deficit Index (DDI)
    b. ⊘ Social Vulnerability Index (SVI)
    c. ○ Local Disaster Index (LDI)
    d. ○ Risk Management Index (RMI)

Questions Related to Module 2: Earthquake Risk Analysis

12. Why and where do earthquakes occur? (May be more than one answer)
    a. ⊘ Plate tectonics; on faults
    b. ○ To release built up energy and stress in the earth; on faults
    c. ○ Because of landslides; on mountains.
    d. ○ Because of directivity; on faults.

13. What is the correct earthquake process?
    a. ○ An earthquake occurs at the epicenter producing P, S and surface waves which travel through the earth to the site where the ground motion is felt.
    b. ⊘ An earthquake occurs at the hypocenter producing P, S and surface waves which travel through the earth to the site where the ground motion is felt.
    c. ○ An earthquake occurs at the site producing ground motion which propagates waves towards the source.

14. Which of these are secondary hazards to earthquake shaking? (May be more than one answer)
    a. ⊘ Tsunami
    b. ⊘ Fire

c. ⊘ Cyclones
d. ⊘ Liquefaction
e. ⊘ Landslides
f. ⊘ Fault Rupture

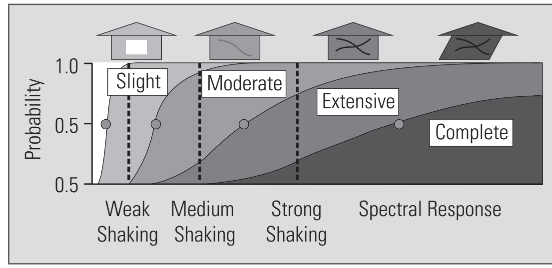
15. Where does the most amplification of soils occur?
    a. ○ Rock sites
    b. ○ In water
    c. ○ Far away from a fault
    d. ⊘ In loose soils or valleys.

16. What are 5 main contributors to the vulnerability of buildings? (May be more than one answer)
    a. ⊘ Design of the building
    b. ⊘ Construction Material
    c. ○ Number of Doors
    d. ○ Number of Windows
    e. ⊘ Age of the building
    f. ⊘ Irregularities in the building
    g. ⊘ Location of the building
    h. ○ Rate of Construction

17. What does 0.85 mean as a damage ratio value in a Damage Probability matrix for a group of buildings of a certain material? Is it a high or low value of damage?
    a. ○ 85% of buildings will be destroyed; Low
    b. ○ 85% of buildings will be destroyed; High
    c. ○ Each of the buildings will have 85% damage; Low
    d. ⊘ Each of the buildings will have 85% damage; High

18. There is a 5 story building and the peak acceleration occurs at 0.5 seconds. Would the building be expected to vibrate strongly?
    a. ⊘ Yes.
    b. ○ No.

19. The capacity spectrum method has been undertaken and it has been found that a group of certain buildings has a high spectral displacement = strong shaking, on the following diagram What are the % of buildings in certain damage states?



   a. ○ 50% slight, 50% moderate
   b. ○ 10% none, 90% complete
   c. ○ 100% moderate, 80% extensive, 20% complete
   d. ⊘ 20% moderate, 60% extensive, 20% complete.

20. What is the difference between risk and hazard for earthquakes?
   a. ○ There is no difference, they are the same.
   b. ○ Hazard is the amount of losses or damage that could occur at a certain location and risk is the probability of occurrence of ground shaking in time.
   c. ⊘ Risk is the amount of losses or damage that could occur at a certain location and hazard is the probability of occurrence of ground shaking in time.
   d. ○ I know there is a difference, but I need to reread the notes.

21. What is a mean damage ratio?
   a. ○ The damage that has occurred in a location which is very mean.
   b. ○ The mean ratio of replacement to repair for a certain location.
   c. ⊘ The mean ratio of repair to replacement for a certain location.

22. Why is earthquake loss analysis important?
   a. ○ Because it provides results that policymakers can employ to improve earthquake design
   b. ⊘ It provides a social and economic result that policy makers can understand and eventually use for mitigation and mediation purposes.
   c. ⊘ It can be used for response and recovery as a first order estimate where similar scenarios have been undertaken previously.

23. What method is proposed to retrofit the existing building stock of 800000 buildings in the "Earthquake Vulnerability of Buildings and a Mitigation Strategy: Case of Istanbul" Reading?
   a. ○ Undertake a non-linear static procedure on each building to determine the capacity.
   b. ⊘ A screening method with prioritization for risk.
   c. ○ An engineering capacity assessment looking at recovery of buildings.

24. According to the reading on Building Technical and Political Capacity for Seismic Risk Reduction, What makes a community vulnerable to earthquakes? (May be more than one answer)
    a. ○ Seismically resistant construction
    b. ⊘ Low construction standards without lateral resistance
    c. ⊘ Siting of certain construction types
    d. ⊘ Building in coastal low lying areas near active fault systems
    e. ⊘ Communication and emergency control centers that are concentrated in a high-hazard location
    f. ○ Hospital facilities that are adequately built and prepared for large numbers of casualties.
    g. ⊘ Flaws in planning

25. Which of the following is true of the performance of buildings in earthquakes? (May be more than one answer)
    a. ○ The poor, elderly, and disadvantaged are less likely to live in the most vulnerable buildings.
    b. ⊘ The performance of specific building types in an earthquake can be used as a guide for improving risk assessments and risk management.
    c. ○ Engineered buildings are likely to collapse in a major earthquake.
    d. ⊘ Buildings constructed in accordance with modern building codes perform well in earthquakes.
    e. ⊘ Unreinforced masonry buildings are more vulnerable to collapse than buildings constructed from other types of building materials like reinforced concrete and timber.

Questions Related to Module 3: Flood Hazard Analysis

26. What are the causes of floods?
    a. ○ Excessive rainfall
    b. ○ Exceedance of retention capacity of the catchment (i.e. infiltration capacity of soils, surface storage)
    c. ○ Exceedance of conveyance capacity of river channels
    d. ⊘ All of the above

27. What inland flood type has the shortest lead time and highest flow velocity?
    a. ○ Tsunamis
    b. ○ River floods
    c. ⊘ Flash floods
    d. ○ Groundwater floods

28. How is the magnitude of a flood defined?
    a. ○ By maximum discharge
    b. ○ By flood volume
    c. ○ By maximum flow velocity
    d. ⊘ By either one or a combination of the above

29. How is the flood intensity index defined?
    a. ○ Flow velocity divided by water level
    b. ⊘ Flow velocity multiplied by water level
    c. ○ Flood velocity multiplied by flood volume
    d. ○ Water level + lead time

30. What characterizes a one-dimensional hydraulic model?
    a. ⊘ That the flow is simulated in one spatial dimension parallel to the river course.
    b. ○ That the flow is simulated in the time domain only.
    c. ○ That only one river reach can be simulated at a time.
    d. ○ That the flow is simulated over a rectangular grid.

31. What are the general expected impacts of climate change on floods?
    a. ○ Generally floods will not change with climate change.
    b. ○ With raised temperatures evaporation will increase, thus floods will decrease.
    c. ○ A warmer climate cause less rainfall and thus less floods.
    d. ⊘ An increased energy content of the atmosphere, both sensible and latent, will cause more frequent and more intense rainfall events, thus floods have to be expected to increase in frequency and magnitude in general.

32. What are the causes of the increasing flood losses in the past decades worldwide, besides increasing number of flood events?
    a. ○ River training
    b. ○ Increasing use of flood plains for urban development
    c. ○ Decreasing awareness of flood risk
    d. ⊘ All of the above

33. Why are flood loss data important?
    a. ○ Because they enable loss model development
    b. ○ Because they enable loss model validation
    c. ○ Because they enable regional loss model adaptation
    d. ⊘ All of the above

34. Why do we have to live with risks?
    a. ○ Because disasters are naturally occurring phenomena
    b. ○ Risks are a consequence of our vulnerability to natural disasters
    c. ○ We can by no means guarantee absolute safety
    d. ⊘ All of the above

35. What is the basis of flood risk analysis?
    a. ⊘ An encompassing set of flood scenarios and damages associated with probabilities of occurrence
    b. ○ A very detailed analysis of the hazards
    c. ○ A very detailed analysis of the vulnerabilities
    d. ○ A sound knowledge of the area

36. What is the correct process chain of a flood risk analysis?
    a. ○ Estimation of flood magnitude —> exposure mapping of elements at risk —> derivation of inundation area and depths —> flood loss estimation
    b. ○ Exposure mapping of elements at risk —> estimation of flood magnitude —> exposure mapping of elements at risk —> derivation of inundation area and depths —> flood loss estimation
    c. ○ Derivation of inundation area and depths —> exposure mapping of elements at risk —> estimation of flood magnitude —> exposure mapping of elements at risk —> flood loss estimation
    d. ⊘ Estimation of flood magnitude—> derivation of inundation area and depths —> exposure mapping of elements at risk —> flood loss estimation

37. How can uncertainty analysis help in flood risk analysis?
    a. ○ Uncertainty analysis supports the credibility of flood risk analysis as well as the interpretation of the results
    b. ○ Not at all, because it undermines the credibility of science
    c. ⊘ It helps only in cases where data quality is good.
    d. ○ It gives only qualitative results, thus it is of limited use.

38. What is the most basic flood hazard map?
    a. ○ Flood velocity map
    b. ○ Flood depth map
    c. ⊘ Flood extend map
    d. ○ Flood duration map

39. What is the specific feature of the damage model FLEMOps+ covered in the case study of the Flood risk analysis module?
    a. ○ It is a relative damage function.
    b. ☑ It considers precautionary measure and contamination in the damage estimation.
    c. ○ It resembles a step-function.
    d. ○ It takes the inundation depth as the dominant damage influencing factor.

40. How are the flood defenses considered in the large scale study of flood risk potential in Europe (covered in the case study of Module 3)?
    a. ○ Very detailed with high resolution
    b. ☑ They were neglected to show the damage potential without the protection by dikes.
    c. ○ They were considered on large rivers only.
    d. ○ They were considered on flash flood prone rivers only.

VIII. Discussion Forum

8.1 Guidelines for Facilitators

Facilitated online courses represent an entirely different mode of learning where peer learning among participants and the facilitation skills of the instructor make significant contributions to the collective learning of the group. Peer education is more effective if it takes place in smaller groups, and the role of a facilitator who reinforces positive behaviors and is able to set the tone and guide the discussions is very important. The following are some suggested guidelines for selecting facilitators in such programs:

1. A knowledgeable person about the course contents and various issues pertaining to the theme of the course who can introduce the subject content in a "Step by Step" manner from simple to complex and from general to specifics.
2. A good communicator who can bring out the objectives of the course and raise relevant issues to the main and sub themes of the discussion.
3. A person who can analyze the initial behavior of all participants and understand the training need of the participants.
4. A mature person who can handle the participants with different entry behavior and also can resolve the issues during discussion to an agreeable conclusion.
5. A person with lots of patience who can motivate and encourage participants to take active part in the discussion forums.
6. A person who can give constructive feedbacks, who is not biased and selective in giving his observation to participants with different fields of expertise.

8.2 Techniques for Course Facilitation

In an online communication, it is important to consider following three important factors:

1. The way we formulate questions—the way we formulate our questions serves as the spring boards for generating various or different ideas and points of view. If we want to have a lively online environment, we need to focus our question to what is the need of the learners and how it will earn more response.
2. The way we understand—it is important to understand the viewpoint expressed by the participants. We have to pay attention to various points of views, opinions in order to stay focused on the discussion.
3. The way we give feedback—in an online course, we have to give always a constructive feedback. We need to reread and rethink before we give our feedback so as not to discourage the participant. One needs to choose the right timing on when, where and whom to give a certain feedback.

A course facilitator should do the following:

1. Making the participants feel at ease. The participants should have the "comfortable push" to start the activities. This could be done by giving the participants easy tasks, time to move around the training tools and posting brief personal profile. Instruction on how to do the activities must not be intimidating but rather friendly. An ice breaker activity could also set the pace.
2. Ice breaking exercise is a very important tool for the facilitators. It generally helps in relieving the participants from unnecessary tension and does help them in opening up to share their ideas. Icebreakers should be introduced at the beginning of the course in order for the participants to know one another. Encourage them to look into all the participants' profile which will generate interest and create a friendly atmosphere. Facilitator can encourage a participant by posing relevant questions in a simple manner, which will ultimately help him in sharing his ideas in a free and friendly manner.
3. There are participants who behave like a "know-all", which sometimes become irritating and intimidating and as such, could affect the quality of the other participants' involvement in the discussions. The facilitator must keep on citing constant reminders about allowing everybody to contribute into the discussions and continuous encouragement/motivation for other participants to share their thoughts as well as the approaching deadlines of submissions of assignments and the ECP.

8.3 Summary Table for Weekly Discussions

The following table outlines the weekly schedule of discussion questions and topics.

