Springer Natural Hazards

Jörn H. Kruhl
Rameshwar Adhikari
Uwe E. Dorka *Editors*

Living Under the Threat of Earthquakes

Short and Long-term Management of Earthquake Risks and Damage Prevention in Nepal

Springer

Springer Natural Hazards

The Springer Natural Hazards series seeks to publish a broad portfolio of scientific books, aiming at researchers, students, and everyone interested in Natural Hazard research. The series includes peer-reviewed monographs, edited volumes, textbooks, and conference proceedings. It covers all categories of hazards such as atmospheric/climatological/oceanographic hazards, storms, tsunamis, floods, avalanches, landslides, erosion, earthquakes, volcanoes, and welcomes book proposals on topics like risk assessment, risk management, and mitigation of hazards, and related subjects.

More information about this series at http://www.springer.com/series/10179

Jörn H. Kruhl
Rameshwar Adhikari
Uwe E. Dorka
Editors

Living Under the Threat of Earthquakes

Short and Long-term Management of Earthquake Risks and Damage Prevention in Nepal

Springer

Editors
Jörn H. Kruhl
Department of Civil, Geo and Environmental Engineering
Technische Universität München
München
Germany

Uwe E. Dorka
Department for Civil- and Environmental Engineering
Universität Kassel
Kassel
Germany

Rameshwar Adhikari
Research Center for Applied Science and Technology (RECAST)
Tribhuvan University
Kathmandu
Nepal

ISSN 2365-0656 ISSN 2365-0664 (electronic)
Springer Natural Hazards
ISBN 978-3-319-68043-9 ISBN 978-3-319-68044-6 (eBook)
https://doi.org/10.1007/978-3-319-68044-6

Library of Congress Control Number: 2017953806

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer International Publishing AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

On April 25, 2015, a magnitude 7.8 earthquake ("Gorkha Earthquake") shook the central part of Nepal, including the capital Kathmandu, followed by a magnitude 7.3 aftershock on May 12. More than 8700 people were killed and nearly 800,000 buildings damaged or destroyed, leaving millions of people homeless. The implications of the earthquake reached far beyond the loss of lives and the destruction of buildings. Nepal's infrastructure was strongly harmed, with wide-ranging effects for many parts of society and country.

The damage or destruction of numerous temples and world heritage monuments directly affected the daily religious worship of the population and the social-economic conditions and cultural identity of the country. Moreover, groups underprivileged already prior to the earthquake, based on gender, ethnicity, or caste, strongly suffered from the impacts of earthquake, and the social cohesion of the society and the society's feeling of security and a worth living future were affected.

Earthquakes, like other types of larger natural catastrophes, always have multifaceted effects on all parts of a society and a country. Therefore, they should be looked at and studied from an inter- and intra-disciplinary viewpoint. This requires a continuous dialogue between science, politics, administration, public organizations, and the people, with special view to the society's approach toward recurrent catastrophes.

From this perspective, an interdisciplinary conference (Humboldt Kolleg) was organized in Kathmandu, February 2016, where geoscientific, technical, medical, economic, social, political, and legislative aspects of the Gorkha earthquake were presented and discussed in detail as well as with respect to the special situation of Nepal as a developing country. Particularly, the connections and interactions between these fields were emphasized. Based on panel discussions, suggestions were presented, in which way preparedness of the society on all levels of technical and medical precaution, administration, politics, and, not least, with respect to culture and social structure can be reached and resilience toward future earthquakes and other catastrophes can be increased.

The present book assembles conference contributions from all earthquake-relevant fields and is designed to give an overview on their multi- and interdisciplinarity. Specifically, it deals with possibilities of earthquake-resistant building and settlement, efforts for restoration of world heritage sites, and questions related to technical and medical relief, and to economy, administration, politics, and public life in a high-risk seismic zone.

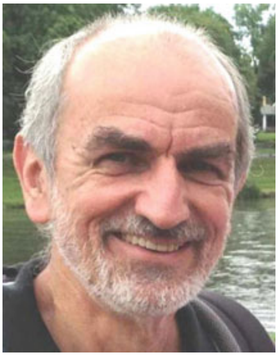
We gratefully acknowledge the generous financial support of the Alexander von Humboldt Foundation, which enabled the organization of the conference, which in turn formed the basis for the present book.

Munich, Germany — Jörn H. Kruhl
Kathmandu, Nepal — Rameshwar Adhikari
Kassel, Germany — Uwe E. Dorka
August 2017

Contents

Editors and Contributors

About the Editors



Jörn H. Kruhl is alumni of the Alexander von Humboldt Foundation and retired Professor of structural geology at Technische Universität München, Germany. He received his Dr.rer.nat. from the university of Bonn and held appointments at universities in Mainz, Salzburg, Berlin, and Frankfurt/M. Numerous research and teaching stays brought him to universities in Australia, Brasil, Canada, China, Italy, Jordan, Nepal, and the USA. His special interests are related to geotourism and sound rocks. Currently, he is guest researcher at Ludwig-Maximilians-Universtät München.

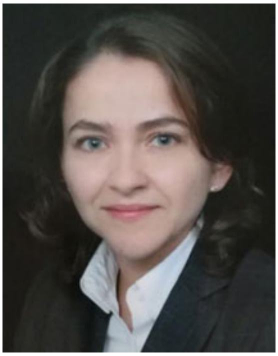
Prof. Dr. Rameshwar Adhikari is an Executive Director at Research Centre for Applied Science and Technology (RECAST) in Tribhuvan University, Kathmandu; graduate of Martin Luther University Halle-Wittenberg (Germany); Fellow of IUPAC; recipient of POLYCHAR International Materials Science Prize, Georg-Forster Fellowship of AvH Foundation and Technology Award of Nepal Academy of Science and Technology (NAST); author of over 120 research papers in peer-reviewed journals, coauthor/editor of eight books; served as visiting Professor at Rouen University (France), Mahatma Gandhi University (India), and Tokyo Institute of Technology (Japan).

Uwe E. Dorka is professor and head of the Steel and Composite Structures Section, Department of Civil and Environmental Engineering, Universität Kassel, Germany. He studied civil engineering at Ruhr-Universität Bochum, Germany, and University of Washington, Seattle, USA, and holds a doctorate from Ruhr-Universität Bochum. He is a Fellow of the Alexander v. Humboldt Foundation. His research interests are in structural control, innovative bridge concepts and protecting cultural heritage from earthquakes. He is a leading expert in hybrid simulation.

Contributors

Iswar Mani Adhikari works as a permanent faculty at Tribhuvan University. He is currently a Ph.D. Research Scholar at Central Department of Mathematics, Tribhuvan University.

Alejandra Arciniega-Ceballos studied geophysics at National Autonomous University of Mexico where she also got her MSc and Ph.D. degrees in seismology and physics of the Earth's interior. After the reawakening of Popocatepetl volcano in 1994, she became specialist in volcano seismology. Her research interests also comprise experimental volcanology and elasto-acoustic properties of rocks. Alejandra is alumni of the Alexander von Humboldt Foundation, and she has been several times invited researcher in USA, Germany, and Italy.



Marcela Baena-Rivera was born in Colombia and is Civil Engineer from Politécnico Colombiano Jaime Isaza Cadavid. She got her M.Sc. and Ph.D. from the School of Engineering at the National Autonomous University of Mexico (UNAM). Her studies include surface wave tomography and seismic wave propagation on arrays using frequency-wavenumber analysis. Currently, she is a Postdoc in the Institute of Engineering at UNAM and is Assistant Professor of Earth Sciences at UNAM.

Ananda M. Bhattarai Ph.D. is a Hubert Humphrey Fellow (2002–03 at Massachusetts Institute of Technology, USA) and Alexander von Humboldt Fellow (2005–06 at Max Planck Institute of International Law and Comparative Public Law, Heidelberg, Germany). He holds LLM and JSD in Law from National Law School of India University, Bangalore, India. Currently, he is a judge at the Supreme Court of Nepal.

Monika Brodmann Maeder Dr.med. is a Senior Consultant in the Emergency Department of Bern University Hospital, Lecturer at Bern University, and Senior Researcher in the Institute of Mountain Emergency Medicine at EURAC in Bolzano/Italy. As medical doctor and educator, she supports the PLNN Hospital in Lukla/Nepal, works as medical instructor for Nepalese mountain rescue teams, and regularly goes mountaineering in the Himalaya. In the 2015 Gorkha earthquake, she provided medical care for the victims from Everest Base Camp in Lukla.

Edward M. Brooks is a Ph.D. candidate in Earth & Planetary Sciences at Northwestern University. He completed his bachelor's degree at Johns Hopkins University, double majoring in Physics and Earth & Planetary Sciences, and he completed his master's degree in Statistics at Northwestern. His research focuses on developing metrics to assess the performance of earthquake hazard maps.

Tanka Nath Dhamala is professor at Tribhuvan University, works there since 1990, and has completed Ph.D. in Optimization from Germany. He has been serving as a DAAD Research Ambassador, AvH Research Fellow, President of Nepal Mathematical Society, and member of many academic organizations and scientific publications. His current research interests include mathematical modeling and solving real-life problems using optimization and simulation techniques, especially the evacuation optimization.

Martina Di Mauro is a civil engineer, with a master's degree in building engineering and architecture from the University of Salerno. She was an Erasmus trainee at the School of Built Environment, Salford University, in 2016.

Alice Fothergill is Professor of Sociology at the University of Vermont in the USA. She has worked in the disaster field for two decades. She is the author of two books, *Children of Katrina* (with L. Peek) and *Heads Above Water: Gender, Class, and Family in the Grand Forks Flood*. She has conducted research on volunteerism in the aftermath of the September 11, 2001, terrorist attacks in New York City, and is an editor of *Social Vulnerability to Disasters*.

Zeynep Gunay is an urban planner and Professor of urban and regional planning at the Istanbul Technical University (BSc/METU, Dipl/IHS, MSc/ITU, MSc/Cardiff, Ph.D./ITU). Her major areas of research are heritage, heritage preservation, and heritage-led regeneration theories and policies with a focus on memory and heritage industry. Taking part in several international and national projects, she was also awarded with Medal in Europa Nostra Awards 2004 and Gerd Albers Award 2015. She is the member of ICOMOS, ACHS, and ISOCARP.

Ramesh Guragain is Deputy Executive Director at National Society for Earthquake Technology-Nepal (NSET). He received a Ph.D. in Earthquake Engineering from The University of Tokyo. He has more than 15 years of experience in the field of earthquake risk management. His research interests and area of works include seismic risk assessment of buildings and infrastructures, seismic fragility functions development for buildings and infrastructures, especially for masonry buildings, development and promotion of retrofitting options for masonry buildings, earthquake reconstruction.

Ganesh R. Joshi is a Resource Economist and holds M.Sc. and Ph.D. from University of the Philippines Los Banos. He is working as a Commissioner in the Commission for the Investigation of Abuse of Authority (CIAA), Nepal.

Narayan B. Joshi is a Sociologist and holds M.A. degree from Tribhuvan University. He is the Chairperson of Sustainable Research and Development Center, Nepal.

Mian Liu is Curators' Distinguished Professor and William H. Byler Distinguished Chair in Geological Sciences, Department of Geosciences, University of Missouri. He received his B.Sc. from Nanjing University, China, M.Sc. from McGill University, Canada, and Ph.D. from the University of Arizona, USA. His research interest is in geodynamics, especially continental tectonics and earthquake physics.

Dev Kumar Maharjan received master's degrees in earthquake engineering and engineering seismology from the universities of Pavia, Italy, and Patras, Greece. He was involved in projects of seismic vulnerability assessment and retrofit design of building and implemented the project "Enhancing Emergency Health and Rehabilitation Response Readiness Capacity of the Health System in the Event of a High Intensity Earthquake in Kathmandu Valley" as team leader. He served as project engineer in "Building Code Implementation Program in Municipalities of Nepal (BCIPN)."

Christian Manhart has a master's in art history and archeology. He joined UNESCO in 1987 where he was mostly working for the conservation of historical sites in South and Central Asia. In 2005, he was appointed to the UNESCO World Heritage Centre, as chief of communication and partnerships, and in charge of museums and international cultural conventions (Conventions of 1954, 1970, 2001; Intergovernmental Committee for Return and Restitution of Cultural Property). Since August 2014, he is UNESCO's representative to Nepal.

Lukas H. Meyer received Ph.D. from the University of Oxford in 1996, and had the following positions: Faculty Fellow in Ethics Harvard University 2000–01, Feodor-Lynen Research Fellow/Columbia University in NYC 2001–02, Privatdozent University Bremen 2003, Assistant Professor of Philosophy/University of Bern 2005–2009, University Professor of Philosophy/University of Graz since 2009, at the University of Graz: Director of the Institute of Philosophy 2009–13, Vice-Dean of the Faculty of Arts and Humanities 2011–13; now, he is working as Dean of the Faculty of Arts and Humanities 2013–17, Speaker of the FWF Doctoral Programme "Climate Change" since 2014.

Hari Nandan Nath works as a permanent faculty at Tribhuvan University. He is currently a Ph.D. Research Scholar at Central Department of Mathematics, Tribhuvan University.

