

## SEISMIC LOSS ESTIMATION FOR EFFICIENT DECISION MAKING

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### SUMMARY

In order to incorporate seismic risk of facilities into a decision making framework, procedures are needed to quantify such risk for stakeholders. Seismic loss estimation methods combine seismic hazard, structural response, damage fragility, and damage consequences to allow quantification of seismic risk. This paper presents a loss estimation methodology which provides various measures of seismic risk for a specific facility. The methodology is component-based and can therefore distinguish between different structural configurations or different facility contents and is consistent with state-of-the-art loss assessment procedures. Loss is measured in the forms of direct structural and non-structural repair costs, and although not considered in the example, business disruption and occupant injuries can also be considered. This framework has been packaged in a computer code available for future dissemination in the public domain so that users need only to have a basic understanding of the methodology and the input data that is required. Discussion is given to the flexibility of the framework in terms of the rigour which can be employed at each of the main steps in the procedure. Via a case study of a high-rise office building, the use of the methodology in decision-making is illustrated. Methodological requirements and further research directions are discussed. →

### INTRODUCTION

Current seismic design codes provide guidelines for the design and detailing of structures with the primary goal of preventing global collapse during strong ground motion shaking. Observations from worldwide earthquakes in the past two decades have illustrated that with few exceptions, structures designed to these state-of-practice guidelines are sufficient for providing life safety with a high degree of confidence. However, these events illustrated the severe economic consequences resulting from earthquakes in highly developed regions of society. These economic consequences can be primarily attributed to: (i) direct economic losses associated with repairing damage within a structure; (ii) direct losses associated with injuries and casualties; and (iii) indirect losses associated with the loss of income due to business disruption. These three forms of losses (damage, death and downtime) are known as the '3D's'. Some examples from the United States include the 1994 Northridge (\$17-26 billion), and 1989 Loma Prieta (\$11 billion) earthquakes [1]. In response to these observed losses it has become apparent that seismic design of structures should consider all of these potential consequences and their likelihood of occurrence.

Quantification of seismic risk is a difficult task which is subject to inherent variability. Although it can be roughly forecasted, it is not known when and where future significant fault ruptures will occur. Even when an earthquake occurs at a particular location, due to the complex rupture mechanism, process of seismic wave propagation and site effects, the intensity, frequency content and duration of ground motions at

a particular site are also uncertain. These uncertainties in the ground motions affecting a given site cause corresponding uncertainty in the level of structural response, and associated damage in the structure. Finally, the cost to repair a damaged structure is also uncertain and depends on available resources and demand. In order to rigorously assess the seismic risk of a structure all of the above uncertainties should be accounted for. Thus it becomes necessary that the problem of seismic risk is cast into a probabilistic framework which can propagate such uncertainties in each of the input variables and give a probabilistic output useful for decision making processes.

These aforementioned uncertainties result from either inherent randomness in a process, or uncertainty due to the limited knowledge and application of engineering models. These two different types of uncertainty are referred to as aleatory randomness and epistemic uncertainty, respectively. An example of aleatory randomness would be the variation in the level of ground motion observed at a site due to different ground motions resulting from the same rupture magnitude and source-to-site distance, while epistemic uncertainty would result from which ground motion prediction equation is used to estimate the level of ground motion at the site. As aleatory randomness is deemed as an inherent property of complex phenomena, it cannot be reduced; epistemic uncertainty being knowledge-based can be reduced if better knowledge of the phenomena is acquired. As these two different uncertainties are related to different aspects of the considered problem they deserve separate treatment within a decision making process.