Table 8.1 Consolidated Weekly Discussion Questions

Week	Topic	Recommended Questions
Week 1	Basic Concepts of Risk Analysis (initial questions)	1. Describe your background and professional role, and how you envision an assessment of risk and vulnerability due to various hazards prevailing in your program/project/area can be helpful.
	Elements of Risk Analysis (initial questions)	2. It is a well-known fact that enhanced vulnerabilities, due to developmental practices, are posing a greater challenge to development practitioners, physical planners, emergency response personnel and disaster risk reduction experts in recent times. Briefly explain various processes/factors that make areas vulnerable to disasters as well as increase their vulnerability over time.
	Instruments and Approaches in Risk Analysis (initial questions)	3. These days, national governments are pursuing disaster risk mitigation activities very seriously. Under such activities, risk and vulnerability analysis programs are being taken up at various levels. Please share your experiences about the risk analysis and/or vulnerability analysis instruments and approaches applied in your program/project/area.
	Basic Concepts of Risk Analysis (follow-up questions)	4. What do you see as obstacles in mainstreaming risk analysis into your disaster risk management? 5. What role do "risk acceptance" and "risk perception" play in the way the results of a risk analysis is used by decision makers?
	Elements of Risk Analysis (follow-up questions)	6. Please identify a dimension of vulnerability relevant to your community/area/sector/prevalent hazard. What do you see at the root causes of this dimension of vulnerability that you have identified? Can you think of some indicators that describe the susceptibility as well as lack of resilience of your community with respect to this dimension of vulnerability?
	Instruments and Approaches in Risk Analysis (initial questions)	7. Please elaborate which of the risk analysis tools introduced in Session 3 you might use in your program/project/area and state your reasons for it.

Table 8.1 Consolidated Weekly Discussion Questions

Week	Topic	Recommended Questions
Week 1 (continued)	Discussion of Module 1 Assignment	8. What does the map say about the risk of earthquake in the United States? Does the map include any information about vulnerability of buildings and populations? Interpret the information provided in this map in your own words. 9. What level of risk is "acceptable" for the design of constructed facilities and lifelines? How does this level of earthquake probability compare with the risk from other natural disasters (such as damaging floods or) everyday threats such as car wrecks and plane crashes? 10. More people die each year world-wide from floods (i.e., consider Bangladesh), how does this hazard compare with earthquakes? 11. How concerned should we be about the level of earthquake threat given these other threats? How much risk is "acceptable"? What value should be placed on human life? How is risk perceived differently by different people? For instance, not being in control is why people tend to believe that jet travel is inherently riskier than riding in a car, even though we seldom think about the fact that we spend much more time driving than flying.
Week 2	Earthquake Hazard (initial questions)	12. Do you expect an earthquake to occur in your area in your lifetime? 13. What is the general level of perception of earthquake risk in your community? 14. What program and measures have been employed in your community to mitigate the threat of earthquakes? 15. Also, if you have experienced an earthquake please explain when this was, what you felt and what impacts this has had on you.
	Earthquake Vulnerability Analysis (initial questions)	16. Earthquakes can result in huge devastations of built environment and large number of deaths especially in developing and underdeveloped countries. To mitigate the impending earthquake risk, one of the prerequisite is the earthquake risk analysis. Please discuss the availability of various tools and techniques to assess the earthquake risk at national and international level that you know or have heard about.
	Earthquake Loss Estimation (initial questions)	17. What are some attributes of people, society, infrastructure and cultures that make them vulnerable to earthquakes? How are earthquake hazards as low probability events with severe consequences different from other more frequently occurring natural disasters?
	Earthquake Hazard (follow-up questions)	18. Why are ground motion prediction equations not exact? 19. How do site conditions affect ground motion? 20. What is the difference between a probabilistic and a deterministic analysis? When would you use one over the other? 21. What are some secondary hazards associated with earthquakes?

Table 8.1 Consolidated Weekly Discussion Questions

Week	Topic	Recommended Questions
Week 2 (continued)	Earthquake Vulnerability Analysis (follow-up questions)	22. Why can't we calculate vulnerability exactly? 23. What is a fragility curve and how does it work? 24. What are some examples of social vulnerability?
	Earthquake Loss Estimation (follow-up questions)	25. What is a damage loss conversion 26. What are some sources of uncertainties in earthquake loss estimation? 27. What are direct and indirect impacts of earthquakes 28. Why can't we know exactly how many people will die in an earthquake?
Week 3	Flood Hazard (initial questions)	29. Do you expect a flood to occur in your area? 30. What is the general perception of flood risk in your community? 31. What program and measures have been employed in your community to mitigate the threat of floods? 32. Also, if you have experienced a flood please explain when this was, and what impacts this has had on you.
	Flood Vulnerability (initial questions)	33. Floods are one of the most common natural hazards faced by the world. The flood risk mitigation also starts with its risk assessment. There are several tools and techniques available to assess the risk. You are kindly requested to elaborate about any tools and techniques to assess flood risks that you know about or would be of interest to you. 34. What is the most valuable information for your purpose/expertise/background that you can derive from a flood risk analysis?
	Flood Risk Management (initial questions)	35. What are some attributes of people, society, infrastructure and cultures that make them vulnerable to floods? 36. How do you think climate change can influence the occurrence of floods in the future? 37. Can you think of some demographic trends and other factors that can lead to increased vulnerability to floods in the future?
	Flood Hazard	38. What defines a flood hazard? 39. How can the magnitude and probability of a flood scenario be determined? 40. What is the problem in estimating extreme events? 41. Why is it necessary to pay attention to dikes in flood hazard analysis? 42. What is a hydrological cycle and the main causes of floods? 43. What are the general tendencies of climate change impacts on floods? How can climate change impacts be estimated? Is there a global tendency of climate change impact on floods?

Table 8.1 Consolidated Weekly Discussion Questions

Week	Topic	Recommended Questions
Week 3 (continued)	Flood Vulnerability (follow-up questions)	44. What does climate change and susceptibility have in common? 45. Why is susceptibility analysis so regionally specific? 46. What reduces susceptibility? Why is preparedness so efficient in reducing susceptibility? 47. Who and what is at risk of flooding? Who and what is exposed to floods? How susceptible are the exposed elements at risk to floods and how to calculate this? Identification and quantification of resilience to floods.
	Flood Risk Management (follow-up questions)	48. What are some sources of uncertainties in flood loss estimation? 49. How reliable is flood risk analyses and how can we increase confidence in flood risk analysis results? 50. How do we get from flood risk analysis to flood risk management? 51. What is the prerequisite of efficient and sustainable flood risk management?
	Open Questions	52. How could the lessons learned help in flood risk management of your environment? 53. Do you see some open questions in the context of your profession? 54. Which part of the whole procedure do you regard most critical for an application in your environment? 55. Are there any special elements at risk in your environment that were not covered in the course? And how would you analyze their vulnerability? 56. Do you live in a multi-hazard environment and how would you perform a risk assessment there?

Table 8.1 Consolidated Weekly Discussion Questions

Week	Topic	Recommended Questions
Week 4–5	Discussion of Module 2 Assignment	Put yourself in the perspective that you are involved in the decision-making process for the future of the city for which you have just completed the risk analysis assignment with RADIUS. Having just seen the earthquake loss estimation results t—46 deaths, 400 injuries and mean damage ratio is 0.323 for a town of 5000—what can be done if the town is expected to grow to the size of 50000 people within 10 years due to some mining discoveries. Answer the following questions from the perspective of assumed roles as: experts, local government officials, local homeowners, national government officials, local business owners, disaster management specialists. 57. Is there a solution that can be in every stakeholders' interest? 58. Now that you know about DSHA and PSHA, and using your new roles, what do you think will be your strategic interests? 59. What could be the possible mitigation and mediation strategies? How will that affect your way of life? 60. Which values do you trust more; RADIUS, or the case study method? Or should you do a PSHA and an analytical method? 61. Given that the uncertainty in such analyses is usually a factor of two greater or lesser, how does this affect your decision-making? 62. What would be found will be that the experts believe that there should be earthquake policy change? 63. What are the consequences for a town of 50,000 people with rapid construction? 64. Where would be the best place to site a hospital to ensure that it can withstand a large number of injuries from such an earthquake? 65. There is usually not a solution that is in every stakeholders' interest. 66. Local homeowners in Epart, may be very worried as they have a much larger chance of destruction given their soil type. Also with a rapidly expanding town, it has to be looked at if they will build in Epart or Beeville. 67. National government officials will always be worried in terms of the amount of money that they need to invest into earthquake preparedness and policy change. As the next election is only in 4 years, they will be most likely reluctant to do anything. 68. Local business owners will be more interested in any effect that increases insurance rates, or the worry of the new mine owners due to this earthquake policy meeting

Table 8.1 Consolidated Weekly Discussion Questions

Week	Topic	Recommended Questions
Week 4–5 (continued)	Discussion on Assignment, Module 3	Put yourself in the perspective that you are involved in the decision-making process for the future of the Xa for which you have just completed the flood risk analysis assignment. Having just seen the 20. 100 and 500 year flood risk maps for the town of Xa, please discuss the questions below: 69. Please explain how you would perform a risk appraisal (i.e., prioritize objects at risk) for each of the three inundation scenarios (i.e., 20, 100, and 500 year event) based on the following three criteria. 70. Identify the most important risks in the 100 year event. 71. Name and explain two criteria for flood mitigation planning. 72. What can be done if the town is expected to grow to the size of 50,000 people within 10 years due to some mining discoveries? How would the critical infrastructure and assets be protected? These questions can be played out as a role playing exercise.

8.4 Guidelines for Preparing Discussion Summary

By the end of Week 3, facilitators should have covered all aspects of the module and highlighted the main points described above. At the end of the week, the facilitator should post a summary of discussions reflecting on the main topics. The discussion summary should be concise and not more than one and a half pages. It should highlight the important issues discussed during the week.

The direction of the anticipate discussion will depend on the participants and their interactions. The discussion summary should first assess the discussion regarding the main points. The points correctly emphasized should be highlighted, followed by a list of issues that were not identified and properly discussed. Facilitators can point where the topics are covered in the learning materials.

8.5 Evaluation

In week 4 and 5 of the Risk Analysis Course participants need to work on the End-of-Course Project, pass the Final Test and fill out the Evaluation Questionnaire while also participate in the discussion. A new Forum space can be opened for questions related to the preparation of the EPC.

Completing all the tasks above in addition to the timely submission of the assignments of each module is necessary to meet the course requirements and receive a certificate. Participants can receive a maximum of 30 points for the project and 25 points for the test. They should score 70% in the final test to pass. Currently the final exam can be taken only once however this can be modified by the facilitator. 45 points can be collected by submitting the module assignments (15 points per module). Discussion forum contributions result in additional 30 points. To pass the course, a score of at least 90 points are needed and the final test and ECP are mandatory requirements for course completion.

The End-of-Course Project and the test should be completed within two weeks of finishing the review of basic training materials. The evaluation of the End-of-Course will be based on the following criteria:

1. Correct answers for the quantitative part of the assignment
2. Focus, substance and depth of the analysis, including data and illustrations
3. Use of and reference to course content

The best ECP reports can be included in future courses as reference materials.

Consolidated Weekly Discussion Questions

Table 8.2 Grading Rubric

Activity	Point Allocation
Module 1 Assignment	15
Module 2 Assignment	15
Module 3 Assignment	15
End of Course Project	30
Final Test	25
Active participation in	
Module 1 discussion	10
Module 2 discussion	10
Module 3 discussion	10
Total Points	130

IX. Annex

9.1 Glossary

Term	Definition	Cat*
Elements At Risk	These are the elements of infrastructure that are subjected to earthquake loading.	A
Acceleration	The rate of change of velocity of a reference point. Commonly expressed as a fraction or percentage of the acceleration due to gravity (g) where g = 980 cm/s^2.	E
Accelerogram	The record from an accelerograph showing ground acceleration as a function of time.	E
Accelerograph	A compact, rugged, and relatively inexpensive instrument that records the signal from an accelerometer. Film is the most common recording medium.	E
Accelerometer	A sensor whose output is almost directly proportional to ground acceleration. The conventional strong-motion accelerometer is a simple, nearly critically damped oscillator having a natural frequency of about 20 Hz–100Hz.	E
Acceptable Risk	The level of potential losses that a society or community considers acceptable given existing social, economic, political, cultural, technical and environmental conditions for a disaster. In engineering terms, acceptable risk is also used to assess and define the structural and non-structural measures that are needed in order to reduce possible harm to people, property, services and systems to a chosen tolerated level, according to codes or "accepted practice" which are based on known probabilities of hazards and other factors.	A
Accuracy	A measure of how close the results of an experiment are to the true value; a measure of the correctness of the result.	A
Active Fault	A fault that is considered likely to undergo renewed movement within a period of concern to humans. Faults are commonly considered to be active if they have moved one or more times in the last 10,000 years, but they may also be considered active when assessing the hazard for some applications even if movement has occurred in the last 500,000 years.	E
Active tectonic regime	A term that refers to regions where tectonic deformation is relatively large and earthquakes are relatively frequent, usually near plate boundaries.	E