Ram Chandra Paudel is a professional trainer/ facilitator with extensive experience in the national and international arena on psychosocial counseling, career counseling, alternative to violence, trauma healing with considerable work within Government, Public, Private institutions, and NGOs/INGOs. He is author of several publications such as Peace Ways, Practical Peace Education for Youth and Founder & Executive Director of CHILDREN-Nepal and lead facilitator of Bikalpa Training Centre. He was awarded as an outstanding social activist by President and Prime Minister of Nepal.

Luigi Petti Ph.D. is a Professor of Earthquake Engineering at University of Salerno (IT), Secretary General of ICOMOS Italy—UNESCO Advisory Body, Expert Member of the International Committee on Risk Preparedness for Cultural Heritage ICORP, Scientific Manager of the Blue Shield National Committee. His research and professional experiences include innovative seismic protections strategies, cultural heritage restorations, and risk assessment.

Suman Pradhan is the Project Manager and Structural Engineer at National Society for Earthquake Technology-Nepal (NSET). He received a master in structural engineering from Sapienza University, Rome, Italy. He has been working with NSET since 2007 in the field of earthquake risk management. He has worked as Project Manager for Building Code Implementation Program in 30 Municipalities of Nepal and Team Leader on Details Damage Assessments of 15 Cities of Nepal after Gorkha earthquake 2015.

Matiram Pun is a Medical Doctor and Researcher in Mountain Medicine and High Altitude Physiology. During the devastating earthquake, he was in Kathmandu, working in the Department of Clinical Physiology of Institute of Medicine and Mountain Medicine Society of Nepal. He has long been involved in researches, rescues, and preventive measures of altitude illnesses and mountain emergency medicine in Nepal Himalayas. Surviving the earthquake, he got involved in the rescues and rehabilitation process in post-earthquake periods in Nepal.

Rabindra Puri has been working in the field of preservation of cultural heritage since 20 years and, as the first Nepali, received the "UNESCO Asia Pacific Cultural Heritage Preservation Award." He is the Founder and Chairman of Nepal Vocational Academy, an institution for teaching skills to build houses in traditional style as well as teaching traditional knowledge to build houses earthquake resistant. Seven years ago, he established the Rabindra Puri Foundation for Conservation, mainly focusing on preservation of cultural heritage.

Urmila Pyakurel works at Tribhuvan University since 2011 and has completed Ph.D. in Network Optimization from Tribhuvan University. She is going to be an AvH Postdoctoral Research Fellow at TU Bergakademie Freiberg, Germany. Her research area is the evacuation planning optimization.

Khan Rubayet Rahaman is now working as a Research Associate at the Department of Geomatics Engineering at the University of Calgary, AB, Canada. Mr. Khan has received his Ph.D. degree in urban engineering from the University of Tokyo; an MSc. in spatial planning from the Royal Institute of Technology (KTH) at Stockholm; an MA in environmental studies from Wilfrid Laurier University, Ontario; and a bachelor degree in urban and rural planning from Khulna University.

Francisco J. Sánchez-Sesma is a civil engineer with M.Sc. and Ph.D. from the School of Engineering at National Autonomous University of Mexico (UNAM). He is Professor of Structural Engineering and Earth Sciences at UNAM. His research includes wave propagation and the effects of surface geology on seismic ground motion. He got the National Science and UNAM Awards in 1994 and 1998. More recently, he got the 2015 DPRI Award from Kyoto University, Japan.

Volker Schneider holds the Chair of Empirical Theory of the State at the University of Konstanz. He has written extensively on policy networks, politics and policy of technology, government-business relations, and the evolution of governance structures. In a long-term perspective, he is working on a theory of the modern state and public policy in a systemic and relational perspective, combining complexity and network theories.

Surya Narayan Shrestha is the Deputy Executive Director and Senior Structural Engineer at National Society for Earthquake Technology—Nepal (NSET). Mr. Shrestha has been working with NSET since 2000. He holds a master's degree in structural engineering and has an extensive work experience of more than 18 years. Mr. Shrestha has worked as project manager and team leader for several projects related to earthquake risk reduction and post-earthquake reconstruction in Nepal, Pakistan, Indonesia, Bangladesh, Bhutan, Iran, and Mozambique.

Bruce D. Spencer is a statistician whose interests span the disciplines of statistics and public policy with a special focus on the design and evaluation of large-scale statistical data programs, including forecasts. He is author/coauthor of *Statistical Demography and Forecasting* and *Benefit-Cost Analysis of Data Used to Allocate Funds* and *Statistics and Public Policy*. He holds a Ph.D. in Statistics from Yale University and helped found the Department of Statistics at Northwestern University, Evanston, IL, USA.

Emma Squier graduated from the University of Vermont in May 2017 with a major in sociology and a minor in studio art. She was a student and later a teaching assistant for Alice Fothergill's sociology of disaster class. Emma studied abroad in Nepal during the spring semester of her junior year, nearly a year after the 2015 earthquake. While there, she conducted fieldwork interviewing women in various villages about their experiences during and after the disaster.

Seth Stein is Deering Professor of Geological Sciences at Northwestern and in the Institute for Policy Research. He is President-Elect of the American Geophysical Union's Natural Hazards Focus Group. His research focuses on earthquake hazard mitigation science and policy, assessing and improving earthquake hazard mapping methods. He is the author of "*Playing against nature: integrating science and economics to mitigate natural hazards in an uncertain world*," a general audience book about earthquakes, and coauthor of a widely used seismology text.

Harald Stelzer received Dr. phil. from Graz University 2003. He was Research Assistant at University of Minnesota 2002/03, University Assistant at Graz University 2009–12, Fulbright Scholar at University of Washington 2011, Project Scientist at the Institute for Advanced Sustainability Studies, Potsdam 2013–14, and is Professor for Political Philosophy and Head of the Section Political Philosophy at Graz University since 2014. Main research interest includes: decision-making under uncertainty from the perspective of normative theory as well as in applied ethics with a special focus on climate engineering.

Sukriti Suvedi studied bachelors in civil engineering at Tribhuvan University of Nepal and received a M.Sc. in Air Quality, Solid Waste and Waste Water Process Engineering from University of Stuttgart, Germany. Her special interest in development works in Nepal leads her to pursue an additional Masters of Arts in Rural Development at Tribhuvan University of Nepal. She is currently working in the field of infrastructure development of Nepal.

Prem Bahadur Thapa is an Associate Professor at Department of Geology, Tribhuvan University, Nepal. He obtained Master's Degree in Geology from Tribhuvan University; Master's Degree in Hydrogeology and Engineering Geology of Tropical and Sub-Tropical Regions from Eberhard-Karls-Universität Tübingen, Germany; and Doctor of Engineering from Kyushu University, Japan. Dr. Thapa is Humboldtian as well as Fulbrighter. His current research interest is on modeling of landslide hazard, and he has published many geoscientific papers in national and international journals.

Claudia Trillo, Ph.D., RIBA, HEIF, Italian Chartered Architect, qualified at associate professor level in Italy (M.D. 76/2012), is Lecturer in Architecture at the University of Salford, UK. She previously taught in Italy and in the UK and worked in Europe and in the USA as Marie Curie Researcher and Fulbright Senior Scholar. Her research and professional experience include innovation-driven urban regeneration, heritage-led regeneration, evaluation of projects and plans, sustainable urban design and planning, with over 100 publications.

Antje Witting, Dr.rer.soc., is a Postdoctoral Research Fellow at the University of Konstanz who, in the past twelve years, has contributed to policy analysis and advice on urban resilience building. Her published work explores institutional designs and social network attributes that drive or hinder learning in this context. Her research focuses in particular on the planning and funding of public infrastructures that serve metropolitan areas.

Earthquakes as Events of Inter- and Intra-disciplinary Character—With Special Reference to the Gorkha 2015 Earthquake in Nepal

Jörn H. Kruhl, Rameshwar Adhikari and Uwe E. Dorka

Abstract Earthquakes are catastrophes that affect all parts of a society and a country. Consequently, they have to be examined integratively and measures of restoration and precaution have to include not only safer rebuilding and damage minimization but many more fields, such as economy, infrastructure or social structure of the society. Using the example of the Gorkha 2015 earthquake in Nepal, geoscientific, technical, medical, economic, social, political and legislative aspects of such a catastrophe are presented and discussed in detail as well as with respect to the special situation in a developing country. Particularly, the connections and interactions between all these fields are emphasized. In addition, suggestions are presented, in which way preparedness of the society on all levels of technical and medical precaution, administration, politics and not least with respect to culture and social structure can be reached and resilience towards future earthquakes and other catastrophes can be increased.

Keywords Earthquake · Natural catastrophe · Disaster preparedness
Disaster management · Nepal

J.H. Kruhl (✉)
Department of Civil, Geo and Environmental Engineering,
Technische Universität München, Munich, Germany
e-mail: kruhl@tum.de

R. Adhikari
Research Centre for Applied Science and Technology (RECAST),
Tribhuvan University, Kathmandu, Nepal
e-mail: nepalpolymer@yahoo.com

U.E. Dorka
Department for Civil and Environmental Engineering, Universität Kassel,
Kassel, Germany
e-mail: uwe.dorka@uni-kassel.de

J.H. Kruhl et al. (eds.), *Living Under the Threat of Earthquakes*,
Springer Natural Hazards, https://doi.org/10.1007/978-3-319-68044-6_1

1 Introduction

In April and May 2015, an earthquake of magnitude 7.8 and an aftershock of magnitude 7.3 shook Nepal (Avouac et al. 2015; Elliott et al. 2016; Parameswaran and Rajendran 2017; Shrestha et al. 2016; Thapa 2018), 80 years after the devastating earthquake of 1934. This "Gorkha 2015 earthquake" did large damage in the capital Kathmandu but also in the mountain regions north and northeast of Kathmandu (Hashash et al. 2015; Thapa 2018).

Post-earthquake rebuilding in Nepal is slow. Reasons are not only lack of money and resources, typical of a developing country, and the low accessibility of the mountain regions. They are also rooted in the political and social structure of the country and in the insufficient disaster preparedness, which affect all parts of country and society.

The cultural, economic and political situation of Nepal is not only influenced by its situation as land-locked country in the highest mountain range on Earth and its location in a seismogenic zone but also by its history as a Hindu, absolutistic kingdom (Jerry 2016). The feudal system, lasting for centuries and extremely centralized at Kathmandu and the Kathmandu valley, led to a significant economic and political weakening of remote regions. The opening of the country during the fifties and sixties befell only the more easily accessible Kathmandu valley and few larger cities in other parts of the country (Hagen 1998). Since the seventies and eighties, a few high mountain regions were opened up for tourism (climbing and trekking tourism). Nevertheless, the Kathmandu valley with its three old royal towns Kathmandu, Patan and Bhaktapur and its numerous world heritage sites remained principal destination of foreign tourists.

After the ten years lasting civil war the kingdom was transformed to democracy with federal structure (Einsiedel et al. 2012; Jha 2014) and a new constitution was adopted in autumn 2015. However, larger ethnic groups (mostly in Terai) do not feel adequately represented by the constitution. This resulted in riots and a blockade of the Nepal-India border during winter 2015/2016, contributing to the instable political situation. In addition, essential parts of the constitution, mainly those related to the decentralization of the country, still have to be implemented. At least, in May 2017, elections were held on various local levels, after ca. 20 years without, and democratically legitimized representatives of the people could be elected. Most decisions are still made in Kathmandu and most of the money generated in the regions (e.g. by tourism) flows to Kathmandu and is possibly distributed again.

Nepal's location between India and China (Tibet) governs the political and economic situation of the country, with historically induced stronger bounds to India. Nepal's border to India is 'open'. The main sources of foreign currency income are tourism and money transfer of Nepali workers mostly in the Gulf region and Malaysia. Nepal is a developing country and is placed in the lower ranges of various rankings, for example on position 144 (out of 188) in the human development index (UNDP 2016) or on position 131 (out of 176) in the corruption ranking (Transparency International 2017). The public school system in Nepal suffers from underfinancing, a generally insufficient education of teachers, and far too large classes. This is partly also true for private schools.

With respect to ethnic groups, culture, religion and language, Nepal is extremely diverse. 81.3% of the population are Hindu, 9% Buddhist, 4.4% Islamic, 3.1 Kirati and 1.4% Christian (Nepal Census 2011; Nepal Central Bureau of Statistics 2017). This affects the current political situation. The caste system, too, has bearing on the Nepali society.

The situation related to economy, education, and medical care is considerably better in Kathmandu and other larger cities compared to rural and mountainous regions. In the former, an at least partly suitable network of traffic routes exists, whereas in the mountainous regions walking and transport of goods by porters, mules and yaks is required.

Against this background, the implications of the Gorkha 2015 earthquake and further natural disasters in Nepal have to be considered. The present work inspects the geoscientific, technical, medical, economic, social, political and legislative aspects and problems of the country. In addition, suggestions are presented, in which way earthquake precaution should be taken and resilience towards future earthquakes and other catastrophes can be increased.

2 Earthquakes and Related Hazards in Nepal

Earthquakes are unevenly distributed. They mainly occur where plates of the Earth's outermost layer move parallel to each other or converge and are eventually subducted into the upper mantle of the Earth. Consequently, earthquakes are frequent at the margins of the Pacific plate and its small neighboring plates, i.e. along the north- and south-American west coast, the south-eastern part of Japan, within the small-scale plate puzzle of Southeast Asia, along the eastern margin of the Indian-Australian plate, in the zones between the Indian subcontinent and Eurasia, and between Africa, Europe and Anatolia (USGS 2017a).