This paper presents a discussion of the use of seismic loss estimation for decision making at various stages of design

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# Seismic Loss Estimation For Efficient Decision Making

**Fabio Biondini, Dan M. Frangopol**

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## **Seismic Loss Estimation For Efficient Decision Making:**

### **Handbook of Seismic Risk Analysis and Management of Civil Infrastructure Systems** S Tesfamariam, K

Goda, 2013-04-30 Earthquakes represent a major risk to buildings bridges and other civil infrastructure systems causing catastrophic loss to modern society Handbook of seismic risk analysis and management of civil infrastructure systems reviews the state of the art in the seismic risk analysis and management of civil infrastructure systems Part one reviews research in the quantification of uncertainties in ground motion and seismic hazard assessment Part two discusses methodologies in seismic risk analysis and management whilst parts three and four cover the application of seismic risk assessment to buildings bridges pipelines and other civil infrastructure systems Part five also discusses methods for quantifying dependency between different infrastructure systems The final part of the book considers ways of assessing financial and other losses from earthquake damage as well as setting insurance rates Handbook of seismic risk analysis and management of civil infrastructure systems is an invaluable guide for professionals requiring understanding of the impact of earthquakes on buildings and lifelines and the seismic risk assessment and management of buildings bridges and transportation It also provides a comprehensive overview of seismic risk analysis for researchers and engineers within these fields This important handbook reviews the wealth of recent research in the area of seismic hazard analysis in modern earthquake design code provisions and practices Examines research into the analysis of ground motion and seismic hazard assessment seismic risk hazard methodologies Addresses the assessment of seismic risks to buildings bridges water supply systems and other aspects of civil infrastructure

### **Soil-Foundation-Structure Interaction** Rolando P. Orense, Nawawi

Chouw, Michael J. Pender, 2010-07-20 Soil Foundation Structure Interaction contains selected papers presented at the International Workshop on Soil Foundation Structure Interaction held in Auckland New Zealand from 26-27 November 2009 The workshop was the venue for an international exchange of ideas disseminating information about experiments numerical models and practical en

### **Advances in Civil Engineering Materials** Elham Maghsoudi Nia, Mokhtar Awang, 2024-07-05

This book showcases the latest research in civil engineering and architectural materials with a specific focus on the following key areas circularity energy retrofitting building materials structural advancements and transportation innovations The research findings and advancements presented in this book are a part of the 7th International Conference on Architecture and Civil Engineering ICACE 2023 held on 15 November 2023 at the Everly Hotel Putrajaya Malaysia This conference serves as a prominent platform for researchers professionals and industry experts to exchange knowledge and ideas in order to advance the fields of civil engineering and architecture

### *Improved Seismic Monitoring - Improved Decision-Making*

National Research Council, Division on Earth and Life Studies, Board on Earth Sciences and Resources, Committee on Seismology and Geodynamics, Committee on the Economic Benefits of Improved Seismic Monitoring, 2006-02-04 Improved Seismic Monitoring Improved Decision Making describes and assesses the varied economic benefits potentially derived from

modernizing and expanding seismic monitoring activities in the United States These benefits include more effective loss avoidance regulations and strategies improved understanding of earthquake processes better engineering design more effective hazard mitigation strategies and improved emergency response and recovery The economic principles that must be applied to determine potential benefits are reviewed and the report concludes that although there is insufficient information available at present to fully quantify all the potential benefits the annual dollar costs for improved seismic monitoring are in the tens of millions and the potential annual dollar benefits are in the hundreds of millions M.J. Nigel Priestley