Term	Definition	Cat*
Active tectonics	The tectonic movements that are expected to occur or that have occurred within a time span of concern to society.	E
Adaptation	The adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Comment: This definition addresses the concerns of climate change and is sourced from the secretariat of the United Nations Framework Convention on Climate Change (UNFCCC). The broader concept of adaptation also applies to non-climatic factors such as soil erosion or surface subsidence. Adaptation can occur in autonomous fashion, for example through market changes, or as a result of intentional adaptation policies and plans. Many disaster risk reduction measures can directly contribute to better adaptation.	A
Aesthenosphere	The asthenosphere (from Greek asthens 'weak' + sphere) is the highly viscous mechanically weak ductily-deforming region of the upper mantle of the Earth. It lies below the lithosphere, at depths between 100 and 200 km (~ 62 and 124 miles) below the surface, but perhaps extending as deep as 400 km (~ 249 miles). It is involved in plate movements and isostatic adjustments.	E
Affected Population	Those affected in varying degree by a disaster. They should be specifically catalogued in terms of gender, social strata, ethnic or other classification, including those belonging to physically challenged, etc. They are catalogued, in terms of severity of damage, as: Primarily affected. Men, women, children of all social strata, ethnic or social groups, whose livelihoods and welfare is severely affected by a disaster in terms of deaths, injuries, losses or severe damage to their houses and employment, and other major consequences on their well-being. It includes also population evacuated, in temporary shelters or that had to seek refuge after the event. Secondarily affected. Men, women, children of all social strata, ethnic or social groups that had indirect impact in their livelihoods in welfare, that lived in the directly affected area (towns, communities, area directly impacted by the disaster). Tertiary. Men, women, children of all social strata, ethnic or social groups that were impacted by overall (global economic and social) effects by a disaster, i.e., increased prices in goods and services, disruption in the provision of these, psychological trauma, etc.	A
Aftershock	Secondary tremors that may follow the largest shock of an earthquake sequence. Such tremors can extend over a period of weeks, months, or years.	E
Age Of Building	This is the amount of time from when the building was constructed to the present time	E
Aid	The act of assistance or supporting the vulnerable population during a disaster.	A

Term	Definition	Cat*
Amplification	An increase in seismic-signal amplitude within some range of frequency as waves propagate through different earth materials. The signal is both amplified and deamplified at the same site in a manner that is dependent on the frequency band. The degree of amplification is also a complex function of the level of shaking such that, as the level of shaking increases, the amount of amplification may decrease. Shaking levels at a site may also be increased by focusing of seismic energy caused by the geometry of the sediment velocity structure, such as basin subsurface topography, or by surface topography.	E
Amplitude	Zero-to-peak value of any wavelike disturbance—i.e. The maximum height of a wave crest of depth of a trough. (USGS National Earthquake Information Center, 1999)	E
Analytical	Using analysis via calculated or mathematical means.	A
Analytical Curves	Curves (generally defining fragility of a building type) derived by mathematical or first principles, i.e. mathematical-based curves of damage for continuous ground motion intensities. These are modeled rather than using historical data.	E
Analytical vulnerability method	Vulnerability methods constructed via mathematical and mechanical formulae to characterize the given damage per ground motion.	E
Annual Premium	The annual premium is the amount of money you will pay to have the insurance coverage against disasters.	A
Annual Probability of Exceedance	The probability that a given level of seismic hazard (typically some measure of ground motions, e.g., seismic magnitude or intensity) or seismic risk (typically economic loss or casualties) can be equaled or surpassed within an exposure time of one year.	A
Arias Intensity	A ground-motion parameter derived from an accelerogram and proportional to the integral over time of the acceleration squared. Expressed in units of velocity (meters per second).	E
Aseismic	Referring to a fault on which no earthquakes have been observed. Aseismic may be due to lack of shear stress across the fault, a locked-fault condition with or without shear stress, or release of stress by fault creep.	E
Asperity	A region on a fault of high strength produced by one or more of the following conditions: increased normal stress, high friction, low pore pressure, or geometric changes in the fault such as fault bends, offsets, or roughness. This term is used in two contexts: it may refer to sections of a fault that radiate uncommon seismic energy or it may refer to locked sections of the fault that cause fault segmentation.	E
ATC-13	In 1985 the Applied Technology Council (ATC) completed and published the ATC-13 report, Earthquake Damage Evaluation Data for California. Funded by the Federal Emergency Management Agency (FEMA), the ATC-13 report was developed to provide expert-opinion earthquake damage and loss methodology and data for use in estimating local, regional, and national economic impacts from earthquakes in California	E

Term	Definition	Cat*
Attenuation	A decrease in seismic-signal amplitude as waves propagate from the seismic source. Attenuation is caused by geometric spreading of seismic-wave energy and by the absorption and scattering of seismic energy in different earth materials (termed anelastic attenuation). Q and kappa are attenuation parameters used in the attenuation of ground motions.	E
Attenuation Relation	A mathematical expression that relates a ground-motion parameter, such as the peak ground acceleration, to the source and propagation path parameters of an earthquake such as the magnitude, source-to-site distance, or fault type. Its coefficients are usually derived from statistical analysis of earthquake records. It is a common engineering term for a ground motion relation. Also see ground motion prediction equation.	E
Average Annual Loss	Obtained as the sum of all losses weighted by probability of all events that create a loss. The Average Annual Loss concept helps in translating infrequent events and damage values into an annual number that can be used for planning purposes.	A
Base Flood	A flood having a 1 % chance of being equaled or exceeded in any given year. This flood is sometimes called the 1% or 100-year flood	F
Base Flood Elevation	A base flood elevation (BFE) is the height of the base flood, in relation to the National Geodetic Vertical Datum of 1929, the North American Vertical Datum of 1988, or other datum referenced in the Flood Insurance Study report, or the depth of the base flood above the ground surface.	F
Basin	The area of land that a river drains. This is used to determine how much water will enter a river after rainfall.	F
Basin Effects	Where surface waves are trapped in basins or valleys, and rebounding occurs causing increased or focused ground motion	F
Biodiversity	The number and variety of organisms found within a specified geographic region. The variability among living organisms on the earth, including the variability within and between species and within and between ecosystems.	A
Bedrock	Relatively hard, solid rock that commonly underlies softer rock, sediment, or soil.	E
Berm	A horizontal ledge cut into or at the top or bottom of an earth bank or cutting, to ensure the safety of a long slope	F
Blind fault	A fault that does not extend upward to the Earth's surface. It usually terminates upward in the axial region of an anticline. If is dip is less than 45 degrees, it is a blind thrust.	E
Body Waves	A seismic wave that propagates through the interior of the Earth, as opposed to surface waves that propagate near the Earth's surface. P and S waves are examples. Each type of wave has distinctive strain characteristics.	E
Bottleneck	A stage in a process that causes the entire process to slow down or stop.	A

Term	Definition	Cat*
Brittle-Ductile Boundary	A depth in the crust across which the thermomechanical properties of the crust change from brittle above to ductile below. A large percentage of the earthquakes in the crust initiate at or above this depth on high-angle faults; below this depth, fault slip may be aseismic and may grade from high angle to low angle.	E
Building Code	A building code, or building control, is a set of rules that specify the minimum acceptable level of safety for constructed objects such as buildings and non-building structures. The main purpose of building codes are to protect public health, safety and general welfare as they relate to the construction and occupancy of buildings and structures. A seismic code refers to a building code which uses earthquake-resistant design principles.	E
Business Interruption	Any event, whether anticipated (i.e., public service strike) or unanticipated (i.e., blackout) which disrupts the normal course of business operations at a location.	A
Capacity Spectrum method	A method which looks at capacity of the structure in terms of modeling the building as a simplified building versus the hazard demand, and then finds the performance point to classify the damage state.	E
Capacity (in Flood Analysis)	The measure of water capable of flowing through a channel, measured in cubic feet per second (CFS). Also the measure of how much water a stormwater detention facility holds, usually measured in acre-feet (AC-FT).	F
Catchment	The area drained by a river or body of water. Also called catchment basin.	F
Cluster Analysis	Cluster analysis or clustering is the assignment of a set of observations into subsets (called clusters) so that observations in the same cluster are similar in some sense. Clustering is a method of unsupervised learning, and a common technique for statistical data analysis used in many fields	F
Channel	An open conveyance of surface storm water having a bottom and sides in a linear configuration. Channels can be natural or man-made. Channels have levees or dikes along their sides to build up their depth. Constructed channels can be plain earth, landscaped, or lined with concrete, stone, or any other hard surface to resist erosion and scour.	F
Channel Flow	The amount of stormwater flowing through a channel, often measured in cubic feet (of stormwater) per second (or CFS).	F
Coastal Flood	Flooding when winds and/or tides cause a rise in the sea level that floods coastal areas.	F
Coherent Landslide	Landslides that consist of a few relatively intact blocks of rock or soil that move together. The basal failure surface of most of these slides is several meters or tens of meters below the land surface.	E
Collapse-Based	A vulnerability method looking at the complex structural dynamics of collapsed elements to construct an analytical vulnerability.	E
Commercial	A building with 50% or more space that is dedicated to offices.	A

Term	Definition	Cat*
Community	A group of people either bounded through similar location, sense of purpose, work or otherwise.	A
Community Capacity	The combination of all the strengths, attributes and resources available within a community, society or organization that can be used to achieve agreed goals. Capacity may include infrastructure and physical means, institutions, societal coping abilities, as well as human knowledge, skills and collective attributes such as social relationships, leadership and management. Capacity also may be described as capability. Capacity assessment is a term for the process by which the capacity of a group is reviewed against desired goals, and the capacity gaps are identified for further action.	A
Community Structure	This is the make-up of the community (this is generally classified based on economic, social, government, building and other indicators).	A
Community Vulnerability	See socio-economic vulnerability	A
Confluence	The intersection of two or more streams, or where one flows into another.	F
Condition	The quality of the infrastructure	A
Construction Material	The type of material that a building or particular infrastructure is made of.	E
Continental Crust	Outermost solid layer of the earth that forms the continents and is composed of igneous, metamorphic, and sedimentary rocks. Overall, the continental crust is broadly granitic in composition. Contrast with oceanic crust.	E
Continental Drift	See plate tectonics	E
Coping Capacity	The ability of people, organizations and systems, using available skills and resources, to face and manage adverse conditions, emergencies or disasters.	A
Correlation	1. A causal, complementary, parallel, or reciprocal relationship, especially a structural, functional, or qualitative correspondence between two comparable entities: a correlation between drug abuse and crime. 2. Statistics. The simultaneous change in value of two numerically valued random variables: the positive correlation between cigarette smoking and the incidence of lung cancer; the negative correlation between age and normal vision.	A
Cost-Benefit	Cost/Benefit Analysis is a technique for deciding whether to make a change. As its name suggests, it compares the values of all benefits from the action under consideration and the costs associated with it. The cost-benefit ratio is determined by dividing the projected benefits of the program by the projected costs. A program having a high benefit-cost ratio will take priority over others with lower ratios.	A

Term	Definition	Cat*
Creep	Slow, more or less continuous movement occurring on faults due to ongoing tectonic deformation. Also applied to slow movement of landslide masses down a slope because of gravitational forces. Faults that undergo significant and (or) ongoing creep are likely to be aseismic or capable of only small or moderate earthquakes. This fault condition is commonly referred to as unlocked (see locked fault and coupling).	E
Crest	The highest value of the stage or discharge attained by a flood; synonymous with Flood Peak, thus peak stage or peak discharge.	F
Critical Structures	1. Structures whose ongoing performance during an emergency is required or whose failure could threaten many lives. May include: a. structures such as nuclear power reactors or large dams whose failure might be catastrophic; b. major communication, utility, and transportation systems; c. involuntary- or high-occupancy buildings such as schools or prisons; and d. emergency facilities such as hospitals, police and fire stations, and disaster-response centers, e. The primary physical structures, technical facilities and systems which are socially, economically or operationally essential to the functioning of a society or community, both in routine circumstances and in the extreme circumstances of an emergency. 2. Critical Loss Facilities are hospital and health care facilities, public buildings, telecommunications, airports, energy systems (coal, nuclear etc.), bridges and other facilities that are critical to the recovery and rehabilitation of a region post-earthquake.	A
Crust	The outermost major layer of the Earth, ranging from about 10 to 65 km in thickness worldwide. The continental crust is about 40 km thick in the Pacific Northwest. The thickness of the oceanic crust in this region varies between about 10 and 15 km. The crust is characterized by P-wave velocities less than about 8 km/s. The uppermost 15–35 km of crust is brittle enough to produce earthquakes. The seismic crust is separated from the lower crust by the brittle-ductile boundary.	E
Culvert	A hydraulically short conduit which conveys surface water runoff through a roadway embankment or through some other type of flow obstruction.	F
Damage Class	Expected building damage ratios are calculated using vulnerability methods, and are classified in number of limit/damage states—none, slight, partial, moderate, severe and collapse or otherwise. It is essentially a range of percentages in terms of infrastructure damage.	E
Damage Function	Mathematical relationship for estimating building damage due to ground shaking.	E
Damage Probability Matrices	A matrix defining ratios of probable damage for each building type for a given ground motion, or a vulnerability class.	E

