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More reliable physics in seismic hazard assessment (SHA) for disaster risk reduction (DRR)
(More reliable physics in SHA for DRR)

This issue

Book Review: Earthquakes and Sustainable Infrastructure–Neodeterministic (NDSHA) Approach Guarantees Prevention Rather Than Cure
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Book Review

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Earthquakes and Sustainable Infrastructure–Neodeterministic (NDSHA) Approach Guarantees Prevention Rather Than Cure

(https://www.sciencedirect.com/book/9780128235034/earthquakes-and-sustainable-infrastructure)

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The reduction of seismic disaster risk hinges on the reliable assessment of seismic hazard. In the realm of seismic hazard assessment (SHA), there have historically been two methods: the probabilistic SHA (PSHA) and the deterministic SHA (DSHA) (Reiter, 1990). Hazard is defined as inherent physical characteristic that poses potential threats to people, property, or environment. Within the context of seismic hazard, the main purpose of hazard analysis is to quantitatively assess ground shaking level at a site, through either DSHA or PSHA method. It is essential to quantitatively evaluate ground motion level at a target site. The DSHA is typically based on specific attenuation relations and assumed/predefined single earthquake scenario with selected magnitude and source-to-site distance. For PSHA, what focused are the median of the ground motion parameter or the mean of natural-log of ground motion parameter value and standard deviation of earthquake spectra for different levels of given magnitudes, source-to-site distance, and site conditions. That's also one of the drawbacks of PSHA and facilitates the launch of the neo-deterministic approach NDSHA. NDSHA effectively accounts for the tensor nature of earthquake ground motions: (a) formally described as the tensor product of the earthquake source functions and the Green's functions of the transmitting (pathway) medium; and (b) more informally described as mathematical arrays of numbers or functions (indices) “that transform according to certain rules under a change of coordinates” (Panza and Bela, 2020).

In the past nearly thirty years, the NDSHA has garnered significant attention within both the seismological and engineering communities. The book, *Earthquakes and Sustainable Infrastructure-Neodeterministic* (*NDSHA*) *Approach Guarantees Prevention Rather Than Cure*, represents a significant milestone, compiling developments of this new approach over the past 25 years.

As stated in the preface, NDSHA dates back to the turn of the millennium. It represents a scenario and physics-based multidisciplinary approach for the evaluation of seismic hazard that has been proven reliable through 20 years of experiments in numerous countries worldwide. The Scenario-based Seismic Hazard Analysis (SSHA) and Maximum Credible Seismic Input (MCSI) are well established methods, which form integral part of the NDSHA evaluation.

An observation of the NDSHA approach from an layman’s perspective can be summarized as a transition $S^5 \rightarrow S$, where the S^5 to the left of the arrow stands for seismicity, source, structure, seismic wave propagation, and site condition, respectively, and the S to the right of the arrow represents seismic strong ground motion. The recent advancements in modern seismology have significantly enhanced this approach, shifting SHA from a statistical/empirical paradigm to a physical/numerical one.