Symposium Mervyn J. Kowalsky, Sri Sritharan, 2008 *Treatise on Geomorphology*, 2013-02-27 The changing focus and approach of geomorphic research suggests that the time is opportune for a summary of the state of discipline The number of peer reviewed papers published in geomorphic journals has grown steadily for more than two decades and more importantly the diversity of authors with respect to geographic location and disciplinary background geography geology ecology civil engineering computer science geographic information science and others has expanded dramatically As more good minds are drawn to geomorphology and the breadth of the peer reviewed literature grows an effective summary of contemporary geomorphic knowledge becomes increasingly difficult The fourteen volumes of this *Treatise on Geomorphology* will provide an important reference for users from undergraduate students looking for term paper topics to graduate students starting a literature review for their thesis work and professionals seeking a concise summary of a particular topic Information on the historical development of diverse topics within geomorphology provides context for ongoing research discussion of research strategies equipment and field methods laboratory experiments and numerical simulations reflect the multiple approaches to understanding Earth's surfaces and summaries of outstanding research questions highlight future challenges and suggest productive new avenues for research Our future ability to adapt to geomorphic changes in the critical zone very much hinges upon how well landform scientists comprehend the dynamics of Earth's diverse surfaces This *Treatise on Geomorphology* provides a useful synthesis of the state of the discipline as well as highlighting productive research directions that Educators and students researchers will find useful Geomorphology has advanced greatly in the last 10 years to become a very interdisciplinary field Undergraduate students looking for term paper topics to graduate students starting a literature review for their thesis work and professionals seeking a concise summary of a particular topic will find the answers they need in this broad reference work which has been designed and written to accommodate their diverse backgrounds and levels of understanding Editor in Chief Prof J F Shroder of the University of Nebraska at Omaha is past president of the QG G section of the Geological Society of America and present Trustee of the GSA Foundation while being well respected in the geomorphology research community and having won numerous awards in the field A host of noted international geomorphologists have contributed state of the art chapters to the work Readers can be guaranteed that every chapter in this extensive work has been critically reviewed for consistency and accuracy by the World expert Volume Editors and by the

Editor in Chief himself No other reference work exists in the area of Geomorphology that offers the breadth and depth of information contained in this 14 volume masterpiece From the foundations and history of geomorphology through to geomorphological innovations and computer modelling and the past and future states of landform science no stone has been left unturned

**Maintenance, Safety, Risk, Management and Life-Cycle Performance of Bridges** Nigel Powers, Dan M. Frangopol, Riadh Al-Mahaidi, Colin Caprani, 2018-07-04 Maintenance Safety Risk Management and Life Cycle Performance of Bridges contains lectures and papers presented at the Ninth International Conference on Bridge Maintenance Safety and Management IABMAS 2018 held in Melbourne Australia 9 13 July 2018 This volume consists of a book of extended abstracts and a USB card containing the full papers of 393 contributions presented at IABMAS 2018 including the T Y Lin Lecture 10 Keynote Lectures and 382 technical papers from 40 countries The contributions presented at IABMAS 2018 deal with the state of the art as well as emerging concepts and innovative applications related to the main aspects of bridge maintenance safety risk management and life cycle performance Major topics include new design methods bridge codes heavy vehicle and load models bridge management systems prediction of future traffic models service life prediction residual service life sustainability and life cycle assessments maintenance strategies bridge diagnostics health monitoring non destructive testing field testing safety and serviceability assessment and evaluation damage identification deterioration modelling repair and retrofitting strategies bridge reliability fatigue and corrosion extreme loads advanced experimental simulations and advanced computer simulations among others This volume provides both an up to date overview of the field of bridge engineering and significant contributions to the process of more rational decision making on bridge maintenance safety risk management and life cycle performance of bridges for the purpose of enhancing the welfare of society The Editors hope that these Proceedings will serve as a valuable reference to all concerned with bridge structure and infrastructure systems including students researchers and engineers from all areas of bridge engineering

**Interpretable Machine Learning for the Analysis, Design, Assessment, and Informed Decision Making for Civil Infrastructure** M. Z. Naser, 2023-10-18 The past few years have demonstrated how civil infrastructure continues to experience an unprecedented scale of extreme loading conditions i e hurricanes wildfires and earthquakes Despite recent advancements in various civil engineering disciplines specific to the analysis design and assessment of structures it is unfortunate that it is common nowadays to witness large scale damage in buildings bridges and other infrastructure The analysis design and assessment of infrastructure comprises of a multitude of dimensions spanning a highly complex paradigm across material sciences structural engineering construction and planning among others While traditional methods fall short of adequately accounting for such complexity fortunately computational intelligence presents novel solutions that can effectively tackle growing demands of intense extreme events and modern designs of infrastructure especially in this era where infrastructure is reaching new heights and serving larger populations with high social awareness and expectations Computational Intelligence for Analysis Design and Assessment of