Term	Definition	Cat*
Damage State	Damage to building, transportation or lifeline systems described in terms of the nature and extent of damage exhibited by its components. Also see damage class.	E
Damage-Based Scale	Like calculating the size of an earthquake, there are also two main types of ground motion measurement—damage-based. Damage-based indices include MMI (Modified Mercalli Intensity) which is a 12 class system ranging from no damage to complete destruction, based on qualitative measurement of people's perception of damage at a location. Other similar scales include MSK (Russia), JMA (Japan), EMS (Europe) and Ross-Forel. They are not all with 12 damage levels.	E
Damage-Loss Conversion	Damage Loss Conversion, can be defined as the mean damage ratio (ratio of replacement & demolition to repair & restoration cost (economically-speaking), or the social cost (i.e. number of injuries, homeless and deaths).	E
Damping	The reduction in amplitude of a seismic wave or oscillator due to friction and (or) the internal absorption of energy by matter.	E
Dasymetric Map	The dasymetric map is a method of thematic mapping, which uses areal symbols to spatially classify volumetric data. Cartographers use dasymetric mapping for population density over other methods because of its ability to realistically place data over geography. Considered a hybrid or compromise between isopleth and choropleth maps, a dasymetric map utilizes standardized data, but places areal symbols by taking into consideration actual changing densities within the boundaries of the map. To do this, ancillary information is acquired, which means the cartographer steps statistical data according to extra information collected within the boundary. If appropriately approached it is far superior to choropleth maps in relaying statistical data within areas of interest. Dasymetric mapping corrects for error, termed "ecological fallacy", that may occur with choropleth mapping.	F
Deep Earthquake	An earthquake whose focus is located more than 300 kilometers from the earth's surface.	E
Delinquency Rate	The dollar amount of loans past due as a percentage of the dollar amount of loans in a portfolio. The delinquency rate is sometimes calculated on the basis of the number of loans delinquent rather than the dollar amount of loans past due. The delinquency rate is a measure of the proportion of a loan portfolio that is at risk.	E
Depth	The distance (usually measured in km) below the surface of the earth delineated by 0km (the mean spheroid). Also known as earthquake depth—Earthquakes can occur anywhere between the Earth's surface and about 700 kilometers below the surface. For scientific purposes, this earthquake depth range of 0–700 km is divided into three zones: shallow, intermediate, and deep.	E
Design	The engineering principles behind construction.	E

Term	Definition	Cat*
Design Discharge	The nth-year storm for which it is expected that the structure or facility is designed to accommodate.	F
Design Earthquake	The postulated earthquake (commonly including a specification of the ground motion at a site) that is used for evaluating the earthquake resistance of a particular structure.	F
Design ground motion	A level of ground motion used in structural design. It is usually specified by one or more specific strong-motion parameters or by one or more time series. The structure is designed to resist this motion at a specified level of response, for example, within a given ductility level.	F
Design Spectrum	The specification of the required strength or capacity of the structure plotted as a function of the natural period or frequency of the structure and of the damping appropriate to earthquake response at the required level. Design spectra are often composed of straight-line segments and/or simple curves (e.g., as in most building codes), but they can also be constructed from statistics of response spectra of a suite of ground motions appropriate to the design earthquake/s. To be implemented, the requirements of a design spectrum are associated with allowable levels of stresses, ductilities, displacements, or other measures of response.	F
Detention Basin	A basin or reservoir where water is stored for regulating a flood. It has outlets for releasing the flows during the floods.	F
Deterministic Seismic Hazard Assessment or DSHA	Refers to methods of calculating ground motions for single scenario earthquake (historical, maximum or user-defined) based on earthquake-source models and wave-propagation methods that exclude random effects.	E
Digital Elevation Model	A digital map of the elevation of an area on the earth. The data are either collected by a private party or purchased from an organization such as the U.S. Geological Survey (USGS) that has already undertaken the exploration of the area. Digital elevation models are gray scale images wherein the pixel values are actually elevation numbers. The pixels are also coordinated to world space (longitude and latitude), and each pixel represents some variable amount of that space (foot, meter, mile, etc.) depending on the purpose of the model and land area involved. See remote sensing and GIS glossary.	F
Dike	Somewhat the same as a levee. The Corps of Engineers prefers to use the term "levee" for flood protection projects, since dikes are also used in some parts of the world for coastal protection, and since the Corps also constructs pile dikes. The latter consists of timber pilings extending out into a river, built for river control and to reduce shoaling.	F
Discrete	Constituting a separate thing. See synonyms at distinct. Consisting of unconnected distinct parts. Mathematics. Defined for a finite or countable set of values; not continuous.	A
Direct Economic Loss	The costs of structural and non-structural repair, damage to building contents, loss of building inventory, relocation expenses, lost wages and lost income.	A

Term	Definition	Cat*
Direct Risk	Negative consequences of disasters in terms of assets lost, damaged or affected. First perceived in physical terms, i.e. miles of roads, hectares affected either in agricultural land, forests or environmental reserves, production already completed but lost as tons of agricultural products, numbers of industrial production units; or infrastructure affected as number of health services' facilities, number of bed, schools or number or classrooms destroyed, etc. Part of the direct damage, although not quantified specifically in terms of monetary value, are lives lost, injured persons and the primary, secondary or tertiary affected population.	A
Directivity	An effect of a propagating fault rupture whereby earthquake ground motion in the direction of propagation is more severe than that in other directions from the earthquake source.	E
Disaster	An event that causes major disruption on the economy, society and the environment. Its origin or causes may be directly derived from natural phenomena, i.e. geophysical (as volcanic or seismic events that cause collapse of infrastructure, landslides or liquefaction, etc.) or climatic (as hurricanes, typhoons, tornadoes, major variation in rainfall both in terms of excess or deficit causing drought). Although usually not covered by the methodology, disasters may also have a "human" or anthropic origin as chemical spills, industrial accidents, or voluntarily caused events such as war, terrorist actions, etc. Disaster consequences or damage will always be associated with human intervention before, during and after the event (the "disaster cycle").	A
Disaster Cycle	The interconnected phases before, during and after the occurrence of an event. It links the prevention, early warning, response, reconstruction and mitigation actions that are taken in the face of an event.	A
Disaster Reduction	The systemic approach to disasters that consists of prevention and mitigation actions, investments, projects and strategies.	A
Disaster Risk	The potential disaster losses, in lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future time period.	F
Discharge	The amount of water that passes a specific point on a watercourse over a given period of time.	F
Displacement	The difference between the initial position of a reference point and any later position. 1. In seismology, displacement is the ground motion commonly inferred from a seismogram. For example, it may be calculated by integrating an accelerogram twice with respect to time and is expressed in units of length, such as meters. 2. In geology, displacement is the permanent offset of a geologic or man-made reference point along a fault or a landslide.	E
Displacement Capacity	The capacity of the building measured in terms of displacement. If the displacement capacity is exceeded, the building will collapse.	E

Term	Definition	Cat*
Displacement-Based	Pertaining to the use of displacement of a building to calculate vulnerability i.e. the relationship of period of the ground motion to displacement capacity (period of the building).	E
Disrupted Slide	Landslides that are broken during movement into chaotic masses of small blocks, rock fragments, or individual grains. The basal failure surface of most such slides is within a few meters of the land surface.	E
Ductility	The property of a structure or a structural component that allows it to continue to have significant strength after it has yielded or begun to fail. Typically, a well-designed ductile structure or component will show, up to a point, increasing strength as its deflection increases beyond yielding, or cracking in the case of reinforced concrete or masonry.	E
Duration	Time interval between the first and last peaks of strong ground motion above a specified amplitude.	E
Drainage Area	The area (acres, square miles, etc.) from which water is carried off by a drainage system.	F
Drainage Basin	That portion of the surface of the earth which is drained by a river and its tributaries, or which is occupied by a permanent body of water (lake, pond, reservoir) and all of its tributaries. Alternatively, a geographical area which contributes surface water runoff to a particular point. The terms "drainage basin," "tributary area," and "watershed" can be used interchangeably	F
Drawdown	The release of water from a reservoir for power generation, flood control, irrigation or other water management activity.	F
Dredging	The scooping, or suction of underwater material from a harbor, or waterway. Dredging is one form of channel modification. It is often too expensive to be practical because the dredged material must be disposed of somewhere and the stream will usually fill back up with sediment in a few years. Dredging is usually undertaken only on large rivers to maintain a navigation channel.	F
Duration (Floods)	The period of time in minutes or hours in which rainfall of a certain intensity (inches per hour) occurs, or the period of time in which a river is above zero damage or major damage stage.	F
Earthquake	Ground shaking and radiated seismic energy caused most commonly by sudden slip on a fault, volcanic or magmatic activity, or other sudden stress changes in the Earth. An earthquake of magnitude 8 or larger is termed a great earthquake.	E
Earthquake catalogue	A chronological listing of earthquakes. Early catalogues were purely descriptive, giving the date of earthquakes and some descriptions of its effects. Modern catalogues are usually quantitative, listing a set of parameters describing the origin time, hypocenter location, magnitude, moment tensor, etc.	E
Earthquake Record	See seismogram	E

Term	Definition	Cat*
Earthquake Risk	The expected (or probable) life loss, injury, or building damage that will happen, given the probability that some earthquake hazard occurs. Earthquake risk and earthquake hazard are occasionally used interchangeably.	E
Economic Loss Conversion	The conversion of damage to economic losses in dollar amounts.	A
Elastic Rebound	In seismology, a theoretical description of how an elastic Earth responds to fault slip, as represented by a distribution of displacement discontinuities.	E
Embankment	A man-made earth structure constructed for the purpose of impounding water.	F
Empirical	Relating to the use of historic or measured data	A
Emergency Spillway	An outflow from a detention/retention facility that provides for the safe overflow of floodwaters for large storms that exceed the design capacity of the outlet or in the event of a malfunction. The emergency spillway prevents the water from overtopping the facility.	F
Empirical Fatality Rate	A rate of death, determined from past earthquake records.	E
Empirical vulnerability method	Vulnerability calculations constructed from historic earthquake damage loss ratios and assessment.	E
Encroachment	The result of placing a building, fence, berm or other structure in a floodplain in a manner that obstructs or increases the depth (or velocity) of flow on a watercourse.	F
EMS-98	European Macroseismic Scale—another intensity measure with scale 1–12, much the same as MMI	E
Erosion	The wearing away of land by the flow of water.	E
Epicenter	The point on the Earth's surface vertically above the point (focus or hypocenter) in the crust where a seismic rupture nucleates.	E
Essential Facilities	Facilities that provide services and are key to the functioning of a community are considered essential facilities. Examples of essential facilities include hospitals, police stations, fire stations, emergency operations centers (EOC), and schools. See also critical facilities.	A
Evacuated	People who are withdrawn from or vacated from a place or area, especially as a protective measure.	A

Term	Definition	Cat*
Exposure	Earthquake: Exposure is defined as the amount of human activity located in the zones of seismic hazard as defined by the stock of infrastructure in that location (usually defined by geocell). Disaster: People, property, systems, or other elements present in hazard zones that are thereby subject to potential losses. Measures of exposure can include the number of people or types of assets in an area. These can be combined with the specific vulnerability of the exposed elements to any particular hazard to estimate the quantitative risks associated with that hazard in the area of interest.	E
Exposure	People, property, systems, or other elements present in hazard zones that are thereby subject to potential losses. Comment: Measures of exposure can include the number of people or types of assets in an area. These can be combined with the specific vulnerability of the exposed elements to any particular hazard to estimate the quantitative risks associated with that hazard in the area of interest.	A
Exceedance Probability	The probability of a storm occurring during any one year which equals or exceeds the rainfall rate used in the design of the storm-water drainage system.	A
Fault Plane	The surface on which the earthquake movement takes place.	E
Fault Rupture	See rupture front	E
Fault Scarp	Steplike linear landform coincident with a fault trace and caused by geologically recent slip on the fault.	E
Fault Trace	Intersection of a fault with the ground surface; also, the line commonly plotted on geologic maps to represent a fault.	E
Faults	A fracture along which there has been significant displacement of the two sides relative to each other parallel to the fracture.	E
Field Survey	A survey which is done by skilled personnel on-site (usually of building damage or exposure/vulnerability data).	E
Filtering	Attenuation of certain frequency components of a seismic signal and the amplification of others. For a recorded signal, the process can be accomplished electronically or numerically in a digital computer. Filtering also occurs naturally as seismic energy passes through the Earth.	E
Fire Following Earthquakes	Any fire caused by the act of the earthquake or flow-on effects of the earthquake.	E