Frequency and magnitude of earthquakes can be evaluated on a statistical basis. However, earthquakes cannot be predicted and not at all on a short-term basis, which alone would be usable for vital security arrangements, such as evacuations (Wang and Rogers 2017). Uncertainty is increased by the fact that earthquakes can occur in regions that are seen as seismically inactive. For example, the Christchurch earthquake 2011 occurred at an unrecognized fault, ca. 100 km away from the boundary between the Pacific and the Indian-Australian plate and in a region of relatively low seismicity since begin of records (Kaiser et al. 2012).

Historical earthquake records bear uncertainties and may underestimate the frequency of earthquakes and, consequently, the seismic risk of a region (Bilham 2009). Moreover, events with intervals longer than human life disappear from the collective memory. However, this does not mean that preparedness is not possible. Based on regulations and training and education programs, countries located in seismically active zones, such as China, Italy, Japan, Portugal or the United States of America, made efforts to adjust the population to seismicity (Custódio et al. 2016; Gao et al. 1999; Matsumoto and Fujiwara 2014; Nathe 2000), in contrast to e.g. Nepal where indeed the necessity of disaster preparedness was underlined already in 1999 (Basnet et al. 1999), however, without further consequences.

Nepal is located in a young collisional orogen with high uplift rates and an accordingly pronounced morphology, i.e., with partly steep valley sides and elevation differences of up to several thousand meters (Hagen 1969). Additionally, the country is located completely in a zone of high seismicity with at least ten larger earthquakes documented for historical times (Chitrakar and Pandey 1986) and a similar number of earthquakes for pre-historic times (Sakai et al. 2015). The pronounced morphology and the earthquakes lead to further natural disasters, e.g. floods, liquefaction, land subsidence, rock falls, landslides, and debris avalanches. The annual monsoon rain partly increases these disasters.

Even independently of earthquakes, many regions of the country are impacted mostly by mass movements, again dependent on morphology and monsoon rain (Dahal and Hasegawa 2008; Gerrard 1994; Thapa 2018). These mass movements occur not only in the Higher Himalaya but also in the Lesser Himalaya and the Siwaliks (Dahal et al. 2008, 2009; Hasegawa et al. 2009; Timilsina 2014). They represent a continuous danger for villages but also endanger reservoir dams, demolish roads and can lead to flooding even at larger distances. In addition, landslides continuously destroy forests and valuable agricultural soil.

In the mountainous regions people often settle in areas with high risk of landslides and debris avalanches. This risk can be at least partly illustrated by risk maps. They are based on mapping of landslides and estimation of future landslide hazard and ideally result in recommendations for possible relocation of displaced people (Thapa 2018). However, specifically in the mountainous regions of Nepal it might be difficult to find alternative areas that are suited for settlement but not yet settled. Hence, the observation of active landslides is important, which is not only based on analyses of satellite images and remote sensing (Gallo and Lavé 2014) but also on the local geological situation and on-site investigations and ideally leads to measures of landslide stabilization (Thapa 2018).

3 Damage Related to the Gorkha Earthquake—Prevention, Restoration

Nepal's population of approximately 28 million is unevenly distributed. The Kathmandu valley and some regions in Terai show the highest population density, the mountainous regions the lowest one (Nepal Central Bureau of Statistics 2017). In the mountains, however, the space for settlement is scarce and settlements are endangered specifically by slope instabilities. Not least for that reason and despite the low population density, the Gorkha 2015 earthquake led to a high death toll and large property damage in the mountainous regions (Hashash et al. 2015), although Kathmandu and the Kathmandu valley with their high population density were also strongly affected (Thapa 2018).

In the mountain regions, in addition to the 'normal' mass movements—mostly caused by monsoon rain (Dahal et al. 2009), the earthquake triggered thousands of additional rock falls, landslides and debris avalanches (Thapa 2018), which led to destruction of entire villages (Collins and Jibson 2015; Hashash et al. 2015; Kargel et al. 2016; Lacroix 2016). On the other hand, the simple architecture of houses, such as blocks of stone piled one upon the other with simple wooden connections, was not resistant against the horizontal movements during the earthquake, although historical architecture gave rise to earthquake-proof house constructions (Gautam et al. 2016; Puri and Suvedi 2018).

In the Kathmandu valley, mostly underground and location influenced the distribution of damage (Dahal 2015; Hashash et al. 2015). Lacustrine sediments intensified the ground motion leading to increased destruction of houses as well as to tilting and, therefore, damage of houses, due to land subsidence as a result of liquefaction (Fig. 1). In addition, buildings on crests suffered higher damage compared to those at lower levels, as also reported from other earthquake regions worldwide (Geli et al. 1988). Even though these relationships are well known, not much attention was paid to them during settlement of the Kathmandu valley. The quadruplication of the population in Kathmandu within 30 years from ca. 422,000 to ca. 1,744,000 (Nepal Central Bureau of Statistics 2017) and the accompanying pressure of settlement hampered an ordered structure of settlement or even rendered it impossible. In satellite images as well as during approach to the Tribhuvan Airport, this lack of settlement structure is spectacularly visible.

The general assessment of earthquake risk is a fundamental task to be performed in seismic regions. Hazard maps represent the fundament of such assessments. However, often they do not describe the reality of later earthquakes (Newman et al. 2001; Stein et al. 2012) and in the case of Nepal different maps show clearly

Fig. 1 Tilting and subsidence caused by the Gorkha 2015 earthquake; four-story building in Lokanthali, south of Tribhuvan Airport, Kathmandu, Nepal. The *white arrows* indicate the tilting and subsidence path of the left building. *Photo* JH Kruhl (2 May 2015)

different risk for different parts of the country (Stein et al. 2018). Therefore, Stein et al. (2018) suggest, that a simplification of such maps could lead to an optimization, a treatment of Nepal's hazard as uniform, and to a better risk prediction.

Furthermore, the estimation of earthquake risk should include various factors, ranging from the general seismic situation, the occurrence of historic and pre-historic earthquakes, the regional geology, the condition of the underground, the architecture of buildings, up to the general infrastructure and to the preparedness of politics, administration and population. Even the total costs of earthquakes to society should be kept in mind, which depend on the mitigation costs and the expected loss (Stein and Stein 2012, 2013). Finally, it is always worthwhile to look at other earthquake regions and how in these regions earthquakes and their impacts are handled and how provisions against earthquakes are made. This includes the establishment and/or improvement of seismic monitoring systems, revision of building codes, as well as the establishment of a 'prevention culture' through educational programs (Andrews 2001; Arciniega-Ceballos et al. 2018; Shibayama et al. 2012).

However, it is not enough to perform such 'technical' or 'administrative' measures once. Continuous information and training is needed to keep up the people's awareness of living in a country with high natural risk. This is specifically important with respect to earthquakes which typically occur in intervals larger than human life and, therefore, can drop out of the people's treasure of experience. Even though the ground is shaking more or less continuously in all parts of Nepal as shown by the earthquake map of the US Geological Survey (USGS 2017b), these quakes with magnitudes of mostly less than 4.5 Mw cannot be sensed in most parts of the country.

Furthermore, it should kept in mind that disaster risk reduction is also negatively influenced by poverty, corruption and bad governance. "Most of the today's deficiencies in DRR [disaster risk reduction] are not due to a lack of science but are due to a lack in governance and political will for rigorous implementation. …For…a risk reduction approach, it is not only mandatory to reduce the direct risks of natural and man-made disasters, risks having their roots in poverty, corruption and bad governance are equally important factors in need for sustainable management" (Global Risk Forum Davos 2014). Measures for disaster risk reduction, specifically building codes, have to be not only decided but also implemented and adopted. In Nepal, this was and still is not the case, also because of the rapid growth of cities accompanied by a largely uncontrolled building activity (Ahorn et al. 2015). Modern seismic building codes do not consider actual building practice properly (as they should) and lack information on many seismically robust construction concepts that were developed during the last two decades: concepts that combine earthquake-robustness with superior economy (Dorka 2018).

Earthquakes do not kill but the settlement in threatened regions and inadequate ways of construction lead to loss of lives. Again during the Gorkha 2015 earthquake, proof of this simple truth was given. Most of the collapsed or partly destroyed buildings were badly constructed. Mainly buildings with brick masonry but without reinforcement did not resist the ground motions during the earthquake (Fig. 2), just as little as the buildings in the mountain villages constructed with stone masonry (Fig. 3) (Guragain et al. 2018; Hashash et al. 2015). In the past,

Fig. 2 Collapsed front section of a house built completely of bricks without further enforcement; Jamal, Kathmandu, Nepal. *Photo* JH Kruhl (26 April 2015)

Fig. 3 Collapsed house built of stone masonry; village east of Melamchi, Melamchi valley, northeast of Kathmandu, Nepal. *Photo* JH Kruhl (1 May 2015)

buildings in traditional architecture resisted earthquakes in a much better way. If they were damaged during the Gorkha earthquake this partly resulted from long-standing lack of maintenance or insufficient knowledge how such construction should be maintained. This not only applied to historical buildings that were quickly rebuilt and by saving high-quality (and hence expensive) material (Manhart 2018). It has been shown, however, that traditional houses can be restored or new houses can be built with better earthquake resistance (Puri and Suvedi 2018).

The situation with respect to earthquakes and related hazards in Nepal can be summarized as follows.

The 2015 Ghorka earthquake demonstrated again that Nepal is vulnerable to the effects of earthquakes. Although shaking in Kathmandu was not as strong as during the 1934 event, additional hazards triggered by the earthquake, in particular land slides, caused substantial damage to infrastructure and are responsible for the majority of lives lost. Some soil liquefaction was observed in the Kathmandu valley. Post-quake fires did not play an important role this time.

Ground shaking

The major Himalayan subduction zone beneath Nepal Himalaya is capable of creating very strong ground shaking. Extremely large events (Mw $\geq$= 9.0?) seem possible. Magnitudes around Mw = 8 are likely. There is not enough knowledge to estimate the location, time when, where and magnitude of the next event. However, seismic gaps exist in the western Nepal Himalaya for more than 500 years. What is certain though, is the fact that an earthquake stronger than 2015s will hit Nepal. Therefore, earthquake preparedness for a large event is very essential to protect lives and property especially in the Kathmandu valley. Preparing for a large event is therefore essential.

Land slides

This earthquake did not trigger a lot of landslides in the Kathmandu valley. However, large-scale landslides, like the one in the Langtang valley, are very likely to occur again, especially if a large earthquake occurs during the monsoon season. Identifying possible locations especially in the vicinity of near settlements is therefore very important. Proper ground investigation including landslide, subsidence and bank failure should be carried out before remedial measures are taken, e.g. slope stabilization or site selection for resettlement. Remedial measures for such locations can be slope stabilization or in extreme cases, resettlement.

Soil liquefaction

The Gorkha earthquake did not liquefy the soil of Kathmandu valley because ground motion was comparatively small and groundwater level low. However, during monsoon, a situation is created where widespread liquefaction must be expected. Such areas should be identified. Reducing this hazard with technological means has proven to be extremely costly. Resettlement, like in the case of Christchurch, New Zealand, appears to be the most reasonable approach today.

Post-quake fires

In densely populated quarters of Kathmandu, post-quake fires are likely to occur. During a field visit to the historic quarters, it was noted that the fire fighting equipment is stored in an already damaged historic building. There is a clear and present danger that this structure would collapses even under even moderate shaking. This will render most of the equipment stored there unusable. Preventing the spread of fires, and as a result, leading to a large conflagration in the historic quarters of Kathmandu, will be severely curtailed by the loss of said equipment.

Based on a panel discussion at the Humboldt Kolleg "Living under Threat of Earthquake – Short- and long-term management of earthquake risk and damage prevention in Nepal", Kathmandu, February 2016, attended by Lok Bijaya Adhikari – Head of National Seismological Center, Department of Mines and Geology, Lainchaur, Kathmandu, Nepal; Jahangir Alam – Vice Chancellor, Chittagong University of Engineering and Technology (CUET), Bangladesh; Zeynep Gunay – Istanbul Technical University, Istanbul, Turkey; Luigi Petti – Department of Civil Engineering, University of Salerno, Italy; Seth A. Stein – Department of Earth and Planetary Sciences, Northwestern University, Evanston, IL, USA; Ramesh Guragain – Deputy Executive Director, National Society for Earthquake Technology-Nepal (NSET), Kathmandu, Nepal.

Prepared and edited by: Uwe E. Dorka, Seth Stein, Basanta R. Adhikari.

Based on this, effective actions for an earthquake-safe built environment in Nepal should be taken as follows.

The key to a substantial seismic risk reduction in Nepal is reducing the vulnerabilities of structures: "Earthquakes don't kill—structures do!" To this end, the following actions have proven to be effective in other earthquake prone regions:

- Create public awareness by performing level 1 seismic vulnerability assessment ("walk through method") and publish the results in public media. The results will not be very accurate because a realistic damage database is missing for Nepal. But it will create a database of all building typologies in Nepal and raise awareness, which is currently more important than accuracy.
- At the same time, substantially improve the robustness and economy of structures. These require phasing out RCF (reinforced concrete frame with masonry infill) and substitute it with more robust and more economical structural concepts. Although RCF is currently the dominant structural system, it lacks robustness and is not suitable for the construction environment in Nepal. It is also less economical than e.g. reinforced masonry

and systems that control the maximum forces in a structure (Hyde System, Base Isolation and Tendon System: see proceedings). Re-vitalize traditional earthquake resistant concepts (e.g. horizontal tie system, innovative materials) for low-rise non-engineered structures.