Civil Infrastructure highlights the growing trend of fostering the use of CI to realize contemporary smart and safe infrastructure. This is an emerging area that has not fully matured yet and hence the book will draw considerable interest and attention. In a sense the book presents results of innovative efforts supplemented with case studies from leading researchers that can be used as benchmarks to carry out future experiments and or facilitate development of future experiments and advanced numerical models. The book is written with the intention to serve as a guide for a wide audience including senior postgraduate students, academic and industrial researchers, materials scientists and practicing engineers working in civil structural and mechanical engineering. Presents the fundamentals of AI ML and how they can be applied in civil and environmental engineering. Shares the latest advances in explainable and interpretable methods for AI ML in the context of civil and environmental engineering. Focuses on civil and environmental engineering applications day to day and extreme events and features case studies and examples covering various aspects of applications.

Life-Cycle Civil Engineering: Innovation, Theory and Practice Airong Chen, Xin Ruan, Dan M. Frangopol, 2021-02-26. Life Cycle Civil Engineering Innovation Theory and Practice contains the lectures and papers presented at IALCCE2020 the Seventh International Symposium on Life Cycle Civil Engineering held in Shanghai China October 27-30 2020. It consists of a book of extended abstracts and a multimedia device containing the full papers of 230 contributions including the Fazlur R Khan lecture, eight keynote lectures and 221 technical papers from all over the world. All major aspects of life cycle engineering are addressed with special emphasis on life cycle design, assessment, maintenance and management of structures and infrastructure systems under various deterioration mechanisms due to various environmental hazards. It is expected that the proceedings of IALCCE2020 will serve as a valuable reference to anyone interested in life cycle of civil infrastructure systems including students, researchers, engineers and practitioners from all areas of engineering and industry.

Life-Cycle of Engineering Systems: Emphasis on Sustainable Civil Infrastructure Jaap Bakker, Dan M. Frangopol, Klaas Breugel, 2016-11-18. This volume contains the papers presented at IALCCE2016 the fifth International Symposium on Life Cycle Civil Engineering. IALCCE2016 to be held in Delft The Netherlands October 16-19 2016. It consists of a book of extended abstracts and a DVD with full papers including the Fazlur R Khan lecture, keynote lectures and technical papers from all over the world. All major aspects of life cycle engineering are addressed with special focus on structural damage processes, life cycle design, inspection, monitoring, assessment, maintenance and rehabilitation, life cycle cost of structures and infrastructures, life cycle performance of special structures and life cycle oriented computational tools. The aim of the editors is to provide a valuable source for anyone interested in life cycle of civil infrastructure systems including students, researchers and practitioners from all areas of engineering and industry.

*Life-Cycle of Structures and Infrastructure Systems* Fabio Biondini, Dan M. Frangopol, 2023-06-28. Life Cycle of Structures and Infrastructure Systems collects the lectures and papers presented at IALCCE 2023 The Eighth International Symposium on Life Cycle Civil Engineering held at Politecnico di Milano Milan Italy 2

6 July 2023 This Open Access Book contains the full papers of 514 contributions including the Fazlur R Khan Plenary Lecture nine Keynote Lectures and 504 technical papers from 45 countries The papers cover recent advances and cutting edge research in the field of life cycle civil engineering including emerging concepts and innovative applications related to life cycle design assessment inspection monitoring repair maintenance rehabilitation and management of structures and infrastructure systems under uncertainty Major topics covered include life cycle safety reliability risk resilience and sustainability life cycle damaging processes life cycle design and assessment life cycle inspection and monitoring life cycle maintenance and management life cycle performance of special structures life cycle cost of structures and infrastructure systems and life cycle oriented computational tools among others This Open Access Book provides an up to date overview of the field of life cycle civil engineering and significant contributions to the process of making more rational decisions to mitigate the life cycle risk and improve the life cycle reliability resilience and sustainability of structures and infrastructure systems exposed to multiple natural and human made hazards in a changing climate It will serve as a valuable reference to all concerned with life cycle of civil engineering systems including students researchers practitioners consultants contractors decision makers and representatives of managing bodies and public authorities from all branches of civil engineering