Term	Definition	Cat*
First Motion	On a seismogram, the direction of ground motion as the P wave arrives at the seismometer. Upward ground motion indicates an expansion in the source region; downward motion indicates a contraction.	E
Flash Flood	A flood which follows within a few (usually less than six) hours of heavy or excessive rainfall, dam or levee failure, or the sudden release of water impounded by an ice jam.	F
Flexible Building	A building that vibrates reasonably freely. These are generally tall buildings, or long period structures.	E
Flood	A flood is commonly interpreted as the temporary overflow of lands not normally covered by water, but which are used or usable by man when not inundated.	F
Flood Control	Various activities and regulations that help reduce or prevent damages caused by flooding. Typical flood control activities include: structural flood control works (such as bank stabilization, levees, and drainage channels), acquisition of flood prone land, flood insurance programs and studies, river and basin management plans, public education programs, and flood warning and emergency preparedness activities.	F
Floodplain	A land area adjacent to a river, stream, lake, estuary or other water body that is subject to flooding. These areas, if left undisturbed, act to store excess floodwater.	F
Flood Damages	Flood damages usually are classified as tangible or intangible. Tangible damages are the replacement costs or monetary loans resulting from the effects of floodwater and debris on crops, soil, buildings, furnishings, goods, roadways, utilities and levees; the added costs of protective efforts, evacuation and emergency care; and losses because of the interruption of commercial activities. Intangible damages are those which are difficult to measure in dollars, such as harm to life and health, inconvenience and discomfort.	F
Flood Damage State	Generally comparable to "flood stage", but may be somewhat higher or lower than official flood stage designations; refers to the stage in a stream at which damage becomes significant at any specified location, whether caused by overflow or other causes.	F
Flood Duration	Generally, the total length of time the stream is above "flood stage"; however, the term "flooding duration" may be used to designate the length of time a flood stage equals or exceeds any specified stage.	F
Flood of Record	The highest observed river stage or discharge at a given location during the period of record keeping. (Not necessarily the highest known stage.)	F
Flood Proofing	Any combination of changes to a structure or property using berms, flood walls, closures or sealants, which reduces or eliminates flood damage to buildings or property.	F
Flow-On Effect	An ongoing post-event effect that was influenced by the direct earthquake effect.	F
Focal Depth	A term that refers to the depth of an earthquake focus.	F

Term	Definition	Cat*
Flood Hydrograph	A graph of discharge, or of the level of water in a river throughout a period of time. The latter, known as a stage hydrograph, can be converted into a discharge hydrograph by the use of a stage-discharge rating curve. Hydrographs can be plotted for hours, days, or even months. A storm hydrograph is plotted after a rainstorm to record the effect on the river of the storm event.	F
Flood Stage	The stage at which overflow of the natural banks of a stream begins to cause damage in the reach in which the elevation is measured. The stage at which overflow of the natural banks of a stream begins to cause damage in the reach in which the elevation is measured.	F
Flood Volume	The total volume of runoff during a flood, which is equal to the average rate of flow multiplied by time (flood duration). The term "inches runoff" is sometimes used to designate flood volume, which means that the flood volume would cover the drainage area above the point of measurement to a uniform depth equal to the number of inches specified.	F
Flood Warning	A warning issued by the NWS to warn of river flooding which is imminent or occurring. A flood warning is issued when a river first exceeds its flood stage, and it may be reissued if a new river forecast for a forecast point or reach is significantly higher than a previous forecast.	F
Flood Watch	High flow or overflow of water from a river is possible in the given time period. It can also apply to heavy runoff or drainage of water into low-lying areas. These watches are generally issued for flooding that is expected to occur at least 6 hours after heavy rains have ended.	F
Floodplain Management	A program that uses corrective and preventative measures to reduce flood and erosion damage and preserve natural habitat and wildlife resources in flood prone areas. Some of these measures include: adopting and administering Floodplain Regulations, resolving drainage complaint, protecting riparian habitat communities, and assuring effective maintenance and operation of flood control works.	F
Floodway	The channel of a watercourse and portion of the adjacent floodplain that is needed to convey the base or 100-year flood event without increasing flood levels by more than one foot and without increasing velocities of flood water. Alternatively, for purposes of the National Flood Insurance Program (NFIP), a floodway is defined as the channel of a stream, plus any adjacent flood plain areas, that must be kept free of encroachment so that the 100-year flood can be carried without increasing the flood heights by more than 1.0 foot. This concept was designed for typical river valley situations, where the channel represents the lowest point in the flood plain and the most effective conveyance area is immediately adjacent to the channel.	F
Flowline	A line formed representing the lowest point in the bottom of and along a specified length of a channel.	F
Focus	See hypocenter	E

Term	Definition	Cat*
Focusing	See amplification	E
Foreshock	Foreshocks are relatively smaller earthquakes that precede the biggest earthquake in a series, which is termed the mainshock.	E
Fourier Amplitude Spectrum	The relative amplitude at different component frequencies that are derived from a time history by Fourier analysis.	E
Fragility	For earthquakes, this refers to the vulnerability of the building stock.	E
Fragility Function (Curves)	The function that describes the capacity of a building for a certain hazard.	A
Frequency (building)	The building frequency is a measure of the number of times the building shakes back and forth every second. It is the reciprocal of building period. If a building has a period of 2 seconds, its frequency is 0.5 Hz (cycles per second).	E
Frequency (time)	The rate at which something happens or is repeated.	A
Frequency (statistics)	1. The number of measurements in an interval of a frequency distribution. 2. The ratio of the number of times an event occurs in a series of trials of a chance experiment to the number of trials of the experiment performed.	A
Frequency (wave)	The number of wave cycles per unit of time that passes a given point. (usually measured in Hz)	E
Fundamental Period	The longest period for which a structure shows a maximum response. The reciprocal of natural frequency.	E
g	A measure of acceleration where $1g = 9.81 m/s^2$	E
Geocell	A geographical area, used as a section of an analysis to reflect a culmination of the aspects of that area.	A
Geographic Information System (GIS)	Computerized system that relates and displays data collected from a geographic entity in the form of a map. The ability of GIS to overlay existing data with new information and display it in color on a computer screen is used primarily to conduct analyses and make decisions related to geology, ecology, land use, demographics, transportation, and other domains, most of which relate to the human use of the physical environment. Through the process of geocoding, geographic data from a database is converted into images in the form of maps.	A
Geologic Time	Pertaining to a very long time in the history of the Earth—thousands to millions to billions of years. The geologic time scale provides a system of chronologic measurement relating stratigraphy to time that is used by geologists, Paleontologists and other earth scientists to describe the timing and relationships between events that have occurred during the history of the Earth.	E

Term	Definition	Cat*
Geometric Attenuation	That component of attenuation of seismic-wave amplitudes due to the radial spreading of seismic energy with distance from a given source.	E
Geotechnical	Referring to the use of scientific methods and engineering principles to acquire, interpret, and apply knowledge of earth materials for solving engineering problems.	E
GMPE or Ground Motion Prediction Equation	Equations produced to predict the ground motion spectral intensity at certain locations, given the site conditions, magnitude, location and fault mechanism of a scenario earthquake, created using earthquake ground motion record catalogues. This means that it is possible to calculate the ground motion that could occur given a M7.0 earthquake on a fault 100km away, at this very location. A Ground Motion Prediction Equation or GMPE is also known by the name of attenuation relationship. They are generally of the following form: log[Sa(T)] = median fn(M,R,T,V) + uncertainties, where the logarithm of the median spectral acceleration (Sa) can be calculated for given periods (T) using magnitudes (i.e. M=7.0), distances (i.e. R=100km) and shear wave velocities (i.e. V=500m/s) at this site. The output is the median spectral acceleration and a standard deviation of the uncertainties, as there are many uncertainties associated with such a result.	E
Groundwater	Water within the earth that supplies wells and springs; water in the zone of saturation where all openings in rocks and soil are filled, the upper surface of which forms the water table.	F
Government Data	Data that is maintained or collected by government sources	A
Gross Domestic Product (GDP)	The gross domestic product (GDP) or gross domestic income (GDI) is a basic measure of a country's overall economic output. It is the market value of all final goods and services made within the borders of a country in a year.	A
Ground Failure	A general reference to landslides, liquefaction, and lateral spreads.	E
Ground Motion (Shaking)	General term referring to the qualitative or quantitative aspects of movement of the Earth's surface from earthquakes or explosions. Ground motion is produced by waves that are generated by sudden slip on a fault or sudden pressure at the explosive source and travel through the Earth and along its surface.	E
Ground Shaking scenario	A representation for a site or region depicting the possible ground-shaking level or levels due to earthquake in terms of useful descriptive parameters.	E
Gutenberg-Richter	Earthquakes appear to follow a pattern through time in terms of no. Of earthquakes vs. Magnitude. This is called the Gutenberg-Richter criterion.	E

Term	Definition	Cat*
Hazard	Any physical phenomenon associated with an earthquake that may produce adverse effects on human activities. This includes surface faulting, ground shaking, landslides, liquefaction, tectonic deformation, tsunami, and seiche and their effects on land use, manmade structures, and socioeconomic systems. A commonly used restricted definition of earthquake hazard is the probability of occurrence of a specified level of ground shaking in a specified period of time.	A
Hazard Catalogue	A catalogue of previous source, path and site for details for previous earthquakes in a certain location.	A
Hazard Curve	The relative hazard at a certain location for a certain time period	A
Hazard Map	A map of the relative hazard for a certain time period.	A
HAZUS	Hazards United States (HAZUS) is a standardized geographic information system (GIS) based loss estimation tool to estimate potential losses from earthquakes, wind, and flood.	A
HDI	The Human Development Index (HDI) is a composite statistic used as an index to rank countries by level of “human development” and separate developed (high development), developing (middle development), and underdeveloped (low development) countries. The statistic is composed from statistics for Life Expectancy, Education, and GDP collected at the national level.	A
Hertz (Hz)	A unit of frequency. Expressed in cycles per second.	E
Heterogeneous	Heterogeneous is an adjective used to describe an object or system consisting of multiple items having a large number of structural variations. It is the opposite of homogeneous, which means that an object or system consists of multiple identical items. The term is often used in a scientific (such as a kind of catalyst), mathematical, sociological or statistical context.	A
High-Risk	An element where the risk is higher due to a population, critical need or economic stress.	A
Historical Database	A database containing data from past events	A
Homeless	People needing immediate assistance for shelter.	A
Housing	Financial or direct assistance from government to individual. Occupants have their own lock and key. This type of housing could include transient reimbursement, rental assistance, and direct housing.	A
Hybrid Vulnerability Methods	A combination of empirical and analytical methods to calculate vulnerability.	E

Term	Definition	Cat*
Hydraulic Structures	The facilities used to impound, accommodate, convey, or control the flow of water, such as dams, intakes, culverts, channels, and bridges.	F
Hydraulics	The analysis of water or other liquid in motion, and its action. Also a field of study dealing with the flow pattern and rate of water movement based on the principles of fluid mechanics.	F
Hydrology	The scientific analysis of rainfall and runoff, its properties, phenomena and distribution; as well as water dynamics below the ground and in the atmosphere.	F
Hydrograph	A graph of discharge, or of the level of water in a river throughout a period of time. The latter, known as a stage hydrograph, can be converted into a discharge hydrograph by the use of a stage-discharge rating curve. Hydrographs can be plotted for hours, days, or even months. A storm hydrograph is plotted after a rainstorm to record the effect on the river of the storm event.	F
Hydrostatics	Branch of physics that deals with the characteristics of fluids at rest, particularly with the pressure in a fluid or exerted by a fluid (gas or liquid) on an immersed body. In applications, the principles of hydrostatics are used for problems relating to pressure in deep water (pressure increases with depth) and high in the atmosphere (pressure lessens with altitude).	F
Hydrodynamics	The study of fluids in motion. The study is based upon the physical conservation laws of mass, momentum, and energy. The mathematical statements of these laws may be written in either integral or differential form. The integral form is useful for large-scale analyses and provides answers that are sometimes very good and sometimes not, but that are always useful, particularly for engineering applications. The differential form of the equations is used for small-scale analyses. In principle, the differential forms may be used for any problem, but exact solutions can be found only for a small number of specialized flows. Solutions for most problems must be obtained by using numerical techniques, and these are limited by the computer7's inability to model small-scale processes.	F
Hydro-meteorological hazard	Process or phenomenon of atmospheric, hydrological or oceanographic nature that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage. Comment: Hydrometeorological hazards include tropical cyclones (also known as typhoons and hurricanes), thunderstorms, hailstorms, tornados, blizzards, heavy snowfall, avalanches, coastal storm surges, floods including flash floods, drought, heat waves and cold spells. Hydrometeorological conditions also can be a factor in other hazards such as landslides, wildfires, locust plagues, epidemics, and in the transport and dispersal of toxic substances and volcanic eruption material	A
Hypocenter	The point within the Earth where an earthquake rupture initiates. Also commonly termed the focus.	E