- Validate these technologies for Nepal through shaking table tests and demonstrate them in ongoing building projects. Disseminate through public media (TV, radio, internet, booklets for owners etc.).
- Provide guidelines for "Good Practice" and train local contractors, masons and their workforce in these technologies.
- Before final repair or reconstruction of important cultural heritage structures, their seismic performance must be duly understood. Otherwise, it may create serious additional hazards to the building (this has happened in the past). Numerical simulation methods are not yet capable of providing this understanding. Therefore comprehensive testing campaigns (shaking table tests, component tests, hybrid simulations) must be performed before any intervention or reconstruction takes place.
- Seismic monitoring systems should be installed after repair or reconstruction and in structures that have performed well in order to obtain seismic performance data and monitor structural health over time.
- An international scientific committee should be set up to review and monitor all plans and actions aimed at historic structures.

It is already recognized that a large number of structures in Kathmandu is vulnerable and their retrofitting is economically not feasible. Urban renewal is an ongoing process and can be utilized in ways that will not only enhance the seismic resilience of this city, but also act as a potent economic motor and improve the overall quality of life in Kathmandu. To this end, the following actions can improve the situation substantially:

- Typical city wards can be selected (historic quarter, un-checked urban sprawl site) to analyze and demonstrate the need, the potential, the limitations and risks for urban renewal.
- The involvement of the local community in all phases of the renewal process is essential in order to preserve the social fabric and local community life.
- Existing financing instruments work well for middle- and high-income quarters, but in the case of historic and low-income sites, donor involvement is highly recommended to avoid excessive economization, which has proven to be socially disruptive and hazardous to the historic fabric (see Istanbul).

Based on a panel discussion at the Humboldt Kolleg "Living under Threat of Earthquake – Short- and long-term management of earthquake risk and damage prevention in Nepal", Kathmandu, February 2016, attended by Lok Bijaya Adhikari – Head of National Seismological Center, Department of Mines and Geology, Lainchaur, Kathmandu, Nepal; Jahangir Alam – Vice Chancellor, Chittagong University of Engineering and Technology (CUET),

Bangladesh; Zeynep Gunay – Istanbul Technical University, Istanbul, Turkey; Luigi Petti – Department of Civil Engineering, University of Salerno, Italy; Seth A. Stein – Department of Earth and Planetary Sciences, Northwestern University, Evanston, IL, USA; Ramesh Guragain – Deputy Executive Director, National Society for Earthquake Technology-Nepal (NSET), Kathmandu, Nepal.
Prepared and edited by: Uwe E. Dorka, Basanta R. Adhikari, Lugi Petti, Zeynep Gunay.

4 Disaster Management and Economics

The implications of earthquakes reach far beyond the loss of lives and the destruction of buildings. In most cases, most types of infrastructure are strongly afflicted if not completely destroyed, with long-ranging effects for many parts of society. The Gorkha 2015 earthquake destroyed roughly 35,000 classrooms, leaving nearly 1 million students (from a total of 9.1 million school-age children in the country) without school (Daily Mail 2016; KTM Post 2016). The destruction of industrial facilities led to the destruction of work places and trade infrastructures and to reduced economic demands. Moreover, numerous local markets were destroyed or their functions were affected, leading to difficulties in food distribution as well as to price increases (Joshi and Joshi 2018).

The destruction of 956 hospitals and clinics (Daily Mail 2016) affected the medical care mainly in remote mountain regions and will have effects on medical care far in the future. In addition, the earthquake revealed the necessity to strengthen medical and rescue services mostly in rural areas. This requires an increased training of local medical personnel, which cannot be achieved solely by Nepal. International coordinated aid capable of quick assistance needs to be established for future (inevitable) catastrophes. Even if in case of disaster immediate aid is most necessary, in the medium term "… prioritization should be given to facilitating training and simulation exercises at all health care levels" (Brodmann Maeder and Pun 2018).

After the Gorkha 2015 earthquake the number of foreign tourists dramatically dropped (Government of Nepal 2015), probably for fear of further quakes as well as caused by at least ambiguous reports of international media about destruction of the world cultural heritage in large parts (BBC 2015; CNN 2015). This shows that post-earthquake reconstruction must not concentrate solely on physical damage. In addition to it, the lost feeling of security has to be re-established, with respect to local people as well as to foreign visitors. This is particularly a psychological task because the feeling of security often does not correlate with the real threat (Blinkert 2010; Breezke and Pearson 2014) and the feeling of threat can only rarely be eradicated by 'reassuring' numbers.

The decline of tourism after the Gorkha earthquake caused considerable economic difficulties in Nepal. Tourism covers ca. 9% of GDP, represents a significant economic factor, and forms the basis for a large number of jobs (WTTC 2015). Specifically in a country with limited natural resources, tourism is of great importance, the more because it could be expanded in many parts of the country (Sharma 2012). Therefore, measures should be included in the reconstruction of the country, which improve tourism and develop new aspects of tourism (Bhatt 2006; Hagen 1998; Kruhl 2018).

The Gorkha 2015 earthquake destroyed or damaged several temples and historical monuments of world heritage in Kathmandu, Patan and Bhaktapur (Manhart 2018; UNESCO 2016). Specifically the temples in the Kathmandu valley represent indispensable sites of religious life. Their destruction directly affected the daily religious worship of the population. Although many provisional arrangements provided remedy (Fig. 4), the reconstruction of temples and other religious sites represents an important aspect of the general reconstruction measures, to which high priority should be given.

Although immediately after the earthquake many necessary physical safeguarding measures were initiated (Manhart 2018), reconstruction of historical buildings was slow particularly during the first year. This was mainly caused by lack of material, the border blockade to India during winter 2015/2016, awkward bureaucratic processes, and the fact that heritage restoration needs long-standing preparations (Manhart 2018).

The problems, based on lack of material and design, are intensified by lack of qualified craftsmanship (Joshi and Joshi 2018). Even in the medium term, such deficiency cannot be eliminated by high allowances in money of other countries or aid agencies. The few attempts to reduce the lack of specialists in restoration of historical buildings (EcoHimal 2017; Rabindra Puri Foundation for Conservation 2017) are not more than a drop in the bucket.

Fig. 4 Basis of destroyed Chaar Narayan Temple at Patan Durbar Square with provisional tent construction. *Photo* JH Kruhl (15 May 2016)

However, economic loss implies the chance of a fresh start that avoids old mistakes and represents comprehensive and resilient rebuilding in all fields of economy and society (Joshi and Joshi 2018). Obviously, it is important to avoid disaster-related risks and to 'build back better'. But particularly, disaster preparedness should be increased and the people's awareness of specific and continuous risks needs to be raised. "Education on hazards and risk reduction should be provided mandatorily from pre-school to university level. These education activities should support children and students obtaining capabilities to increase their own resilience to disasters, and to support their schoolmates, relatives and neighbors. Both teaching staff and students should be involved in regular drilling exercises" (Global Risk Forum Davos 2014). This requires a continuous dialogue between politics, administration, public organizations and the people. Considering that, a well installed and established democratic system is a precondition.

Beyond the consequences for tourism and religious life, the destruction of temples and other historical buildings affects the social-economic conditions and the cultural identity of the country. Therefore, appropriate reconstruction modes are needed. These include a "place-specific approach to conservation", which is related to the particular culture, the urban context, and traditional materials (Petti et al. 2018). Such type of conservation would be rooted in the culture and tradition of the specific country. A reconstruction that follows a cultural pattern appears perfectly acceptable in the frame of Nepalese tradition, although such approach would not be acceptable to a 'western' viewpoint (Petti et al. 2018). In addition, the Nepalese discourse about heritage and its conservation and reconstruction is more related to continuity than to authenticity. This implies the acceptance of change and renewal against the conventional heritage preservation and should be considered when reconstructing the world cultural heritage buildings in the Kathmandu valley (Gunay 2018).

With respect to rescue operations, preparedness and economy, the situation of Nepal after the Gorkha 2015 earthquake can be summarized and suggestions for future actions can be made as follows.

Following the April 2015 earthquake disaster, Nepal had to go through plenty of painful consequences. A large part of the population in the middle hills districts was suddenly subjected to big physical and psychological stress. In the long term, this will influence the country's economy. A wide spectrum of the society (governmental and non-governmental organizations, civic society, entrepreneurs, media people and individuals) became aware of the high risk, at which Nepal is naturally placed. In addition, the significance of disaster management preparedness became clear. Although the earthquake negatively influenced the country's economy, it opened the opportunity to create sustainable economic developments through proper education and training, media-based mass awareness, and coordinated actions in different parts of the society (including social workers, engineers, psychologists and educationists).

Disaster situation assessment

- The condition right after the earthquake was very severe and full of havoc. Immediate response of Nepalese security forces and international organizations provided a great deal of rescue operations and helps. The government of Nepal was not well prepared for such an unprecedented huge disaster. The government actions were too slow in the beginning. It took a few weeks to resume the necessary rapid actions.
- The situation of unequal distribution of relief materials prevailed due to geographical inaccessibility of many affected regions. To avoid resource duplication in accessible areas and assure relief materials to all affected areas the government implemented the one-door entry of the relief materials arranged by international organizations.
- Looking at the vulnerability of children and women in the badly hit areas for being exploited in different ways, the Nepal government took quite rapid measures to insure their safety. Despite these efforts, there were rumors of trafficking of children and women in the name of providing them shelter, foods and jobs.

Rescue operations in cities and high risk regions

- People started digging out injured people and victims immediately after the earthquake, with the help of the Nepalese army and later also with international relief workers.
- The strong social bond among Nepalese citizens, irrespective of any sort of diversities, and that between international volunteers and Nepalese populations helped a lot for the rescue and recovery actions. The warm relation among the people is the treasure of the country and needs promotion.
- The proper channelization of the rescue and relief operations was made difficult due to limitations such as lack of infrastructure, like roads or airports, and experience.

Overall preparedness

- There was almost no preparedness for the disaster—no proper training to the concerned volunteers and local administrative bodies, no coordinated government-NGOs-experts efforts to cope with such natural calamities, no arrangement of reserves of food, medicines and clothes for disaster situation.
- Inadequate attention towards preparedness was reflected also in the formation of the National Reconstruction Authority (NRA). The NRA is working in a snail pace even today. It is worth to have a proper monitoring mechanism of the NRA—comprising the credible experts and individuals engaged in real problems.
- A national plan for disaster management is necessary for future preparedness. Development of building codes suitable for Nepalese building

practice, and their enforcement should be given utmost priority. The government should develop a proper mechanism to ensure that there is no abuse of authority.

Economic consequences/suggestions

- There is a chance to change the crisis situation into an opportunity—to construct more sustainable infrastructures, using more local resources and traditional technologies and giving a more sustainable framework to the country's economic growth.
- Proper education, training and awareness are important elements. Proper training for all involved in the building process to erect safer buildings, in particular for masons, is a prime necessity.
- Strong political will and good governance are key issues to be considered, in order to tackle the disaster situation and to rebuild economy in sustainable way. Only good governance can help ensuring societal harmony and peace during situations of crisis. The non-governmental organizations and cooperatives should be encouraged to work in coherence with the existing regulations and social norms to avoid any kind of disturbances.

Based on a panel discussion at the Humboldt Kolleg "Living under Threat of Earthquake – Short- and long-term management of earthquake risk and damage prevention in Nepal", Kathmandu, February 2016, attended by Monika Brodmann Mäder – Department of Emergency Medicine, University Hospital Bern, Switzerland; Pramod Dhakal – Chair, NRNA Open University Task Force, Nepal; Ganesh Raj Joshi – Commissioner, Commission for the Investigation of Abuse of Authority (CIAA), Nepal; Jiba Raj Pokharel – Vice Chancellor, Nepal Academy of Science and Technology (NAST), Khumaltar, Lalitpur, Nepal.

Prepared and edited by Rameshwar Adhikari and Jyoti Giri – Central Department of Chemistry, Tribhuvan University, Kathmandu, Nepal.

5 Living with Earthquake Risk

During reconstruction of those regions of Nepal, affected by the Gorkha 2015 earthquake, underprivileged groups of the population need to be considered in particular (NDRI 2017). These groups, underprivileged already prior to the earthquake, based on gender, ethnicity or caste (Karki and Bohara 2014), strongly suffered from the impacts of earthquake. In Nepal, women are discriminated in many areas of public and private life (Ghale 2012) and their situation during and after catastrophes has to be regarded as specifically critical. Their rights should be strengthened. Moreover, it appears important that women participate in the processes of disaster risk reduction, disaster preparedness, and disaster recovery (Fothergill and Squier 2018).

Disaster preparedness includes fields that are usually not in the focus of interest, e.g., evacuation logistics in case of catastrophe (Bretschneider and Kimms 2012; Dhamala 2015; Goerigk et al. 2014) or supply of emergency items in the case of disaster (Lin et al. 2011). It is specifically important to develop risk management models on prevention, preparedness, response and recovery, with focus on evacuation planning and relief distribution (Dhamala et al. 2018). Such modelling is useful because the processes of risk management are mostly complex and, therefore, cannot be comprehended by simple strategies. However, such complex, mathematically profound strategies not only need to be developed but also tested and finally implemented, so that they are available in case of emergency.