As stated in the preface, the purpose of this volume is to advance the establishment of a new paradigm for Reliable Seismic Hazard Assessment. It aims to create a synergy of the most up-to-date available scientific knowledge that ensures prevention and reduction of unacceptable losses rather than merely addressing the consequences of disasters. While the editors describe the book as a compilation of several independent papers and reviews, it appears to be well organized both scientifically and in its application. This organization is evident across its various sections, even though it is not explicitly documented within the book. Part I provides a comprehensive introductory review of the NDSHA method and its significance in reducing the risk of seismic disasters. It includes *Chapter* 1 *Hazard*, *risks*, *and prediction*, *Chapter* 2 *Seismic hazard assessment from the perspective of disaster prevention*, *Chapter* 3 *The view of a structural engineer about reliable seismic hazard assessment*, *Chapter* 4 *Disaster prediction and civil preparedness*, *Chapter* 5 *The integration between seismology and geodesy for intermediate-term narrow-range earthquake prediction according to NDSHA*. Part II, which includes *Chapter* 6 *Modeling the block-and-fault structure dynamics with application to studying seismicity and geodynamics*, *Chapter* 7 *Morphostructural zoning for identifying earthquake-prone areas*, *Chapter* 8 *Earthquake forecasting and time-dependent neo-deterministic seismic hazard assessment in Italy and surroundings*, effectively describes the inputs to NDSHA. These inputs encompass the set of controlling earthquakes characterized by time dependent features. Part III contains *Chapter* 9 *Spreading NDSHA application from Italy to other areas*, *Chapter* 10 *S-wave velocity profiling for site response evaluation in urban areas*, *Chapter* 11 *A user-friendly approach to NDSHA computations*, *Chapter* 12 *Recent applications of NDSHA: seismic input for high rise buildings in Egypt’s New Administrative Capital*, *Chapter* 13 *Neodeterministic method to assess the seismic performance of water distribution networks*, *Chapter* 14 *Seismic hazard analysis in a historical context: experience at Caltrans and elsewhere*, *Chapter* 15 *Where there is no science - probabilistic hazard assessment in volcanological and nuclear waste settings*: *facts*, *needs*, *and challenges in Italy, Chapter* 16 *Seismic hazard and earthquake engineering for engineering community*. This part effectively showcases the application and expansion of the NDSHA approach from Italy to other countries and regions. It illustrates its applicability beyond SHA to include broader perspectives such as civil engineering, key infrastructures, and even cultural heritage. Part IV, Chapters 17 to 30, describes the application of the NDSHA to different countries and/or regions, including the United States (Chapter 17), Central and South-eastern Europe (Chapter 18), Romania (Chapter 20), Bulgaria (Chapter 21), Republic of North Macedonia (Chapter 22), Albania (Chapter 23), the Iberian Peninsula (Chapter 24), North and South-west China (Chapter 25), India (Chapter 26), Pakistan (Chapter 27), Bangladesh (Chapter 28), Iran (Chapter 29), and Sumatra (Chapter 30). Chapter 19 presents the NDSHA simulation of ground motion for two urban areas: (a) Poggio Picenze, which was heavily damaged by the recent earthquake, April 6, 2009 (M_W6.3) and (b) the highly urbanized historical center of Napoli, which experienced moderate damage from the November 23, 1980 earthquake (M_W6.8) and high damage from the historical earthquakes in 1456 and 1688. The consistency between the computed ground accelerations and the observed macroseismic intensity data proves that the NDSHA simulation results could be a strong basis for preparedness to the next destructive earthquake.

This book fosters interdisciplinary discussion by providing a comprehensive and engaging exploration of seismic hazard assessment, bridging the gap between engineering principles and the needs of seismologists, engineering seismologists, and policymakers. In Chapter 3, Paolo Rugarli argues that the policy governing seismic design over the last 40 years requires an upgrade: he highlights that civil engineers must recognize the potential risk associated with the use of PSHA, as it may lead to the design of buildings that are not sufficiently safe.

This book is dedicated to Prof. Vladimir I. Keilis-Borok (1921–2013). Indeed, his scientific contributions to seismic hazard assessment and earthquake forecast have left a profound impact in this field. Some of the forecasting methods originate directly from his work. In Chapter 5, Mattia Crespi, Vladimir Kossobokov, Antonella Peresan, and Giuliano Panza highlight that earthquakes cannot be predicted with absolute precision; therefore, progressively reducing prediction uncertainty in space and time remains a challenge. This challenge persists not only due to the intrinsic complexity of seismic phenomenon but also because of its significant societal implications. To address this, well-tested algorithms (CN and M8) for intermediate-term middle-range prediction have been evaluated. Further advancing these efforts, the book showcases how an integrated approach—leveraging the synergy between high-density geodetic observations (GNSS and SAR) and seismological data—can facilitate intermediate-term narrow-range earthquake prediction. In Chapter 8, Antonella Peresan and Leontina Romashkova outline an operational procedure for time dependent seismic hazard assessment, which has been developed to integrate intermediate-term, middle-range earthquake forecast/prediction derived from pattern recognition analysis (utilizing CN and M8 algorithms) with the (multiple) scenario-based NDSHA approach. This discussion harks back to the biennial International Workshop on Nonlinear Dynamics and Earthquake Prediction, which was held at the Abdus Salam International Center for Theoretical Physics (ICTP) in Trieste from the 1980s through the 2010s. Many authors of the present book participated as students in at least one of these workshops, in which both Prof. Keilis-Borok and Prof. Panza (the leading editor of this book) served as coordinators and lecturers and left a deep impression on everyone with their scientific insights. As stated in the preface, many authors who participated in writing this book keep being inspired by the innovative research of Prof. Keilis-Borok and, in particular, by his ability to find simplicity in complexity, active style, scientific intuition, exceptional warmth of soul and humanity. Prof. Keilis-Borok founded a unique institute where pure mathematicians worked jointly with physicists and geologists in collaboration with the world-famous experts from mathematics, physics, economics, social sciences, law enforcement, environment protection, disaster management, and the government. Prof. Keilis-Borok and editors of this book (Prof. Panza, Prof. Kossobokov, Prof. Laor and Prof. De Vivo) worked closely, many of the results became one of the beginnings of NDSHA shown in this book.