Term	Definition	Cat*
Indirect Risk	Risk, either positive or negative, for flows related to the production, provision, distribution or performance of goods and services, i.e. additional costs of transport, reduced income of enterprises, increased expenses of government, reduced tax revenues, insurance payments received, increased imports or reduced exports, etc.	A
Indirect Economic Loss	In addition to the direct physical damage and economic losses, natural hazards like earthquakes cause a chain reaction, or ripple effect, that is transmitted throughout the regional economy. These could be business interruptions or disruption of retail activities. Such interruptions are indirect economic losses due to an event.	A
Industrial building	A building with 50% or more space that is dedicated to industrial activities.	A
Infrastructure	The system of public works in a country, state or region, including roads, utility lines and public buildings.	A
Injured	People suffering from physical injuries, trauma or an illness requiring medical treatment as a direct result of a disaster.	A
Inundation	Flooding, by the rise and spread of water, of a land surface that is not normally submerged.	F
Insurance	Insurance is defined as the equitable transfer of the risk of a loss, from one entity to another, in exchange for a premium, and can be thought of as a guaranteed and known small loss to prevent a large, possibly devastating loss. An insurer is a company selling the insurance; an insured or policyholder is the person or entity buying the insurance. The insurance rate is a factor used to determine the amount to be charged for a certain amount of insurance coverage, called the premium. Disaster: Government sponsored or private insurance policies for protection against economic losses resulting from disaster.	A
Intensity	A subjective numerical index describing the severity of an earthquake in terms of its effects on the Earth's surface and on humans and their structures. Several scales exist, but the ones most commonly used in the United States are the Modified Mercalli scale and the Rossi-Forel scale.	E
Intermediate Earthquake	An earthquake whose focus is located between 70 to 300 kilometers from the earth's surface.	E
Interplate	Interplate pertains to processes between the plates.	E
Interplate Coupling	The qualitative ability of a subduction thrust fault to lock and accumulate stress. Strong coupling implies that the fault is locked and capable of accumulating stress, whereas weak coupling implies that the fault is unlocked or only capable of accumulating low stress. A fault with weak coupling could be aseismic or could slip by creep. See Locked fault.	E

Term	Definition	Cat*
Intraplate	Intraplate pertains to processes within the Earth's crustal plates.	E
Inventory (building)	Collection of general building stock data that includes residential, commercial, industrial, agricultural, religious, government, and educational buildings.	E
Isoseismal	Referring to a line on a map bounding points of equal intensity for a particular earthquake.	E
JMA	The Japan Meteorological Agency seismic intensity scale is a measure used in Japan and Taiwan to indicate the strength of earthquakes. This scale is a numerical system, assigning earthquakes levels 0–7.	E
Kinematic	Referring to the general movement patterns and directions of the Earth's rocks that produce rock deformation.	E
Landslide	An abrupt movement of geological materials downhill in response to gravity. Landslides can be triggered by an earthquake or other natural causes.	E
Large Loss Facilities	All sources of elements at risk which have high population densities, such as sports stadiums, marketplaces, theatres, churches/temples/mosques and schools. If an earthquake occurs at a certain time, these losses will be huge.	A
Lateral Spreading	Terms to landslides that commonly form on gentle slopes and that have rapid fluid-like flow movement.	E
Latitude	Angular distance north or south from the earth's equator measured through 90 degrees.	E
Levee	As defined by the Corps of Engineers, a levee is a compacted embankment built alongside a river for the purpose of preventing high water from flooding the adjoining land. Alternatively a levee is an embankment constructed on the flood plain for the purpose of confining large flows to a comparatively narrow floodway while protecting the remainder of the flood plain from inundation. Similar structures built to protect lowlands from high tides or to give partial protection to a portion of the flood plain are usually called "dikes".	F
Lifelines	Structures that are important or critical for urban functionality. Examples are roadways, pipelines, powerlines, sewers, communications, and port facilities.	A
Liquefaction	The transformation of a granular material from a solid state into a liquefied state as a consequence of increased pore water pressures and reduced effective stress. In engineering seismology, it refers to the loss of soil strength as a result of an increase in pore pressure due to ground motion. This effect can be caused by earthquake shaking.	E
Lithosphere	The outer solid part of the Earth, including the crust and uppermost mantle. The lithosphere is about 100 km thick, although its thickness is age dependent. The lithosphere below the crust is brittle enough at some locations to produce earthquakes by faulting, such as within a subducted oceanic plate.	E

Term	Definition	Cat*
Local site conditions	A qualitative or quantitative description of the topography, geology, and soil profile at a site that effect ground motions during an earthquake.	E
Locked Fault	A fault that is not slipping because frictional resistance on the fault is greater than the shear stress across the fault. Such faults may store strain for extended periods that is eventually released in an earthquake when frictional resistance is overcome. A locked fault condition contrasts with fault-creep conditions and an unlocked fault.	E
Logarithm	It is simply the exponent required to produce a given number. For a certain base 10, in this case 1 = 10, 2 = 10X10 = 100, 3 = 1000 etc.	A
Longitude	The arc or portion of the earth's equator intersected between the meridian of a given place and the prime meridian and expressed either in degrees or in time.	E
Loss Frequency Curve	Curve showing exceedance probability of an event not exceeding a certain level of damages. The area under the curve represents the expected annual value of damages, i.e. the annual amount of damages that can be expected to occur over a longer time horizon	A
Love Wave	A type of seismic surface wave having a horizontal motion that is transverse to the direction of propagation.	E
Ma.	An abbreviation for one million years ago (Megannum).	E
Magnitude	A number that characterizes the relative size of an earthquake. Magnitude is based on measurement of the maximum motion recorded by a seismograph (sometimes for earthquake waves of a particular frequency), corrected for attenuation to a standardized distance. Several scales have been defined, but the most commonly used are (1) local magnitude (ML), commonly referred to as "Richter magnitude," (2) surface-wave magnitude (Ms), (3) body-wave magnitude (Mb), and (4) moment magnitude (Mw). Scales 1–3 have limited range and applicability and do not satisfactorily measure the size of the largest earthquakes. The moment magnitude (Mw) scale, based on the concept of seismic moment, is uniformly applicable to all sizes of earthquakes but is more difficult to compute than the other types. In principal, all magnitude scales could be cross calibrated to yield the same value for any given earthquake, but this expectation has proven to be only approximately true, thus the need to specify the magnitude type as well as its value. An increase of one unit of magnitude (for example, from 4.6 to 5.6) represents a 10-fold increase in wave amplitude on a seismogram or approximately a 30-fold increase in the energy released. In other words, a magnitude 6.7 earthquake releases over 900 times (30 times 30) the energy of a 4.7 earthquake—or it takes about 900 magnitude 4.7 earthquakes to equal the energy released in a single 6.7 earthquake! There is neither beginning nor end to this scale. However, rock mechanics seem to preclude earthquakes smaller than about –1 or larger than about 9.5. A magnitude—1.0 event releases about 900 times less energy than a magnitude 1.0 quake. Except in special circumstances, earthquakes below magnitude 2.5 are generally not felt.	E

Term	Definition	Cat*
Magnitude-Frequency	The relationship of size of earthquake to the number of earthquakes in a given time.	E
Mainshock	The biggest earthquake in a series is termed the mainshock.	E
Mantle	The layer of rock that lies between the outer crust and the core of the earth. It is approximately 1,802 miles (2,900 kilometers) thick and is the largest of the earth's major layers.	E
Maximum probable earthquake (MCE)	The maximum earthquake that could strike a given area with a significant probability of occurrence.	E
Mean	The average value, calculated by adding all the observations and dividing by the number of observations.	A
Mean Damage Ratio, MDR	The ratio of repair to replacement cost.	A
Median	The median is the value halfway through the ordered data set, below and above which there lays an equal number of data values. It is generally a good descriptive measure of the location which works well for skewed data or data with outliers.	A
Mediation	A problem-solving process in which an outside, impartial, neutral party works with the element at risk to assist in reaching a satisfactory solution to reduce disaster risk.	A
Meteorology	Scientific study of atmospheric phenomena, particularly of the troposphere and lower stratosphere. Meteorology entails the systematic study of weather and its causes, and provides the basis for weather forecasting	A
Microzonation	The identification and mapping at local or site scales of areas having different potentials for hazardous earthquake effects, such as ground-shaking intensity, liquefaction, or landslide potential. Microzonation for any of the earthquake hazards can be produced; The division of a town or county into smaller areas according to their variation in seismic hazard.	A
Mitigation	Actions or investments needed to reduce risk, i.e. exposure to hazards by reducing pre-existing vulnerability.	A
MMI	The Mercalli scale rates the intensity of shaking from an earthquake. The ratings vary from I (felt only under especially favorable circumstances) to XII (total destruction).	E
Moho	A discontinuity in seismic velocity that marks the boundary between the Earth's crust and mantle. Also termed the Mohorovicic' discontinuity, after the Croatian seismologist Andrija Mohorovicic' (1857–1936) who discovered it. The boundary is between 25 and 60 km deep beneath the continents and between 5 and 8 km deep beneath the ocean floor.	E
Moment Magnitude	See magnitude (Mw)	E

Term	Definition	Cat*
Mortality Rate	Mortality rate is a measure of the number of deaths (in general, or due to a specific cause) in some population, scaled to the size of that population, per unit time. Mortality rate is typically expressed in units of deaths per 1,000 individuals per year; thus, a mortality rate of 9.5 in a population of 100,000 would mean 950 deaths per year in that entire population.	AE
MSK	The Medvedev-Sponheuer-Karnik scale, also known as the MSK or MSK-64, is a macroseismic intensity scale used to evaluate the severity of ground shaking on the basis of observed effects in an area of the earthquake occurrence.	
National	Pertaining to a country level	A
Natural Frequency	The discrete frequency(ies) at which a particular elastic system vibrates when it is set in motion by a single impulse and not influenced by other external forces or by damping. The reciprocal of fundamental period.	E
Natural Logarithm	The natural logarithm ln(x) is the logarithm to the base 'e', and mathematically the inverse function of the exponential function ex. E is equal to approximately 2.7183	A
NEHRP Site Classes	These are S-wave velocity in the top 30m of soil based on classifications of soil type via the NEHRP (National Earthquake Hazards Reduction Program). There are 5 classes of soil type from A (hardest) to F (lowest). A is greater than 1,500m/s, E is less than 180m/s in the top 30m and F are soils requiring site specific evaluation. http://www.seis.utah.edu/urban/nehrp.shtml	E
Normal	Dip-slip faults are inclined fractures along which rock masses have mostly shifted vertically. If the rock mass above an inclined fault is depressed by slip, the fault is termed normal.	E
Oblique Slip	Oblique-slip faults have significant components of both slip styles (strike and dip-slip)	E
Ocean Spreading Ridge	A fracture zone along the ocean bottom that accommodates upwelling of mantle material to the surface, thus creating new crust. This fracture is topographically marked by a line of ridges that form as molten rock reaches the ocean bottom and solidifies.	E
Oceanic Crust	The outermost solid layer of Earth that underlies the oceans. Composed of the igneous rocks basalt and gabbro, and therefore basaltic in composition. Contrast with continental crust.	E
Oceanic Trench	A linear depression of the sea floor caused by and approximately coincident with a subduction thrust fault.	E
Oscillator	A mass that moves with oscillating motion under the influence of external forces and one or more forces that restore the mass to its stable at-rest position. In earthquake engineering, an oscillator is an idealized damped mass-spring system used as a model of the response of a structure to earthquake ground motion. A seismograph is also an oscillator of this type	E
Outlet Structure	A hydraulic structure placed at the outlet of a channel, spillway, pipe, etc., for the purpose of dissipating energy and providing a transition to the channel or pipe downstream.	F

Term	Definition	Cat*
Overland Flow	Flooding that occurs when intense local rainfall flows overland to reach a channel. Frequently, these conditions exists when runoff exceeds storm sewer or roadside ditch capacity, and the water can "pond" in the streets deep enough to flood residences that are not even near a creek of bayou. The water will seek a path to the channel by flowing overland (Sheet Flow). When residences and other structures are in that path, flooding occurs and this type of flooding is not identified on the Flood Insurance Rate Maps.	F
P Wave	A seismic body wave that involves particle motion (alternating compression and extension) in the direction of propagation.	E
Path	The direction that the wave energy travels along from the source to the site.	E
Peak Acceleration	The highest acceleration in terms of value.	E
Peak Flow	The maximum rate of flow through a watercourse for a given storm	F
Performance Point	The intersection of building capacity and hazard (demand) for a particular earthquake scenario	E
Period (Building)	Measure of time that a building takes to shake back and forth one time, as a response to an external force, e.g., earthquake shaking. Tall buildings have longer periods on the order of 1 to 4 seconds. Short buildings move back and forth very rapidly and have periods in the order of 0.1 to 0.4 seconds.	E
Period (Ground Motion)	The time interval required for one full cycle of ground motion movement (still a wave)	E
Period (Wave)	The time interval between successive crests in a sinusoidal wave train; the period is the inverse of the frequency of a cyclic event.	E
Period Range	That range of periods being considered in an analysis of ground motion.	E
PGA	The maximum acceleration amplitude measured or expected in a strong-motion accelerogram of an earthquake.	E
Phase	1. A stage in periodic motion, such as wave motion or the motion of an oscillator, measured with respect to a given initial point and expressed in angular measure. 2. A pulse of seismic energy arriving at a definite time.	E
Physical Vulnerability	The vulnerability pertaining to infrastructure effects from a disaster.	A
Plate	A large, relatively rigid segment of the Earth's lithosphere that moves in relation to other plates over the asthenosphere.	E