**MAP Technical Reports Series** ,1987      Seismic Risk Assessment and Design of Building Structures A. Koridze,1988

**Proceedings of the Second MCEER Workshop on Mitigation of Earthquake Disaster by Advanced Technologies (MEDAT-2), Held at Holiday Inn Emerald Springs Hotel, Las Vegas, Nevada, November 30-December 1, 2000**

Michel Bruneau,D. J. Inman,2001      Promoting Seismic Safety Daniel Alesch,2004      **Aménagement Du Territoire Dans Les Zones Sismiques : Reduction Du Risque Sismique Dans la Région Méditerranéenne : Textes Rédigés Au Cours de la Première Phase de L'action Prioritaire (1984-1986)** ,1987      *Earthquake Spectra* ,2005      **Seismological Research Letters** ,2000      **Journal of Geology** ,1999      **Probabilistic Regional Seismic Risk Assessment for Rational Decision Making**

Pablo Camilo Heresi Venegas,2019 Earthquakes in the last 100 years have resulted in 3 trillion U S dollars in economic losses worldwide Even moderate magnitude events such as the Mw6.7 1994 Northridge earthquake and the Mw6.9 1989 Loma Prieta earthquake have caused widespread damage significant economic losses and tens of thousands of families displaced from their homes In the last two decades the performance based earthquake engineering framework developed by the Pacific Earthquake Engineering Research Center also referred to as the PEER PBEE framework has gained much attention from researchers and practitioners not only in the U S but also in most seismic prone countries This framework was focused on individual structures under seismic hazards However large earthquakes occurring close to large urban regions may strike and affect thousands or even millions of structures simultaneously leading to large numbers of casualties and significant disruptions to the normal functionality of communities Hence the concept of performance in PBEE needs to be expanded from an individual to a regional scale with broader definitions of stakeholders and performance

metrics in order to evaluate the seismic risk of groups of structures that are spatially distributed within a region referred to as regional seismic risk. The main goal of this dissertation is to propose improved regional seismic risk methodologies within a probabilistic framework that explicitly quantifies, incorporates, and propagates uncertainties at the different stages of the analysis in order to provide improved information for decision makers. The main contributions of this dissertation are: A mathematical formalization of a regional performance based earthquake engineering (RPBEE) framework for seismic risk assessment of groups of structures and infrastructure spatially distributed within a region. An improved model for the spatial correlation of ground motion intensity measures which is based on 39 well recorded earthquakes and is the first model that explicitly incorporates the event to event variability. Recommendations of ground motion intensity measures to characterize the seismic hazard for regional seismic risk assessment of wood frame single family houses. An investigation on the relative seismic performance of one and two story houses leading to recommendations for future building classification systems for regional seismic risk assessment where one and two story houses are separated into different classes with different seismic vulnerabilities. Novel fragility curves for estimating the probability of damage to chimneys and severe damage to structural shear walls in wood frame single family houses which are particularly useful for improving current approaches to estimate the number of yellow and red tagged wood frame single family houses. A model for explicitly incorporating the correlation between the damage in different structures conditioned on their ground motion intensities for regional seismic risk assessment along with an investigation on the effect of this correlation on regional seismic risk metrics. A probabilistic framework for evaluating and comparing alternative public policies for enhancing the seismic performance of structures in terms of regional seismic risk mitigation. Evaluation of the inherent regional risk of collapse implicit with the probability of collapse of individual buildings that is currently specified as acceptable in U.S. seismic design provisions. A simplified seismic design approach that explicitly considers the regional seismic risk in the seismic design criteria of structures referred to as regional risk targeted seismic design.