Women and children belong to those who are most vulnerable in disaster situations (Maharjan and Paudyal 2016) and need special protection. Their influence on politics and their economic resources are low and they are more strongly exposed to violence (Fothergill and Squier 2018).

Prior to the Gorkha 2015 earthquake, the economic and social situation of children was already critical, not least because of the more than two decades lasting political and social conflicts, which led to high violence (Jha 2014). This critical situation was intensified by the earthquake. It can be well understood as part of disaster preparedness to provide better living conditions to children and take care of their mental health. In Nepal, few independent organizations successfully look after education and health care of children, in order to improve their economic situation and reduce emotional stress (EcoHimal Academy 2017; Paudel 2018; Plan International 2016; TPO Nepal 2017). In addition, governmental-supported, larger programs for general mental health care would be necessary. It remains to be seen if individual project approaches are successful in future (Jordans et al. 2015; Upadhaya et al. 2014).

Resilience towards catastrophes can also be created through a system of volunteering and a feeling of solidarity and can be increased by establishing a system of good governance, which reaches down to local levels (Rahaman 2018). Helpfulness and support within the population immediately after the Gorkha earthquake show that a basis for creating stronger resilience towards catastrophes is definitely present in Nepal (Brodmann Maeder and Pun 2018).

Generally, the necessity of resilience in society as a whole represents a strong argument for decentralization of Nepal on political, economic and social levels, which has been claimed emphatically (Hagen and Dixit 1998; Hagen 2012); since in the first instance resilience is created on a local level. Moreover, measures of reconstruction and future disaster preparedness are located best on local levels (Joshi and Joshi 2018). Mainly education in disaster preparedness is needed and should be clearly intensified (Tuladhar et al. 2015).

In addition to resilience and disaster preparedness created by the people through solidarity and support, politics should generate suitable boundary conditions for catastrophe resilience on regional and state level. As a consequence of the 1988 earthquake, a national policy framework for Disaster Risk Reduction and a country-wide building code were developed (Schneider and Witting 2018). However, implementation of disaster preparedness measures hanged heavily over many years. On the one hand, this is related to the fact that Nepal is one of the poorest countries worldwide and struggles with many types of catastrophes. On the other hand, implementation was hampered by the radical social and political changes and the instability of the last decades (Jha 2014), which blocked initiatives on all levels.

Independently of the question if society and government are able to install precaution measures, many impacts of an earthquake can be regarded as ‘unavoidable’. It appears appropriate to take such impacts as reason and occasion for a redistribution of resources and for ‘distributive justice’. It is a reasonable way of justice to balance the burden a society has to carry due to an earthquake (Meyer and Roser 2010; Meyer and Stelzer 2018).

This leads to the question how a country’s legislation or the entire legal system should be geared to large-scale and pervasive catastrophes. For mitigating disaster effects, ‘environmental’ and ‘earth justice’ have been suggested, which center around equality and ensure “fair treatment and some degree of protection” (Bhattarai 2018). With respect to disaster resilience of a society, it appears necessary specifically in countries with fragile political systems to establish a justice system that is oriented towards a fair sharing of burden and protection of underprivileged and, moreover, is stable enough to enforce the observance of these principles.

The situation of Nepal after the Gorkha 2015 earthquake, specifically in relation to the country’s constitution, the legal system and the role of the state, can be summarized as follows.

- Nepal can be proud of its new constitution. However, it has to be implemented and a ‘democratic setup’ is needed, as well as improvement in the field of rule of law. The Constitution of Nepal has unveiled an inclusive system, which needs to be implemented in practice. Inclusivity needs to be supported by vertical mode, i.e. federalism, and horizontal mode, i.e. a multi-party structure. The system should be self-regulatory.
- The new constitution also puts in place a federal system. It needs to be built from bottom to top; so the local level should be involved in the process as soon as possible. Unless self-rule and shared rule in the form of true federalism is established, risks of fragmentation of the country may surface. From this perspective farsightedness and more leadership is needed. Social super-groups currently bargain with the state.
- Accountability and transparency of all sectors have to be supported. This requires a strong judiciary—one, which is functional and one, which people can trust. Media and civil societies are just as necessary to ensure that the development efforts by the responsible bodies do not go unchecked.
- The Gorkha earthquake hit the country at time of enormous political transition. It brought to light the current status regarding the physical, social and economic conditions of the country. Disaster has stripped away the veil of the society. In general, the role of the state is important. However, the reconstruction approaches and efforts from the central government of Nepal

have been inadequate. Although the Constitution of Nepal declares rights of shelter and safe settlements as basic rights, the reality is different.

- The role of the state should be that of facilitating the processes of reconstruction and development by empowering the local bodies and communities and community-led grass-root approaches. Decentralization leading to empowerment of local administration is necessary along with concerted efforts from NGOs and INGOs. Earthquake preparedness has to be carried out in a scientific way with research conducted on various reconstruction issues. More earthquake-safer settlements are needed.
- The post-earthquake 'window of opportunity': It can mean doing as much as we can to prevent disaster risks. It also means developing safer and integrated settlements. It refers to fostering agents of change—'agents of change' being the youth dividend of the country who will, indeed, bring prosperity to the nation. Social nets have to be put in place, which helps smaller and vulnerable community-led grass-roots initiatives to overcome financial hurdles during the aftermath of a disaster. While 'window of opportunity' means implementation of constitutional laws, policies and impending bills, it also refers to giving an opportunity to planners and policy-makers to create safe, resilient and inclusive communities. Finally, 'window of opportunity' means transfer of knowledge and sharing lessons learnt through conferences like this one.

Based on a panel discussion at the Humboldt Kolleg "Living under Threat of Earthquake – Short- and long-term management of earthquake risk and damage prevention in Nepal", Kathmandu, February 2016, attended by Ananda Mohan Bhattarai – Chief Judge, Court of Appeal Nepal, Patan, now: Supreme Court of Nepal, Kathmandu, Nepal; Alice Fothergill – Department of Sociology, University of Vermont, USA; Matthias Meyer – Ambassador of the Federal Republic of Germany to the Federal Democratic Republic of Nepal, Kathmandu, Nepal; Ganesh Shah – former Minister for Science and Technology, Nepal; Inge Patsch – Volkshochschule (VHS), Bhaktapur, Nepal; Volker Schneider – Dean of Politics, Law and Economics Faculty, Universität Konstanz, Germany.
Prepared and edited by Barsha Chitrakar and Jörn H. Kruhl.

6 Conclusion and Perspectives

Independently of their causes, earthquakes are catastrophes that affect all parts of a society: the infrastructure of buildings, transport and communication; supply with goods; medical care; administrative and political structures; and not least the situation of generally underprivileged and vulnerable parts of the population, the social cohesian of the society and the society's feeling of security and a worth living future. Therefore, not only the consequences of earthquakes have to be examined integratively but also all precautionary measures for damage minimization. Such precaution cannot be solely related to earthquake-safer building and settlements, earthquake-safer restoration of damaged, above all culturally important buildings, and technical and medical aid in times of disaster. It should also comprise the design of political and administrative structures and the preparation of society in relation to possible large catastrophes.

It is important to be sensible of the connections between these aspects that appear strongly different at first sight. The view of the geoscientist to the social aspects, the engineer's understanding of the economic situation of the country, the physician's openness towards political contexts and administrative structures and, not least, the discussion between the different disciplines—all this is important. It is important for connecting the different specialist disciplines and supporting integrative approaches that are necessary for rebuilding and restructuring as well as for precaution for the next catastrophe. Only an integrating view and the combination of different activities will ensure a continuous resilience of the country and its population towards catastrophes.

Earthquakes, like other types of larger natural catastrophes, are always events with multi-facetted effects on all parts of a society and a country. Therefore, they should be looked at and studied from an inter- and intra-disciplinary viewpoint. This is specifically important with respect to the future approach of a society towards recurrent catastrophes. 'Disaster preparedness' has to be the central topic—preparedness of the society on all levels of technical and medical precaution, administration, politics and not least with respect to culture and social structure.

Nepal is amongst the poorest countries on Earth. However, the Gorkha 2015 earthquake—in spite of the huge difficulties to heal up its impacts—entails the chance of improving administrative and political structures and gaining realignment in all parts of state and society. Reconstruction should be oriented not only towards 'building back better' houses but also towards 'building back better' political, administrative and social structures.

The previous process of discussion after the earthquake in Nepal about the numerous problems of one's own making stirs up hope. These discussions are open and vivid in all parts of society and include the future orientation of the country. If the earthquake is considered as 'wake-up call', despite all the damage it can have positive effects into the future.

Acknowledgements The authors thank the Alexander von Humboldt Foundation for financial support, which enabled to hold an international conference (Humboldt Kolleg) in Kathmandu, February 2016, about the Gorkha 2015 earthquake. Our paper represents an outcome of this conference. JHK gratefully acknowledges funding by the German Academic Exchange Service (DAAD) for a teaching and research stay in Nepal from December 2015 to May 2016, which facilitated preparation of the conference.

References

Ahorn J, Lennartz T, Nüsser M (2015) Rapid urban growth and earthquake risk in Musikot, Mid-Western Hills, Nepal. Erdkunde 69(4):307–325

Arciniega-Ceballos A, Baena-Rivera M, Sánchez-Sesma FJ (2018) The 1985 (M8.1) Michoacán Earthquake and its effects in Mexico City. In: Kruhl JH, Adhikari R, Dorka UE (eds) Living under the Threat of Earthquakes—Short and Long-term Management of Earthquake Risks and Damage Prevention in Nepal, Springer, Berlin, p 65–75

Andrews JH (2001) Safe in the 'Hood'—earthquake preparedness in midcity Los Angeles. Nat Hazards Rev 2(1):2–11

Avouac J-P, Meng L, Wei S, Wang T, Ampuero J-A (2015) Lower edge of locked Main Himalayan Thrust unzipped by the 2015 Gorkha earthquake. Nat Geosci Lett 8:708–713. doi:10.1038/NGEO2518

Basnet SS, Bothara JK, Cardona C, Dixit AM, Dwelley L, Nakarmi M, Pradhanang SB, Tucker B, Villacis C (1999) Country report on seismic hazard and risk management in Kathmandu Valley, Nepal. Bull Int Inst Seismol Earthquake Eng 33:315–340

BBC (2015) Nepal earthquakes: devastation in maps and images. http://www.bbc.com/news/world-asia-32479909. Accessed 10 June 2017

Bhatt DP (2006) Ecotourism in Nepal. A Bhatt Publ, Kathmandu

Bhattarai AM (2018) Earthquake and earth justice: emergence of the environmental justice movement and its relevance in addressing unanticipated events. In: Kruhl JH, Adhikari R, Dorka UE (eds) Living under the Threat of Earthquakes—Short- and Long-term Management of Earthquake Risks and Damage Prevention in Nepal, Springer, Berlin, p 285–292

Bilham R (2009) The seismic future of cities. Bull Earthquake Eng 7:839–887. doi:10.1007/s10518-009-9147-0

Blinkert B (2010) Fear of crime and perceptions of security and insecurity in Europe. Monatsschr Kriminologie Strafrechtsreform 93(2):106–125

Breetzke GD, Pearson AL (2014) The feat factor: examining the spatial variability of recorded crime on the feat of crime. Appl Geogr 46:45–52

Bretschneider S, Kimms A (2012) Pattern-based evacuation planning for urban areas. Eur J Oper Res 216(1):57–69

Brodmann Maeder M, Pun M (2018) Medical aspects of the Gorkha earthquake 2015: disaster preparedness and response. In: Kruhl JH, Adhikari R, Dorka UE (eds) Living under the Threat of Earthquakes—Short and Long-term Management of Earthquake Risks and Damage Prevention in Nepal, Springer, Berlin, p 155–173

Chitrakar GR, Pandey MR (1986) Historical earthquakes of Nepal. Bull Geol Soc Nepal 4:7–8

CNN (2015) http://edition.cnn.com/2015/04/25/world/gallery/nepal-earthquake/index.html. Accessed 10 June 2017

Collins BD, Jibson RW (2015) Assessment of existing and potential landslide hazards resulting from the April 25, 2015 Gorkha, Nepal earthquake sequence. U.S. Geol Survey Open-File Rep 2015-1142, 50p. doi:10.3133/ofr20151142

Custódio S, Silveira G, Matias L, Mata I, Matos C, Palma-Oliveira JM, Rocha F, Lopes FC (2016) Educating for earthquake science and risk in a tectonically slowly deforming region. Seismol Res Lett 87(3):773–782. doi:10.1785/0220150239

Dahal RK (2015) Engineering geological issues after Gorkha earthquake 2015 in Nepal—a preliminary understanding. 10th Asian Regional Conference of IAEG

Dahal RK, Hasegawa S (2008) Representative rainfall thresholds for landslides in the Nepal Himalaya. Geomorphology 100:429–443

Dahal RK, Hasegawa S, Nonomura A, Yamanaka M, Dhakal S, Paudyal P (2008) Predictive modelling of rainfall-induced landslide hazard in the Lesser Himalaya of Nepal based on weights-of-evidence. Geomorphology 102:496–510