Term	Definition	Cat*
Plate Tectonics	A theory supported by a wide range of evidence that considers the Earth's crust and upper mantle to be composed of several large, thin, relatively rigid plates that move relative to one another. Slip on faults that define the plate boundaries commonly results in earthquakes. Several styles of faults bound the plates, including thrust faults along which plate material is subducted or consumed in the mantle, oceanic spreading ridges along which new crustal material is produced, and transform faults that accommodate horizontal slip (strike slip) between adjoining plates.	E
Poisson Distribution	A probability distribution that characterizes discrete events occurring independently of one another in time.	A
Policy	The formal rules of the game—including laws, regulations and institutions. Policy reform may occur to address a problem or achieve a goal such as improved earthquake resistant building, changes in zonation for hazards.	A
Population Data	Data on the people living in a certain area, including age, detailed description of living conditions, employment and other life-linked details.	A
Population Density	Population density (in agriculture standing stock and standing crop) is a measurement of population per unit area or unit volume. It refers to people in our case.	A
Post-Event	In the time occurring after the main shock has finished.	E
Postulated	1. To make claim for; demand. 2. To assume or assert the truth, reality, or necessity of, especially as a basis of an argument. 3. To assume as a premise or axiom; take for granted. See synonyms at presume.	A
Poverty Rate	The state of being poor; lack of the means of providing material needs or comforts.	A
Pre-Event	Any time prior to the onset of the mainshock.	
Preparedness	Definition: The knowledge and capacities developed by governments, professional response and recovery organizations, communities and individuals to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions. Comment: Preparedness action is carried out within the context of disaster risk management and aims to build the capacities needed to efficiently manage all types of emergencies and achieve orderly transitions from response through to sustained recovery. Preparedness is based on a sound analysis of disaster risks and good linkages with early warning systems, and includes such activities as contingency planning, stockpiling of equipment and supplies, the development of arrangements for coordination, evacuation and public information, and associated training and field exercises. These must be supported by formal institutional, legal and budgetary capacities. The related term "readiness" describes the ability to quickly and appropriately respond.	A

Term	Definition	Cat*
Prevention	Actions or investments needed in the face of imminent hazards. Distinct from mitigation, which is a permanent strategy, prevention is seen as a pre-disaster set of activities.	A
Primary Wave	See P Wave	E
Probabilistic Seismic Hazard Assessment or PSHA	Seismic hazard assessment using a probabilistic combination of earthquake scenarios in order to determine the hazard for the given area, generally to take into account the variability between different earthquake scenarios.	E
Probability	The number of cases that actually occur divided by the total number of cases possible.	A
Probability of exceedance	1. The odds that the size of a future earthquake will exceed some specified value. 2. The probability that, in a given area or site, an earthquake ground motion will be greater than a given value during some time period.	A
Probable Maximum Loss	A probable upper limit of the losses that are expected to occur as a result of a damaging earthquake, normally defined as the largest monetary loss associated with one or more earthquakes proposed to occur on specific faults or within specific source zones.	A
Rate	An expression that describes a change in position or velocity with respect to time.	A
Rate Of Exceedance	How often a certain size earthquake will occur (usually measured in no. Of earthquakes per year)—Rate of exceedance, is the chance of the x-axis parameter is exceeded. Annual rate, refers to 1/return period. In the following diagram, there is a 0.0025% (0.000025) chance in that year or one earthquake every 400,000 years, a PGA of 0.43g will be exceeded. There is a 0.001 (0.1%) chance that 0.1g will be exceeded.	A
Rayleigh Wave	A seismic surface wave causing an elliptical motion of a particle at the free surface, with no transverse motion.	E
Reach	A term used to describe a specific length of a stream or watercourse. For example, the term can be used to describe a section of a stream or watercourse between two bridges. Alternatively, the length of a river between two gaging stations.	F
Recovery	The restoration, and improvement where appropriate, of facilities, livelihoods and living conditions of disaster-affected communities, including efforts to reduce disaster risk factors. The recovery task of rehabilitation and reconstruction begins soon after the emergency phase has ended, and should be based on pre-existing strategies and policies that facilitate clear institutional responsibilities for recovery action and enable public participation. Recovery program, coupled with the heightened public awareness and engagement after a disaster, afford a valuable opportunity to develop and implement disaster risk reduction measures and to apply the “build back better” principle.	A

Term	Definition	Cat*
Recurrence Interval	The average time span between events (such as large earthquakes, ground shaking exceeding a particular value, or liquefaction) at a particular site. Also termed return period.	A
Regulatory	Subject to the control of or required to follow rules set forth by a governmental agency. With respect to washes or streams it refers to those areas where the federal government restricts the use or development of areas it has deemed to be "Waters of the U.S." These regulations are part of the Clean Water Act.	A
Regulatory Floodplain	A portion of the geologic floodplain that may be inundated by the base flood where the peak discharge is 100 cubic feet per second (C.F.S.) or greater. Regulatory floodplains also include areas which are subject to sheet flooding, or areas on existing recorded subdivision plats mapped as being flood prone.	F
Reinsurance	Form of insurance that insurance companies buy for their own protection, "a sharing of insurance." An insurer (the reinsured) reduces its possible maximum loss on either an individual risk or a large number of risks by giving (ceding) a portion of liability to another insurance company (reinsurer).	A
Remote Sensing	The science, technology and art of obtaining information about objects or phenomena from a distance (i.e., without being in physical contact with them). This is generally referring to the collection of exposure data.	A
Repair Cost	The cost of repairing the damage done to the property (including demolition and debris removal if required).	A
Replacement Cost	The cost of replacing property without a reduction for depreciation. By this method of determining value, damages for a claim would be the amount needed to replace the property using new materials.	A
Rescue Manpower	The amount of human support for recovery and rescue, post-disaster.	A
Reserves	This is generally referring to the amount of assets that are available when a disaster occurs.	A
Residential	A building should be regarded as residential building when more than half of the floor area is used for dwelling purposes. Other buildings should be regarded as non-residential. Two types of residential buildings can be distinguished: houses (ground-oriented residential buildings): comprising all types of houses (detached, semi-detached, terraced houses, houses built in a row, etc.) each dwelling of which has its own entrance directly from the ground surface; other residential buildings: comprising all residential buildings other than ground-oriented residential buildings as defined above.	A

Term	Definition	Cat*
Resilience	Definition: The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions. Comment: Resilience means the ability to "resile from" or "spring back from" a shock. The resilience of a community in respect to potential hazard events is determined by the degree to which the community has the necessary resources and is capable of organizing itself both prior to and during times of need.	A
Resonance	An increase in the amplitude of vibration in an elastic body or system when the frequency of the shaking force is close to one or more of the natural frequencies of a shaking body	E
Response	The motion in a system resulting from shaking under specified conditions.	E
Response Spectrum	The maximum response to a specified acceleration time series of a set of single-degree-of-freedom oscillators with chosen levels of viscous damping, plotted as a function of the undamped natural period or undamped natural frequency of the system. The response spectrum is used for the prediction of the earthquake response of buildings or other structures.	E
Residual Risk	The risk that remains in unmanaged form, even when effective disaster risk reduction measures are in place, and for which emergency response and recovery capacities must be maintained. Comment: The presence of residual risk implies a continuing need to develop and support effective capacities for emergency services, preparedness, response and recovery together with socio-economic policies such as safety nets and risk transfer mechanisms.	A
Retrofitting	Definition: Reinforcement or upgrading of existing structures to become more resistant and resilient to the damaging effects of hazards. Comment: Retrofitting requires consideration of the design and function of the structure, the stresses that the structure may be subject to from particular hazards or hazard scenarios, and the practicality and costs of different retrofitting options. Examples of retrofitting include adding bracing to stiffen walls, reinforcing pillars, adding steel ties between walls and roofs, installing shutters on windows, and improving the protection of important facilities and equipment.	E
Return Period	See recurrence interval.	A
Reverse Fault	Dip-slip faults are inclined fractures along which rock masses have mostly shifted vertically. If the rock above the fault is elevated by slip, the fault is termed reverse (or thrust fault).	E

Term	Definition	Cat*
Revetment	A facing of stone, concrete, or even such materials as tires, placed on a riverbank or levee to protect them from erosion.	F
Riprap	Rocks or broken pieces of concrete often placed in areas where the flow of stormwater is expected to cause erosion. The riprap serves as "armor" for areas of channels and detention basins to minimize the occurrence of erosion.	F
Risk	The probabilistic determination of the damages a certain hazard can cause given the existing vulnerability, location and time.	A
Risk Transfer	The process of formally or informally shifting the financial consequences of particular risks from one party to another whereby a household, community, enterprise or state authority will obtain resources from the other party after a disaster occurs, in exchange for ongoing or compensatory social or financial benefits provided to that other party. Comment: Insurance is a well-known form of risk transfer, where coverage of a risk is obtained from an insurer in exchange for ongoing premiums paid to the insurer. Risk transfer can occur informally within family and community networks where there are reciprocal expectations of mutual aid by means of gifts or credit, as well as formally where governments, insurers, multi-lateral banks and other large risk-bearing entities establish mechanisms to help cope with losses in major events. Such mechanisms include insurance and re-insurance contracts, catastrophe bonds, contingent credit facilities and reserve funds, where the costs are covered by premiums, investor contributions, interest rates and past savings, respectively.	A
Risk Perception	Risk perception is the subjective judgment that people make about the characteristics and severity of a risk. The phrase is most commonly used in reference to natural hazards and threats to the environment or health, such as nuclear power. Several theories have been proposed to explain why different people make different estimates of the dangerousness of risks. Three major families of theory have been developed: psychology approaches (heuristics and cognitive), anthropology/sociology approaches (cultural theory) and interdisciplinary approaches (social amplification of risk framework).	A
Risk Analysis	A methodology to determine the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend. Risk assessments (and associated risk mapping) include: a review of the technical characteristics of hazards such as their location, intensity, frequency and probability; the analysis of exposure and vulnerability including the physical social, health, economic and environmental dimensions; and the evaluation of the effectiveness of prevailing and alternative coping capacities with respect to likely risk scenarios.	A

Term	Definition	Cat*
Risk Management	The systematic approach and practice of managing uncertainty to minimize potential harm and loss. Comment: Risk management comprises risk assessment and analysis, and the implementation of strategies and specific actions to control, reduce and transfer risks. It is widely practiced by organizations to minimize risk in investment decisions and to address operational risks such as those of business disruption, production failure, environmental damage, social impacts and damage from fire and natural hazards. Risk management is a core issue for sectors such as water supply, energy and agriculture whose production is directly affected by extremes of weather and climate.	A
Rossi-Forel	The Rossi-Forel scale is a measure of intensity of shaking from an earthquake. This scale was replaced by the Mercalli intensity scale.	E
Runoff	Surface water resulting from rainfall or snowmelt that flows overland to streams, usually measured in acre-feet (the amount of water which would cover an acre one foot deep). Volume of runoff is frequently given in terms of inches of depth over the drainage area	F
Rupture	The instantaneous boundary between the slipping and locked parts of a fault during an earthquake. Rupture in one direction on the fault is referred to as unilateral. Rupture may radiate outward in a circular manner or it may radiate toward the two ends of the fault from an interior point, referred to as bilateral.	E
Rupture Velocity	The speed at which a rupture front propagates during an earthquake.	E
S Wave Velocity	The velocity of a secondary or S wave. Generally measured in m/s.	E
Scenario	A description of situations that could occur; it is a set of informed assumptions about a situation	A
Screening Methods	These methods involve assigning a vulnerability rating, given different structural characteristics on an infrastructure-by-infrastructure basis usually via site visit.	E
Scour	Erosion caused by rapid flow of water.	F
Secondary Wave	A seismic body wave that involves a shearing motion in a direction perpendicular to the direction of propagation. When it is resolved into two orthogonal components in the plane perpendicular to the direction of propagation, SH denotes the horizontal component and SV denotes the orthogonal component. Also known as S waves and shear waves.	E
Sector	Area of economic or social activity, such as agriculture, industry, education, health services, etc. Grouped, for the purpose of valuation, into three: social, infrastructural and productive (including both goods and services)	A
Seismic code	See building code.	E

Term	Definition	Cat*
Seismic hazard	Risk of a certain ground motion occurring at a location (this can be defined by scenario modeling via stochastic catalogues, DSHA, PSHA or other such methods, and can include different types of earthquake effects)	E
Seismic Moment	A measure of the size of an earthquake based on the area of fault rupture, the average amount of slip, and the shear modulus of the rocks offset by faulting. Seismic moment can also be calculated from the amplitude spectra of seismic waves.	E
Seismic Risk	See earthquake risk, also the probabilistic risk is the odds of an earthquake occurring and causing damage within a given time interval and region.	E
Seismic Risk Curve	A plot of seismic risk (usually specified in terms of annual probability of exceedance or return period) versus a specified loss for a given property or portfolio of properties.	E
Seismic Station	A ground position at which a geophysical instrument is located for an observation.	E
Seismic Waves	An elastic wave generated by an impulse such as an earthquake or an explosion. Seismic waves may propagate either along or near the Earth's surface (for example, Rayleigh and Love waves) or through the Earth's interior (P and S waves).	E
Seismic Zonation	Geographic delineation of areas having different potentials for hazardous effects from future earthquakes. Seismic zonation can be done at any scale – national, regional, local, or site. See Microzonation.	E
Seismic Zoning Map	A map used to portray seismic hazard or seismic design variables, for example, maps used in building codes to identify areas of uniform seismic design requirements.	E
Seismicity	The geographic and historical distribution of earthquakes. A term introduced by Gutenberg and Richter to describe quantitatively the space, time, and magnitude distribution of earthquake occurrences. Seismicity within a specific source zone or region is usually quantified in terms of a Gutenberg-Richter relationship.	E
Seismogram	A record written by a seismograph in response to ground motions produced by an earthquake, explosion, or other ground-motion sources.	E
Seismometer	A seismometer is a damped oscillating mass, such as a damped mass-spring system, used to detect seismic-wave energy. The motion of the mass is commonly transformed into an electrical voltage. The electrical voltage is recorded on paper, magnetic tape, or another recording medium. This record is proportional to the motion of the seismometer mass relative to the Earth, but it can be mathematically converted to a record of the absolute motion of the ground. Seismograph is a term that refers to the seismometer and its recording device as a single unit.	E
Sequence	Pertains to the possible foreshock, mainshock and aftershock occurrence and time period.	E
Severity	Both intensity and magnitude—i.e. the size/strength of an earthquake.	A