## **Seismic Loss Estimation For Efficient Decision Making** Book Review: Unveiling the Power of Words

In a global driven by information and connectivity, the energy of words has be evident than ever. They have the capacity to inspire, provoke, and ignite change. Such is the essence of the book **Seismic Loss Estimation For Efficient Decision Making**, a literary masterpiece that delves deep into the significance of words and their affect our lives. Published by a renowned author, this captivating work takes readers on a transformative journey, unraveling the secrets and potential behind every word. In this review, we shall explore the book is key themes, examine its writing style, and analyze its overall effect on readers.

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### **Table of Contents Seismic Loss Estimation For Efficient Decision Making**

1. Understanding the eBook Seismic Loss Estimation For Efficient Decision Making
  - The Rise of Digital Reading Seismic Loss Estimation For Efficient Decision Making
  - Advantages of eBooks Over Traditional Books
2. Identifying Seismic Loss Estimation For Efficient Decision Making
  - Exploring Different Genres
  - Considering Fiction vs. Non-Fiction
  - Determining Your Reading Goals
3. Choosing the Right eBook Platform
  - Popular eBook Platforms
  - Features to Look for in an Seismic Loss Estimation For Efficient Decision Making
  - User-Friendly Interface
4. Exploring eBook Recommendations from Seismic Loss Estimation For Efficient Decision Making
  - Personalized Recommendations
  - Seismic Loss Estimation For Efficient Decision Making User Reviews and Ratings
  - Seismic Loss Estimation For Efficient Decision Making and Bestseller Lists

5. Accessing Seismic Loss Estimation For Efficient Decision Making Free and Paid eBooks
  - Seismic Loss Estimation For Efficient Decision Making Public Domain eBooks
  - Seismic Loss Estimation For Efficient Decision Making eBook Subscription Services
  - Seismic Loss Estimation For Efficient Decision Making Budget-Friendly Options
6. Navigating Seismic Loss Estimation For Efficient Decision Making eBook Formats
  - ePub, PDF, MOBI, and More
  - Seismic Loss Estimation For Efficient Decision Making Compatibility with Devices
  - Seismic Loss Estimation For Efficient Decision Making Enhanced eBook Features
7. Enhancing Your Reading Experience
  - Adjustable Fonts and Text Sizes of Seismic Loss Estimation For Efficient Decision Making
  - Highlighting and Note-Taking Seismic Loss Estimation For Efficient Decision Making
  - Interactive Elements Seismic Loss Estimation For Efficient Decision Making
8. Staying Engaged with Seismic Loss Estimation For Efficient Decision Making
  - Joining Online Reading Communities
  - Participating in Virtual Book Clubs
  - Following Authors and Publishers Seismic Loss Estimation For Efficient Decision Making
9. Balancing eBooks and Physical Books Seismic Loss Estimation For Efficient Decision Making
  - Benefits of a Digital Library
  - Creating a Diverse Reading Collection Seismic Loss Estimation For Efficient Decision Making
10. Overcoming Reading Challenges
  - Dealing with Digital Eye Strain
  - Minimizing Distractions
  - Managing Screen Time
11. Cultivating a Reading Routine Seismic Loss Estimation For Efficient Decision Making
  - Setting Reading Goals Seismic Loss Estimation For Efficient Decision Making
  - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Seismic Loss Estimation For Efficient Decision Making
  - Fact-Checking eBook Content of Seismic Loss Estimation For Efficient Decision Making
  - Distinguishing Credible Sources
13. Promoting Lifelong Learning

- Utilizing eBooks for Skill Development
  - Exploring Educational eBooks
14. Embracing eBook Trends
- Integration of Multimedia Elements
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