Dahal RK, Hasegawa S, Yamanaka M, Dhakal S, Bhandary NP, Yatabe R (2009) Comparative analysis of contributing parameters for rainfall-triggered landslides in the Lesser Himalaya of Nepal. Eviron Geol 58:567–586. doi:10.1007/s00254-008-1531-6

Daily Mail (2016) A list of some effects from Nepal's earthquake 1 year ago. http://www.dailymail.co.uk/wires/ap/article-3551129/A-list-effects-Nepals-earthquake-1-year-ago.html#ixzz4cPdln8Ej. Accessed 7 June 2017

Dhamala TN (2015) A survey on models and algorithms for discrete evacuation planning network problems. J Ind Manage Optim 11(1):265–289

Dhamala TN, Adhikari IM, Nath HN, Urmila Pyakurel, U (2018) Meaningfulness of OR models and solution strategies for emergency planning. In: Kruhl JH, Adhikari R, Dorka UE (eds) Living under the Threat of Earthquakes—Short and Long-term Management of Earthquake Risks and Damage Prevention in Nepal, Springer, Berlin, p 175–194

Dorka UE (2018) Can we prevent structural failure under earthquakes? In: Kruhl JH, Adhikari R, Dorka UE (eds) Living under the Threat of Earthquakes—Short and Long-term Management of Earthquake Risks and Damage Prevention in Nepal, Springer, Berlin, p 117–127

EcoHimal (2017) Handwerker-Training für den Wiederaufbau. http://www.ecohimal.org/index.php?id=145&L=1. Accessed 8 June 2017

EcoHimal Academy (2017) Children education scholarship programme. http://ecohimal.org.np/cesp/. Accessed 8 June 2017

Elliott JR, Jolivet R, González PJ, Avouac JP, Hollingsworth J, Searle MP, Stevens VL (2016) Himalayan megathrust geometry and relation to topography revealed by the Gorkha earthquake. Nat Geosci 9:174–180

Fothergill A, Squier E (2018) Women and children in the 2015 earthquake in Nepal. In: Kruhl JH, Adhikari R, Dorka UE (eds) Living under the Threat of Earthquakes—Short and Long-term Management of Earthquake Risks and Damage Prevention in Nepal, Springer, Berlin, p 253–271

Goerigk M, Deghdak K, Heßler P (2014) A comprehensive evacuation planning model and genetic solution algorithm. Transp Res Part E 71:82–97

Gallo F, Lavé J (2014) Evolution of a large landslide in the High Himalaya of central Nepal during the last half-century. Geomorphology 223:20–32

Gao M, Hao J (1999) Gu J (1999) Disaster preparedness and reduction and social sustained development in Japan. Recent Dev World Seismol 3:6–9

Gautam D, Prajapati J, Paterno KV, Bhetwal KK, Neupane P (2016) Disaster resilient vernacular housing technology in Nepal. Geoenviron Disasters 3(1):1–14. doi:10.1186/s40677-016-0036-y

Geli L, Bard P-Y, Jullien B (1988) The effect of topography on earthquake ground motion: a review and new results. Bull Seis Soc Am 78(1):42–63

Gerrard J (1994) The landslide hazard in the Himalayas: geological control and human action. Geomorphology 10:221–230

Ghale Y (2012) Nepalese women's empowerment by 2030. In: Sharma SR, Upreti BR, Pyakuryal K (eds) Nepal 2030: A Vision for Peaceful and Prosperous Nation, South Asia Regional Coordination Office of the Swiss National Centre of Competence in Research and Department of Development Studies, Kathmandu University, pp 111–125

Global Risk Forum Davos (2014) Integrative risk management—the role of science, technology & practice. Outcomes Report, Part 1—5th International Disaster and Risk Conference IDRC Davos 2014, pdf accessed from https://idrc.info/index.php?id=522 29 May 2017

Government of Nepal (2015) Nepal Tourism Statistics 2015. http://www.tourism.gov.np/images/download/Nepal_Tourism_Statistics_2015_forwebsite_edited1.pdf. Accessed 2 Jan 2017

Gunay Z (2018) A critical appraisal on Turkey's neoliberal quest of urban renewal in historic urban landscapes. In: Kruhl JH, Adhikari R, Dorka UE (eds) Living under the Threat of Earthquakes—Short and Long-term Management of Earthquake Risks and Damage Prevention in Nepal, Springer, Berlin, p 129–141

Guragain R, Shrestha SN, Maharjan DK, Pradhan S (2018) Lessons from building damage patterns during April 25, 2015 Gorkha Earthquake in Nepal. In: Kruhl JH, Adhikari R, Dorka UE (eds) Living under the Threat of Earthquakes—Short and Long-term Management of Earthquake Risks and Damage Prevention in Nepal, Springer, Berlin, p 79–93

Hagen T (1969) Report on the Geological Survey of Nepal, Volume 1—Preliminary Reconnaissance. Denkschriften der Schweizerischen Naturforschenden Gesellschaft LXXXVI/1, reprinted by Nepal Geological Society 2013

Hagen T (1998) Toni Hagen's Nepal—The Kingdom in the Himalaya, 4th edn. Himal Books, Lalitpur, Nepal

Hagen T (2012) Decentralization and Development. The Role of Democratic Principles. HimalAsia Foundation and RP Bhandar Publ, Kathmandu

Hagen T, Dixit KM (1998) Afterword. Hagen T (1998) Toni Hagen's Nepal—The Kingdom in the Himalaya, 4th edn. Himal Books, Lalitpur, Nepal, pp 239–245

Hasegawa S, Dahal RK, Yamanaka M, Bhandary NP, Yatabe R, Inagaki H (2009) Causes of large-scale landslides in the Lesser Himalaya of central Nepal. Environ Geol 57:1423–1434. doi:10.1007/s00254-008-1420-z

Hashash YMA, Tiwari B, Moss RES, Asimaki D, Clahan KB, Kieffer DS, Dreger DS, Macdonald A, Madugo CM, Mason HB, Pehlivan M, Rayamajhi D, Acharya I, Adhikari B (2015) Geotechnical field reconnaissance: Gorkha (Nepal) earthquake of April 25 2015 and related shaking sequence. Geotechnical Extreme Event Reconnaissance (GEER) Association Report No. GEER-040, Version 1.1. doi:10.18118/G61591, pdf accessed from http://geerassociation.org/reconnaissance-reports 7 June 2017

Jerry S (2016) History of Nepal. Sonit Education Academy, Abidjan

Jha P (2014) Battles of the New Republic—a Contemporary History of Nepal. Aleph Book Co., New Delhi

Jordans MJD, Luitel NP, Pokhrel P, Patel V (2015) Development and pilot testing of a mental healthcare plan in Nepal. Br J Psychiatry. doi:10.1192/bjp.bp.114.153718

Joshi GR, Joshi NB (2018) Economic loss from earthquake in Nepal and strategies for recovery and resilience building. In: Kruhl JH, Adhikari R, Dorka UE (eds) Living under the Threat of Earthquakes—Short and Long-term Management of Earthquake Risks and Damage Prevention in Nepal, Springer, Berlin, p 195–209

Kaiser A, Holden C, Beavan J, Beetham D, Benites R, Celentano A, Collett D, Cousins J, Cubrinovski M, Dellow G, Denys P, Fielding E, Fry B, Gerstenberger M, Langridge R, Massey C, Motagh M, Pondard N, McVerry G, Ristau J, Stirling M, Thomas J, Uma SR, Zhao J (2012) The Mw 6.2 Christchurch earthquake of February 2011: preliminary report. NZ J Geol Geophys 55(1):67–90. doi:10.1080/00288306.2011.641182

Kargel JS, Leonard GJ, Shugar DH, Haritashya UK, Bevington A, Fielding EJ, Fujita K, Geertsema, M, Miles ES, Steiner J, Anderson E, Bajracharya S, Bawden GW, Breashears DF, Byers A, Collins B, Dhital MR, Donnellan A, Evans TL, Geai ML, Glasscoe MT, Green D, Gurung DR, Heijenk R, Hilborn A, Hudnut K, Huyck C, Immerzeel,WW, Liming J, Jibson R, Kääb A, Khanal NR, Kirschbaum D, Kraaijenbrink PDA, Lamsal D, Shiyin L, Mingyang LV, McKinney D, Nahirnick NK, Zhuotong N, Ojha S, Olsenholler J, Painter TH, Pleasants M, KC P, Yuan Q, Raup BH, Regmi D, Rounce DR, Sakai A, Donghui S, Shea JM, Shrestha AB, Shukla A, Stumm D, van der Kooij M, Voss K, Xin W, Weihs B, Wolfe D, Lizong W, Xiaojun Y, Yoder MR, Young N (2016) Geomorphic and geologic controls of geohazards induced by Nepal's 2015 Gorkha earthquake. Science 351(6269). doi:10.1126/science.aac8353

Karki M, Bohara AK (2014) Evidence of earnings inequality based on caste in Nepal. Dev Econ 51(3):262–286

Kruhl JH (2018) Directions and avenues of geotourism—with particular view to Nepal. In: Kruhl JH, Adhikari R, Dorka UE (eds) Living under the Threat of Earthquakes—Short and Long-term Management of Earthquake Risks and Damage Prevention in Nepal, Springer, Berlin, p 229–250

KTM Post (2016) 18th National Earthquake Safety Day Special. Kathmandu Post, Saturday, 16 Jan 2016

Lacroix P (2016) Landslides triggered by the Gorkha earthquake in the Langtang valley, volumes and initiation processes. Earth Planet Space 68:46. doi:10.1186/s40623-016-0423-3

Lin Y-H, Batta R, Rogerson PA, Blatt A, Flanigan M (2011) A logistics model for emergency supply of critical items in the aftermath of a disaster. Socio-Econ Plann Sci 45:132–145
Maharjan M, Paudyal KR (2016) Gender perspective in flood risk management: a case study in Dodhara-Chandani areas of Kanchanpur district, far western Nepal. J Nepal Geol Soc 50:113–123
Manhart C (2018) Nepal cultural heritage earthquake rehabilitation. In: Kruhl JH, Adhikari R, Dorka UE (eds) Living under the Threat of Earthquakes—Short and Long-term Management of Earthquake Risks and Damage Prevention in Nepal, Springer, Berlin, p 95–99
Matsumoto T, Fujiwara A (2014) Advancing disaster preparedness in Okinawa Prefecture. Japan Geoscience Union Meeting 2014. http://www2.jpgu.org/meeting/2014/PDF2014/2014ALL_e.pdf. Accessed 14 June 2017
Meyer LH, Roser D (2010) Climate justice and historical emissions. Crit Rev Int Soc Political Philos 13:229–253
Meyer LH, Stelzer H (2018) Assessing policies of responding to the risk of earthquakes from a justice perspective. In: Kruhl JH, Adhikari R, Dorka UE (eds) Living under the Threat of Earthquakes—Short and Long-term Management of Earthquake Risks and Damage Prevention in Nepal, Springer, Berlin, p 293–302
Nathe SK (2000) Public education for earthquake hazards. Nat Hazards Rev 1(4):191–196
NDRI (2017) Poverty and vulnerability in four earthquake affected districts. Nepal Development Research Institute. http://www.ndri.org.np/projects.html. Accessed 8 June 2017
Nepal Census (2011) Nepal Census Info 2011 Dashboard. Central Bureau of Statistics. http://dataforall.org/dashboard/nepalcensus/. Accessed 11 June 2017
Nepal Central Bureau of Statistics (2017) 2015 Statistical Yearbook Nepal. Government of Nepal, Central Bureau of Statistics, 15th edn, 534p, pdf accessed from http://cbs.gov.np/, 5 June 2017
Newman A, Schneider J, Stein S, Mendez A (2001) Uncertainties in seismic hazard maps for the New Madrid seimic zone and implications for seismic hazard communication. Seism Res Lett 72(6):647–663
Parameswaran RM, Rajendran K (2017) Structural context of the 2015 pair of Nepal earthquakes (Mw 7.8 and Mw 7.3): an analysis based on slip distribution, aftershock growth, and static stress changes. Int J Earth Sci (Geol Rundsch) 106:1133–1146. doi:10.1007/s00531-016-1358-4
Paudel RC (2018) Emotional care in social work. In: Kruhl JH, Adhikari R, Dorka UE (eds) Living under the Threat of Earthquakes—Short and Long-term Management of Earthquake Risks and Damage Prevention in Nepal, Springer, Berlin, p 273–284
Petti L, Trillo C, Di Mauro M (2018) Heritage and reconstruction: different perspectives. In: Kruhl JH, Adhikari R, Dorka UE (eds) Living under the Threat of Earthquakes—Short and Long-term Management of Earthquake Risks and Damage Prevention in Nepal, Springer, Berlin, p 101–116
Plan International (2016) Nepal earthquake response. https://plan-international.org/publications/Nepal/One-Year-Report-Earthquake-Response, pdf. Accessed 18 June 2017
Puri R, Suvedi S (2018) Traditional buildings and preliminary report in construction methods to combat earthquake. In: Kruhl JH, Adhikari R, Dorka UE (eds) Living under the Threat of Earthquakes—Short and Long-term Management of Earthquake Risks and Damage Prevention in Nepal, Springer, Berlin, p 143–152
Rabindra Puri Foundation for Conservation (2017) http://www.rabindra.com.np/. Accessed 7 June 2017
Rahaman KR (2018) Social capital and good governance—a nexus for disaster management: lessons learned from Bangladesh. In: Kruhl JH, Adhikari R, Dorka UE (eds) Living under the Threat of Earthquakes—Short and Long-term Management of Earthquake Risks and Damage Prevention in Nepal, Springer, Berlin, p 211–228
Sakai T, Gajurel AP, Tabata H (2015) Seismites in the Pleistocene succession and recurrence period of large earthquakes in the Kathmandu Valley, Nepal. Geoenviron Disasters 2:25. doi:10.1186/s40677-015-0033-6
Schneider V, Witting A (2018) Earthquake preparedness policy in Nepal. In: Kruhl JH, Adhikari R, Dorka UE (eds) Living under the Threat of Earthquakes—Short and Long-term