The book serves both as a summary of the achievements of NDSHA over the past quarter-century and as a guideline for further development. One notable example is the formal definition of the Maximum Credible Earthquake (MCE). Panza and Bela (2020) and Rugarli et al. (2019) have demonstrated that the NDSHA can formally define the MCE. Its designated magnitude, M_{design}, can tentatively, and until proven otherwise, be set equal to the maximum observed magnitude, whether historical or instrumental (M_{max}), plus a multiple of the global standard deviation of magnitude $\gamma_{\text{EM}}\sigma_{\text{M}}$. The value of σ_{M} is the central value of magnitude standard deviation at global scale, which varies within the range of 0.2–0.3, i.e., σ_{M} =1/4 as reported by Båth (1973), Bormann et al. (2007) and Kossobokov (2007). To adopt a conservative approach and in alignment with the principle established by Hutton, it is currently prudent to set $\gamma_{\text{EM}}\sigma_{\text{M}}$ as 0.7, when magnitude estimation is truncated to one decimal digit. This calculation firmly links the M_{design} to the sum of M_{max} and 0.7, to the upper magnitude limit of the largest observed or estimated magnitudes (e.g., pattern recognition of morphostructural zonation, Gorshkov et al., 2003) in any given study area, i.e., $M_{\text{design}} = M_{\text{max}} + \gamma_{\text{EM}}\sigma_{\text{M}} = M_{\text{max}} + 0.7$. Since the M_{design} value provides the lower boundary for the MCE magnitude and effectively encompasses the available seismic catalogue, the MCE value needs to be updated only if a large seismic event, occurring after the M_{design} evaluation, significantly exceeds the M_{design} value itself. Similar to Båth's law (Richter, 1958), which points that the difference in magnitude between the main shock and its largest aftershock is generally about 1.2, the Panza-Rugarli law states that for MCE, the design magnitude M_{design}, can be set, given the current state of knowledge, equal to the sum of M_{max} and 0.7, and it is an intriguing topic for further discussion.

As stated in the preface, The book "Earthquakes and Sustainable Infrastructure: Neo-Deterministic (NDSHA) Approach Guarantees Prevention Rather Than Cure" aims to communicate in one volume the "state-of-the-art" scientific knowledge on earthquakes and related seismic risks. Earthquakes occur in a seemingly random way and in some cases it is possible to trace seismicity back to the concept of deterministic chaos. Therefore, seismicity, apparently, can be explained by a deterministic mechanism that arises as a result of various convection movements in the Earth's mantle, expressed in the modern movement of lithospheric plates fueled by tidal forces. The polarized plate tectonics (Doglioni and Panza, 2015) and the complex nature of seismic phenomena highlight the need to avoid the use of overly simplistic models, particularly for the assessment of the risks associated with earthquakes. In a perspective of prevention, coherent and compatible with the most advanced theories, it is essential that at least the infrastructure installations and public structures are designed so as to resist (or sustain) future strong earthquakes and continue to operate in their original capacity.

References

[1] Båth M (1973). Introduction to Seismology. Birkhäuser, Basel.

[2] Bormann P, Liu RF, Ren X, Gutdeutsch R, Kaiser D and Castellaro S (2007). Chinese National Network magnitudes, their relation to NEIC magnitudes and recommendations for new IASPEI magnitude standards. Bull Seismol Soc Am **97**(1B): 114–127. https://doi.org/10.1785/0120060078.

[3] Doglioni C and Panza GF (2015). Polarized Plate Tectonics. Advances in Geophysics **56** : 1–167. doi: 10.1016/bs.agph.2014.12.001.

[4] Gorshkov A, Kossobokov V and Soloviev A (2003). Recognition of earthquake-prone areas. In: Keilis-Borok VI and Soloviev AA eds. Nonlinear Dynamics of the Lithosphere and Earthquake Prediction. Springer, Berlin, pp 239–310. https://doi.org/10.1007/978-3-662-05298-3_6.

[5] Kossobokov V (2007). What do we know about earthquakes and their sequences? *Ninth Workshop on Non-linear Dynamics and Earthquake Predictions*. The Abdus Salam International Centre for Theoretical Physics.

[6] Panza GF and Bela J (2020). NDSHA: A new paradigm for reliable seismic hazard assessment. Eng Geol **275**: 105403. https://doi.org/10.1016/j.enggeo.2019.105403.

[7] Reiter L (1990). Earthquake Hazard Analysis: Issues and Insights. Columbia University Press, New York.

[8] Richter CF (1958). Elementary Seismology. Freeman, San Francisco.

[9] Rugarli P, Vaccari F and Panza G (2019). Seismogenic nodes as a viable alternative to seismogenic zones and observed seismicity for the definition of seismic hazard at regional scale. Vietnam J Earth Sci **41**(4): 289–304. https://doi.org/10.15625/0866-7187/41/4/14233.

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