Term	Definition	Cat*
Shakemaps	ShakeMaps, a product of the United States Geological Survey (USGS) Earthquake Hazards Program, are near-real-time maps of ground motion and shaking intensity that are produced following significant earthquakes. They appear as a set of links keyed to areas which have recently experienced an earthquake. The maps display instrumental intensity (modified Mercalli scale), peak ground acceleration, and peak ground velocity. They are downloadable as image (JPEG) or zipped postscript (PS) files, and datasets are downloadable as text, zipped shapefiles, KML, XML, or HTML files. Older shakemaps are stored in an archive. The most recent maps are also available as RSS feeds.	E
Shallow Earthquake	An earthquake whose focus is located within 70 kilometers of the earth's surface.	E
Sheet Flooding	A condition where storm water runoff forms a sheet of water to a depth of six inches or more. Sheet flooding is often found in areas where there are no clearly defined channels	F
Sheet flow	Very shallow overland discharge (See overland flow)	F
Site	The location where the earthquake ground motion is being felt or measured	E
Site category	The category of site geologic conditions affecting earthquake ground motions based on descriptions of the geology, measurements of the S-wave velocity standard penetration test, shear strength, or other properties of the subsurface. For example, the site geologic condition is classified into categories from A (hard rock) to F (very soft soil), and different amplification factors are assigned for them.	E
Site classification	The process of assigning a site category to a site by means of geologic properties (e.g., crystalline rock or Quaternary deposits) or by means of a geotechnical characterization of the soil profile (e.g., standard penetration test and S-wave velocity).	E
Site effect	The effect of local geologic and topographic conditions at a recording site on ground motions. It is implicitly assumed that the source, path, and site effects on ground motions are separable.	E
Site response	The modification of earthquake ground motion in the time or frequency domain caused by local site conditions.	E
Slab	Slab refers to any crustal plate that is consumed by the Earth's mantle. See Plate tectonics.	E
Slip	The relative displacement of formerly adjacent points on opposite sides of a fault, measured on the fault surface.	E
Slip Rate	The average rate of displacement at a point along a fault as determined from geodetic measurements, from offset man-made structures, or from offset geologic features whose age can be estimated. It is measured parallel to the predominant slip direction or estimated from the vertical or horizontal separation of geologic markers.	E

Term	Definition	Cat*
Slum community	The slum community was in turn defined as a geographical entity where more than half of the households had the characteristics of slum households. As data on security of tenure do not exist, the estimates were based on the first four indicators, which were later termed indicators of shelter deprivation. To avoid introducing too many concepts simultaneously, the terms "shelter deprivation" and "slums" are used to reflect the same phenomenon.	A
Slum household	The proportion of slum dwellers within the urban population refers to the number of households; the slum household, therefore, was defined as an entity which lacked one or more of the following conditions: 1. Access to improved water supply 2. Access to improved sanitation 3. Durability of housing 4. Adequate living space 5. Security of tenure	A
Social Disparity Index	An index design to show the differences in social settings between two entities.	A
Social Loss Conversion	The conversion of building damage to social loss estimates (deaths, injured, homeless, affected etc.)	A
Socio-Economic Vulnerability	The susceptibility of short and medium-term conditions for (a) key economic indicators and overall economic performance and (b) key social indicators and social capital—it is essentially any vulnerability not pertaining directly to infrastructure (physical vulnerability), which has an aggravating effect. It can also be classed as the vulnerability of the community, i.e. the people and economics at risk.	A
Soil	All unconsolidated material above the bedrock	E
Soil amplification	Growth in the amplitude of earthquakes when seismic waves pass from rock into less rigid material such as soil.	E
Source	The geologic structure that generates a particular earthquake.	E
Spectral Acceleration	1. This is the acceleration measured at different periods at a seismic station. Commonly refers to either the Fourier amplitude spectrum of ground acceleration or the PSRV. 2. Response of a suite of single-degree-of-freedom oscillators to an earthquake, used to represent forces on a structure. (The acceleration of earthquake motion at a specified building period)	E
Spectral Amplification	A measure of the relative shaking response of different geologic materials. The ratio of the Fourier amplitude spectrum of a seismogram recorded on one material to that computed from a seismogram recorded on another material for the same earthquake or explosion.	E

Term	Definition	Cat*
Spectrum	In seismology, a curve showing amplitude and phase as a function of frequency or period.	E
Spillway	An outlet pipe or channel serving to discharge water from a dam, ditch, gutter, or basin.	F
Standard Deviation	The square root of the average of the squares of deviations about the mean of a set of data. Standard deviation is a statistical measure of spread or variability.	A
Stage	The water-surface height of a stream, usually registered in feet and tenths of a float on a fixed staff gage.	F
Stiff Buildings	A building that does not vibrate very freely	E
Stochastic	Applied to processes that have random characteristics.	A
Storm Drainage System	A drainage system for collecting runoff of storm water on highways and removing it to appropriate outlets. The system includes inlets, catch basins, storm sewers, drains, reservoirs, pump stations, and detention basins.	F
Stormwater	Precipitation from rain or snow that accumulates in a natural or man-made watercourse or conveyance system.	F
Stress	Force per unit area acting on a plane within a body. Six values are required to characterize completely the stress at a point: three normal components and three shear components.	E
Strike-Slip	Strike-slip faults are vertical (or nearly vertical) fractures along which rock masses have mostly shifted horizontally. If the block opposite an observer looking across the fault moves to the right, the slip style is termed right lateral; if the block moves to the left, the motion is termed left lateral.	E
Strong Motion	Ground motion of sufficient amplitude and duration to be potentially damaging to a building's structural components or architectural features.	E
Subduction	A plate tectonics term for the process whereby the oceanic lithosphere collides with and descends beneath the continental lithosphere.	E
Surface Faulting	Displacement that reaches the Earth's surface during slip along a fault. Commonly accompanies moderate and large earthquakes having focal depths less than 20 km. Surface faulting also may accompany aseismic tectonic creep or natural or man-induced subsidence.	E
Surface Wave	Seismic waves that propagate along the Earth's surface. Love and Rayleigh waves are the most common.	E
Surface Water	Water that flows in streams and rivers and in natural lakes, in wetlands, and in reservoirs constructed by humans.	F
Tailwater	The water surface elevation in the channel downstream of a hydraulic structure.	F
Thalweg	The line of maximum depth in a stream. The thalweg is the part that has the maximum velocity and causes cutbanks and channel migration.	F

Term	Definition	Cat*
Tectonic Region	Tectonic refers to rock-deforming processes and resulting structures that occur over regional sections of the lithosphere. Thus, the tectonic region is generally defined as the location which is either active, stable, subductive, volcanic etc.	E
Technological Hazard	A hazard originating from technological or industrial conditions, including accidents, dangerous procedures, infrastructure failures or specific human activities, that may cause loss of life, injury, illness or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage. Comment: Examples of technological hazards include industrial pollution, nuclear radiation, toxic wastes, dam failures, transport accidents, factory explosions, fires, and chemical spills. Technological hazards also may arise directly as a result of the impacts of a natural hazard event.	A
Tele-communications	transmission of signals over a distance for the purpose of communication—internet, telephone etc.	A
Thrust fault	A reverse fault in which the upper rocks above the fault plane move up and over the lower rocks at an angle of 30o or less so that older strata are placed over younger.	E
Time History	The sequence of values of any time – varying quantity (such as a ground motion measurement) measured at a set of fixed times. Also termed time series.	E
Time Series	A series of measurements over time, usually at regular intervals, of a random variable. A prime concern is the forecasting of future values. It is often necessary to	F
Topography	The relief features or surface configuration of an area.	F
Transportation	In this course, pertaining to a method of transport	A
Traveltime Curve	A graph of arrival times, commonly P or S waves, recorded at different points as a function of distance from the seismic source. Seismic velocities within the Earth can be computed from the slopes of the resulting curves.	A
Tributary	A stream that contributes its water to another stream or body of water.	F
Tsunami	An impulsively generated sea wave of local or distant origin that results from large-scale seafloor displacements associated with large earthquakes, major submarine slides, or exploding volcanic islands.	A
Tsunamigenic	Referring to those earthquake sources, commonly along major subduction-zone plate boundaries such as those bordering the Pacific Ocean, which can generate tsunamis.	E
Uncertainty	error; an estimate of the differences in values from test to test that are divided into two types, systematic and random, depending on their origin.	A
Unconsolidated	Loosely arranged, not cemented together, so particles separate easily.	E

Term	Definition	Cat*
Urban Flooding	The inundation of streets, basements, ground level floors of buildings, et cetera in urban areas.	F
Urban Renovation (Renewal)	Process of redeveloping deteriorated section of a city, often through demolition and new construction. Although urban renewal may be privately funded, it is most often associated with government renewal programs. The typical program attempts to demolish concentrations of dilapidated housing and attract developers of middle-income or mixed housing.	E
Variability	The range of possible outcomes of a given situation.	A
Velocity	In reference to earthquake shaking, velocity is the time rate of change of ground displacement of a reference point during the passage of earthquake seismic waves commonly expressed in centimeters per second.	A
Vulnerability	1. Conditions of economic, physical, social and environmental infrastructure that determine the probability that a certain hazard will cause a certain degree of damage. 2. This can also be defined as susceptibility of the infrastructure stock. 3. The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.	A
Vulnerability Analysis	Vulnerability analysis is the process of estimating the vulnerability to potential disaster hazards of specified elements at risk	A
Vulnerability Curves	A curve showing the relative vulnerability of a building or infrastructure element given a certain hazard.	A
Vulnerability Indices	An index showing the relative vulnerability of a building or infrastructure element given a certain hazard.	A
Warning System	Arrangements to rapidly disseminate information concerning imminent disaster threats to government officials, institutions and the population at large in the areas at immediate risk. They normally relate to tropical storms and floods.	A
Watertable (Water Table)	Level below the earth's surface at which the ground becomes saturated with water. The surface of an unconfined aquifer which fluctuates due to seasonal precipitation.	F
Watershed	An area from which water drains into a lake, stream or other body of water. A watershed is also often referred to as a basin, with the basin boundary defined by a high ridge or divide, and with a lake or river located at a lower point.	F
Wavefront	Imaginary surface or line that joins points at which the waves from a source are in phase (e.g., all at a maximum or all at a minimum).	E
Wavelength	The distance between successive points of equal amplitude and phase on a wave (for example, crest to crest or trough to trough).	E

Term	Definition	Cat*
Weir	A structure typically constructed to control the timing and amount of stormwater flowing into an adjacent detention basin. As the stormwater level in the channel increases, water flows into the basin over the weir. The lower a weir, the sooner the rising stormwater enters the basin. The longer a weir, the greater the flow of stormwater entering the basin.	F
Zoning	Zoning is the process in physical planning, or the results thereof, in which specific functions or uses are assigned to certain areas (for example, industrial zones, residential areas)	A

* Categories A: All; E: Earthquake F: Flood

Glossary References

The glossary is an aggregate of the following sources:

Fundamentals of Risk Analysis

UN/ISDR Terminology on Disaster Risk Reduction – UN/ISDR
International Red Cross. – ICRC
Prevention Web Glossary of Terms – Prevention Web
OECD Glossary of Terms – OECD
Relief Web Glossary of Terms – Relief Web
Statistics Glossary – STEPS

Earthquake Risk Analysis

REV (Rapid Earthquake Viewer) Glossary
Association of Corporate Treasurers (ACT) Glossary
USGS Glossary of Terms
Earthquake Canada Glossary of Terms – EQ Canada
HAZUS Glossary
Pacific Disaster Center (PDC) Glossary
University of Utah Earthquake Glossary
ICW Group – Insurance Company Glossary

Flood Risk Analysis

Center for Columbia River History, Oregon
FEMA Severe Weather Watches and Warnings Definitions
Fishbase.org Glossary
Flood Control District of Maricopa County, Arizona
Harris County Flood Control District, Texas
National Weather Service – West Gulf Forecast Center - D
Skagit County Flood Advisory Conditions, Washington
StreamNet Glossary of Dam Related Terms

9.2 References

9.2.1 Module 1 References

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