Management of Earthquake Risks and Damage Prevention in Nepal, Springer, Berlin, p 303–326
Sharma P (2012) Tourism in Nepal 2030. In: Sharma SR, Upreti RB, Pyakuryal K (eds) Nepal 2030: A Vision for Peaceful and Prosperous Nation. South Asia Regional Coordination Office of the Swiss National Centre of Competence in Research and Department of Development Studies, Kathmandu University, pp 73–92
Shibayama M, Muslim D, Kagawa N (2012) Earthquake and tsunami disasters prevention education for children in Indonesia. 34th International Geological Congress, Abstracts:768
Shrestha AB, Bajracharya SR, Kargel JS, Khanal NR (2016) The impact of Nepal's 2015 Gorkha earthquake-induced geohazards. International Centre for Integrated Mountain Development (ICIMOD), Research Report 2016/1
Stein S, Geller RJ, Liu M (2012) Why earthquake hazard maps often fail and what to do about it. Tectonophysics 562–563:1–25
Stein S, Brooks EM, Spencer BD, Liu M (2018) Should all of Nepal be treated as having the same earthquake hazard? In: Kruhl JH, Adhikari R, Dorka UE (eds) Living under the Threat of Earthquakes—Short and Long-term Management of Earthquake Risks and Damage Prevention in Nepal, Springer, Berlin, p 27–44
Stein J, Stein S (2012) Rebuilding Tohoku: a joint geophysical and economic framework for hazard mitigation. GSA Today 22(10):42–44
Stein S, Stein J (2013) How good do natural hazard assessments need to be? GSA Today 23(4/5). doi:10.1130/GASTG167GW.1
Thapa PB (2018) Analysis of landslides triggered by the 2015 Gorkha Earthquake, Nepal. In: Kruhl JH, Adhikari R, Dorka UE (eds) Living under the Threat of Earthquakes—Short and Long-term Management of Earthquake Risks and Damage Prevention in Nepal, Springer, Berlin, p 45–63
Timilsina M, Bhandary NP, Dahal RK, Yatabe R (2014) Distribution probability of large-scale landslides in central Nepal. Geomorphology 226:236–248
TPO Nepal (2017) Transcultural Psychosocial Organization Nepal. http://tponepal.org/. Accessed 8 June 2017
Transparency International (2017) Corruption perceptions index 2016. https://www.transparency.org/news/feature/corruption_perceptions_index_2016#table. Accessed 11 June 2017
Tuladhar G, Yatabe R, Dahal RK, Bhandary NP (2015) Disaster risk reduction knowledge of local people in Nepal. Geoenviron Disasters 2:5. doi:10.1186/s40677-014-0011-4
Upadhaya N, Luitel NP, Koirala S, Adhikari RP, Gurung D, Shrestha P, Tol WA, Kohrt BA, Jordans MJD (2014) The role of mental health and psychosocial support non-governmental organizations: reflections from post conflict Nepal. Intervention 12(Supplement 1):113–128
UNDP (2016) Human development report 2016. United Nations Development Programme. http://hdr.undp.org/sites/default/files/2016_human_development_report.pdf. Accessed 11 June 2017
UNESCO (2016) State of conservation of properties inscribed on the World Heritage List. UNESCO World Heritage Committee, 14th session, Istanbul, Turkey, July 10–20, 2016. http://whc.unesco.org/archive/2016/whc16-40com-7BAdd-en.pdf . Accessed 12 June 2017
US Geological Survey (USGS) (2017a) Global earthquakes 1900–2013. ftp://hazards.cr.usgs.gov/web/learn/worldseis.pdf. Accessed 11 June 2017
US Geological Survey (USGS) (2017b) https://earthquake.usgs.gov/earthquakes/map/ . Accessed 2 June 2017
von Einsiedel S, Malone DM, Pradhan S (eds) (2012) Nepal in Transition: From People's War to Fragile Peace. Cambridge University Press, Cambridge
Wang K, Rogers GC (2017) Beating fear with hope: on sustaining earthquake preparedness. Seismol Res Lett 88(1):171–176. doi:10.1785/0220160106
WTTC (2015) Travel and tourism economic impact 2015 Nepal. World Travel and Tourism Council, London, 24p, https://www.wttc.org/-/media/files/reports/economic%20impact%20research/countries%202015/nepal2015.pdf. Accessed 5 June 2017

Part I
Earthquakes and Related Hazards

Should All of Nepal Be Treated as Having the Same Earthquake Hazard?

Seth Stein, Edward M. Brooks, Bruce D. Spencer and Mian Liu

Abstract Current earthquake hazard maps for Nepal predict substantial variations in hazard within the nation, with noticeable differences between maps. We thus suggest that given present knowledge, all of Nepal may be better regarded as equally hazardous and perhaps vulnerable to much larger earthquakes than those currently known because of their long recurrence times. This proposal is based on the limitations of the historical earthquake record, the recognized deficit in seismic moment release, and GPS data showing a similar level of coupling along the arc. Support for using smoother maps can be had from analysis for Japan, which is also located on and parallel to a subduction boundary, showing that in some ways the hazard maps may be overparameterized, in that including too high a level of detail may lower the maps' ability to predict shaking. Treating Nepal's hazard as uniform and developing mitigation strategies accordingly may help reduce damage in future earthquakes.

Keywords Nepal · Earthquake hazard · Hazard mitigation

S. Stein (✉) · E.M. Brooks
Department of Earth and Planetary Sciences and Institute for Policy Research, Northwestern University, Evanston, IL, USA
e-mail: seth@earth.northwestern.edu

E.M. Brooks
e-mail: emb.earth@gmail.com

B.D. Spencer
Department of Statistics and Institute for Policy Research, Northwestern University, Evanston, IL, USA
e-mail: bspencer@northwestern.edu

M. Liu
Department of Geological Sciences, University of Missouri, Columbia, MO, USA
e-mail: lium@missouri.edu

J.H. Kruhl et al. (eds.), *Living Under the Threat of Earthquakes*,
Springer Natural Hazards, https://doi.org/10.1007/978-3-319-68044-6_2

1 Introduction

In February 2016, the Alexander von Humboldt Foundation organized a conference in Kathmandu on the topic of "Living under the threat of earthquakes: Short- and long-term management of earthquake risk and damage prevention in Nepal." The conference sought to explore "future ways of perceiving risk, prevention of damage, and disaster management in all parts of society, administration, and politics in Nepal."

Like many nations seriously threatened by earthquakes, Nepal is a developing nation in a seismically active plate boundary zone. It faces a major seismic hazard with severely limited resources available to mitigate it.

The steady subduction of the Indian plate beneath Eurasia has raised the Himalayas, Nepal's primary asset. However, the subduction gives rise to major earthquakes. The conference occurred almost a year after the April 2015 M_w 7.8 Ghorka earthquake caused nearly 9000 deaths and damaged many buildings, including about 500,000 residences, temples and palaces forming part of a UNESCO World Heritage site, schools, and many public facilities. Damage is estimated at about 1/3 of Nepal's GDP (Government of Nepal 2015). This enormous impact reflected the fact that Nepal is one of the poorest nations in Asia, with per capita GDP of about $750—derived largely from tourism, agriculture, and remittances from Nepalese working in other countries.

Based on studies prior to and after the Ghorka earthquake (Bilham et al. 2001; Bilham and Ambraseys 2005; Ader et al. 2012; Martin et al. 2015; Hayes et al. 2015), the 2015 earthquake was much smaller and caused much less intense shaking than larger earthquakes that occurred in the past and are expected to occur in the future. Hence existing earthquake hazard maps used to develop construction codes may substantially underestimate the future hazard. Moreover, much of the damage and deaths in 2015 reflected poorly constructed buildings, and similar buildings will perform even more poorly in future larger earthquakes (Goda et al. 2015).

Current earthquake hazard maps for Nepal predict substantial variations in hazard within the nation, with noticeable differences between maps, indicating substantial uncertainty in hazard estimates. This is not surprising given the limitations of the historical record in Nepal and the lack of knowledge of how strain from plate convergence is released in earthquakes. This paper explores the question of whether, given these uncertainties, all of the nation might be better regarded as equally hazardous and perhaps vulnerable to much larger earthquakes than those currently known, with long recurrence times. The paper is not a comprehensive review of data and previous work for Nepal, but merely notes some issues and suggests an approach that we think is worth considering.

2 Current Hazard Maps

Figure 1 shows three hazard maps for Nepal, all of which predict the shaking expected with 10% probability of being exceeded during 50 years, or on average once in 475 years. The predicted hazard varies from west to east, along the subduction zone.

The map predictions differ in both the level of detail and in some specifics. In particular, the GSHAP (1999) and Ram and Guoxin (2013) maps both show the center of the country, near 84°E longitude, the area of Pokhara, Nepal's second largest city, as having lower hazard than areas to the east and west. In contrast, Chaulagain et al. (2015) show this area as having higher hazard than its surroundings.

These differences reflect different choices among the many parameters required to develop a hazard map. Hazard maps require a wide range of assumptions about earthquake source locations, recurrence, and magnitudes, along with models of the resulting ground motion. As has been observed elsewhere, different plausible assumptions about key parameters yield quite different hazard maps (Newman et al. 2001).

Research is ongoing to address these issues. At present, however, given the differences between maps, two approaches could be taken. One is to try to decide which assumptions to prefer, and adopt the resulting map as preferable. Another is

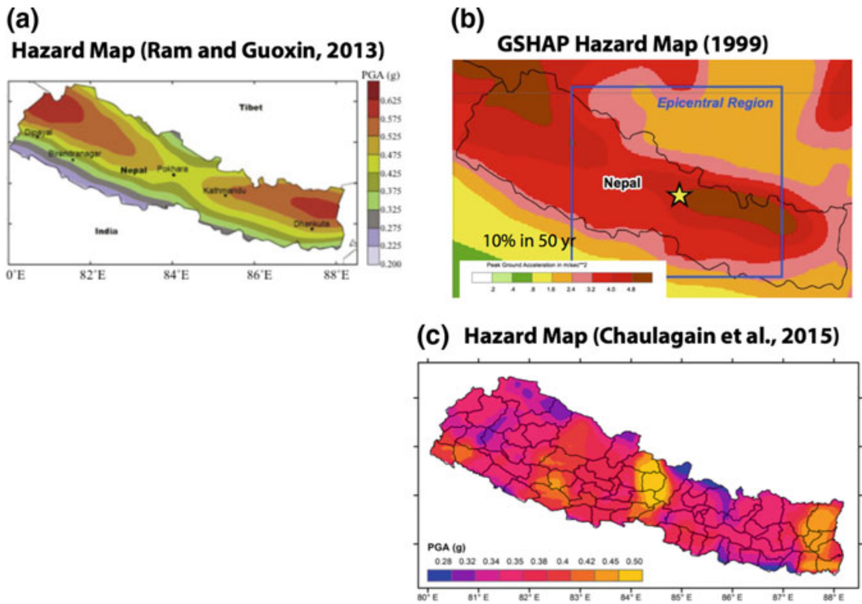


Fig. 1 Three earthquake hazard maps for Nepal: **a** Ram and Guoxin (2013), **b** GSHAP (1999), and **c** Chaulagain et al. (2015) that differ in both the level of detail and in some specifics

to assume that key parameters are sufficiently uncertain that making a smoother map, with less detail, may be more useful for predicting the future earthquake hazard.

The second approach, which we explore here, is to assume that including too high a level of detail to describe past or future earthquakes may lower hazard maps' ability to predict future shaking. As we will see, there is considerable uncertainty in Nepal's earthquake history, and a good case can be made that earthquakes much larger than those assumed in the map development may occur. Hence what is known—or assumed to be known—from previous earthquakes may not completely show what will happen in the future.

3 How Detailed Should Hazard Maps Be?

Because earthquake hazard maps are forecasts, we can get insight from other forecasting applications. Forecasting something involves starting with a conceptual model of the process, implementing it—usually on a computer—to produce a forecast, and then comparing the forecast to what actually happens. Assessing how well this works involves looking at both stages, via operations called verification and validation. Verification asks how well the algorithm used to produce the forecast implements the conceptual model ("have we built the model right?"). Validation asks how well the model forecasts what actually occurs ("have we built the right model?").

Our focus here is on a validation issue: improved maps to forecast future shaking. The classic resolution-stability tradeoff (Parker 1977) tells us that more detailed a model is, the more sensitive it is to uncertainty, and thus the more likely it is to perform worse when assumptions fail. Hence the challenge is to seek an optimal level of detail.

This phenomenon arises in many applications and termed "overfitting" or "overparameterization." For example, given a set of observations at k distinct points in time, one can perfectly fit them with a curve described by k parameters, such as a polynomial of degree $k - 1$. However, a perfect fit to past data need not yield a good forecast—a good fit to future data. Figure 2 shows an example of using a model derived from past data to predict the future evolution of a function. A linear model fits the past data and predicts the future reasonably well, and a quadratic does both even better. However, an 8th order polynomial that fits the past data perfectly does a poor job of predicting the future. The more detailed model seems like it should be better because it matches the past so well, but imposing that level of detail makes the forecast worse.

This situation is common in both geophysical and other forecasting applications. Hence to forecast the future, the goal should be not to build the most detailed model, but instead one that is robust or stable in the sense that small changes in the uncertain model parameters do not dramatically change the model's forecasts (Parker 1977; Box 1979).

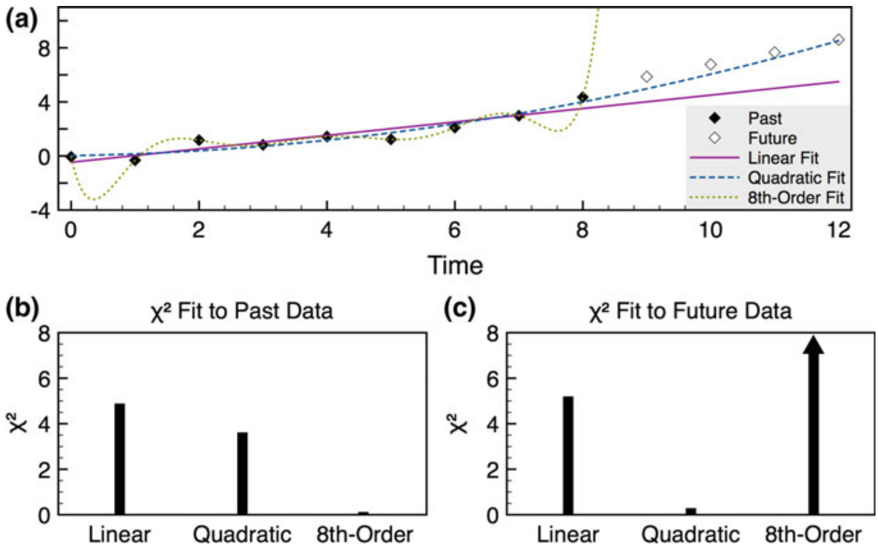


Fig. 2 Example of the effect of overparameterization on forecasting. A high order polynomial fits past data better than linear or quadratic models, but this more detailed model predicts the future worse than the simpler models (Brooks et al. 2016a)

In a hazard map application, one can think conceptually of the past data as containing both a "signal" of a long-term pattern of seismicity and shaking, and additional "noise", where the latter includes both details of past events that will not be repeated and errors due to inaccurate assumptions about what actually occurred. The more detailed a model we make, the more it is influenced by the noise, and, beyond some level of detail, the less likely it is to forecast the future well.

4 Hazard Map Uncertainties for Nepal

The limitations of available data pose limit how accurate an earthquake hazard map can be (e.g., Stein et al. 2012; Stein and Friedrich 2014). For Nepal, at least three issues are crucial:

(1) **The locations and magnitudes of major past earthquakes are not well known**. Figure 3 (Hayes et al. 2015) compares three different scenarios for the rupture length of major historical earthquakes from Kumar et al. (2006, 2010), Mugnier et al. (2013), and Bollinger et al. (2004, 2014). Solid rectangles show the overlap between scenarios, and dashes represent the disagreement between them, which can be taken as a measure of the present uncertainty. In general terms, longer ruptures would have corresponded to larger magnitudes, greater slip, and longer duration and higher intensity of shaking. Similarly, longer

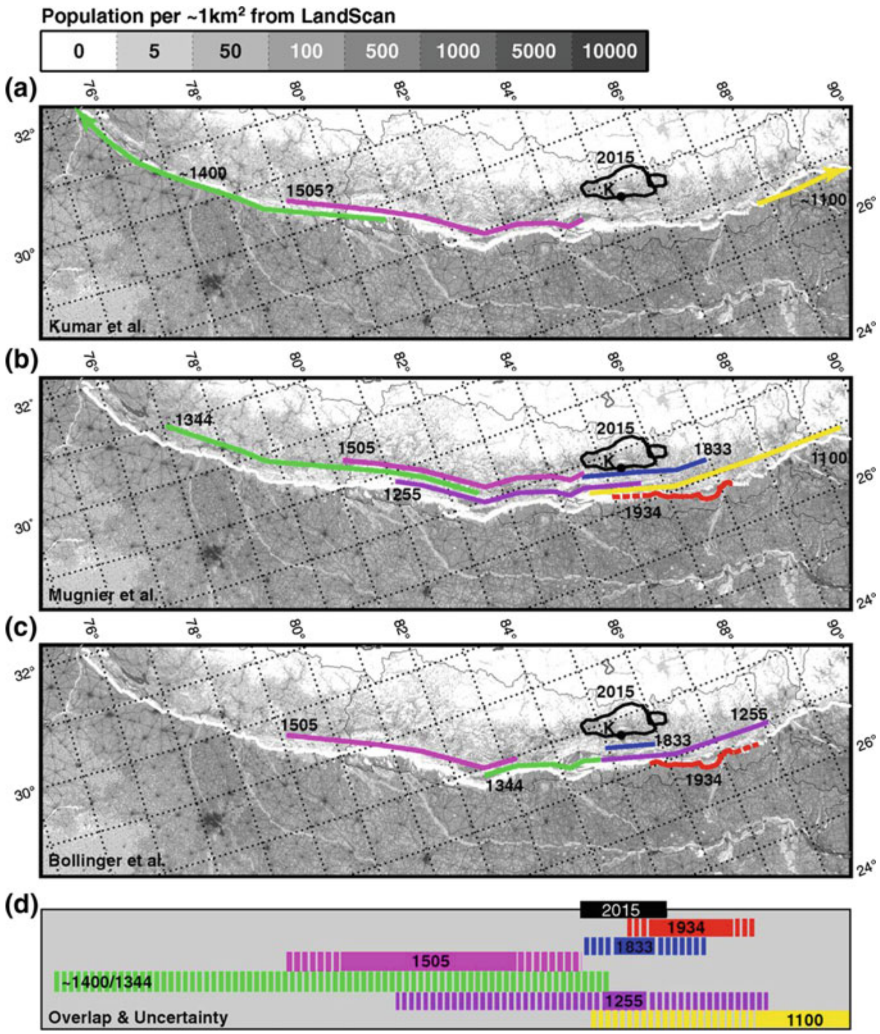


Fig. 3 Source region of the 2015 earthquake (*black polygon*, *K* Kathmandu) compared with published scenarios for rupture in earlier major earthquakes (*colored solid lines*). The back-ground image in shows population density. *Solid lines* show where estimated rupture areas for a given earthquake overlap, dashes represent disagreement (Hayes et al. 2015)

ruptures place more locations closer to the fault, and thus exposed to stronger shaking. For example, the central area west of the 2015 earthquake rupture would have been much more strongly shaken for some scenarios of the 1255 and 1505 earthquakes than for others. Thus the locations and magnitudes of future large earthquakes—and the resulting shaking—are difficult to reliably infer, even if future earthquakes were similar to past ones, which need not be the case.

(2) **A seismic moment deficit suggests that earthquakes much larger than observed in the past few hundred years may occur.** Bilham et al. (2001) noted that the inferred seismic moment release over the past few hundred year is substantially less than would be expected from the geodetically observed convergence rate across the Himalayan front, suggesting a moment release deficit that may be made up in future earthquakes larger than known to date (Fig. 4). This view is supported by subsequent analyses (Bilham and Ambraseys 2005; Ader et al. 2012; Stevens and Avouac 2016) and is being explored by paleoseismic studies that are developing a much longer time series and thus better estimates of long-term seismic slip rates (Kumar et al. 2006, 2010; Mugnier et al. 2013; Bollinger et al. 2014).

(3) **GPS data for Nepal are consistent with future great earthquakes**. These data (Fig. 5) show no significant variation in coupling along the arc, defined as the fraction of plate convergence accumulated as slip deficit. Though compiled before the 2015 earthquake, the area that ruptured in that earthquake does not show stronger coupling. In contrast, at oceanic subduction zones, GPS data show variations in coupling, and stronger coupling often indicates the locations of future large earthquakes (Moreno et al. 2010; Loveless and Meade 2011; Protti et al. 2014). The difference in coupling patterns between Nepal and

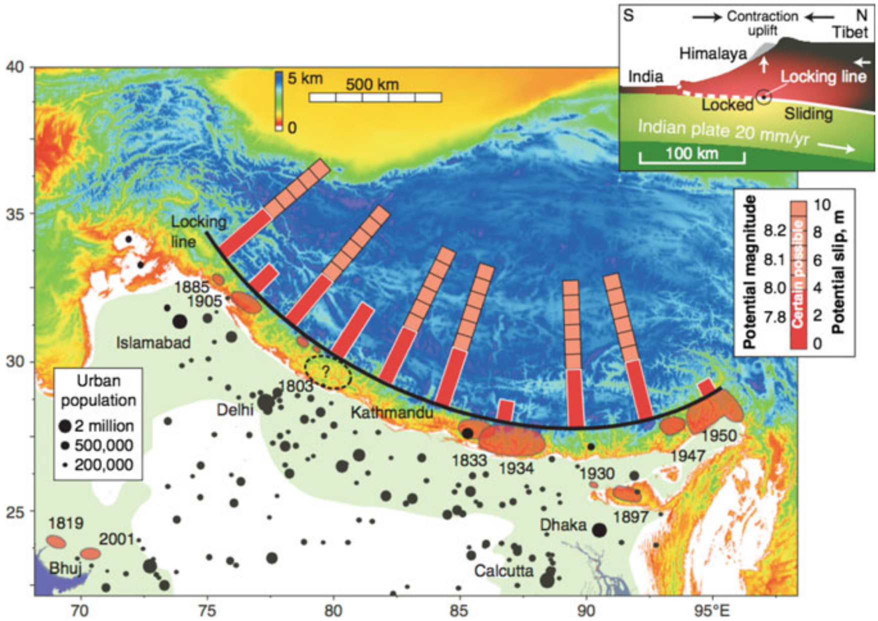


Fig. 4 Estimated potential for slip in future earthquakes along the Himalaya. *Red segments of bars* show the potential slip that accumulated since the last recorded great earthquake, or since 1800. The *pink portions* show possible additional slip permitted by the limited historic record (Bilham et al. 2001)

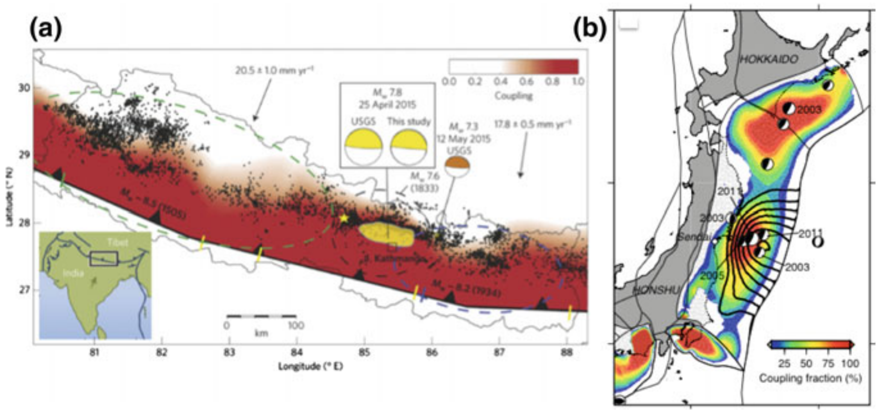


Fig. 5 **a** Coupling fraction across Nepal, showing no significant variation along the arc, including the area of the 2015 earthquake (Avouac et al. 2015) **b** Coupling along northern Japan prior to the March 2011 Tohoku-oki earthquake (*colors*), and coseismic slip in this earthquake (*contours*). The ~400 km-long region estimated to have slipped ≥ 4 m corresponds to an area of the subduction zone interface that was coupled at $\geq 30\%$ of the plate convergence rate, with peak slip near a region coupled $\geq 80\%$ (Loveless and Meade 2011)

> oceanic subduction zones could reflect a difference between continental and oceanic subduction, or some aspect of the data and analysis. Alternatively, it might indicate that the entire arc is strongly coupled and could rupture in an earthquake or earthquakes much larger than observed to date, releasing the accumulated moment deficit.

The possibility of much larger earthquakes, which would rupture larger areas along the subduction zone, favors treating the seismic hazard as uniform along the zone, given our limited knowledge. This amounts to saying that because the entire country is in a similar tectonic situation, the hazard might well be viewed as uniform.

5 Insights from Japan

Although the issues just discussed suggest that smoother—possibly uniform—hazard maps may be better for Nepal, we presently lack a long enough record of shaking observations to explore this possibility qualitatively. However, this possibility is also suggested by analyses we conducted for Japan, which is also located on and parallel to a subduction boundary (Fig. 6). For Japan, we have the advantage that a 510-year-long record has been compiled (Miyazawa and Mori 2009), giving the largest known shaking on the Japan Meteorological Agency (JMA) instrumental intensity scale at points within Japan from 1498 to 2007. Hence we compared these observations to both the Japanese national hazard maps and smoother versions of these maps (Brooks et al. 2016a, b).

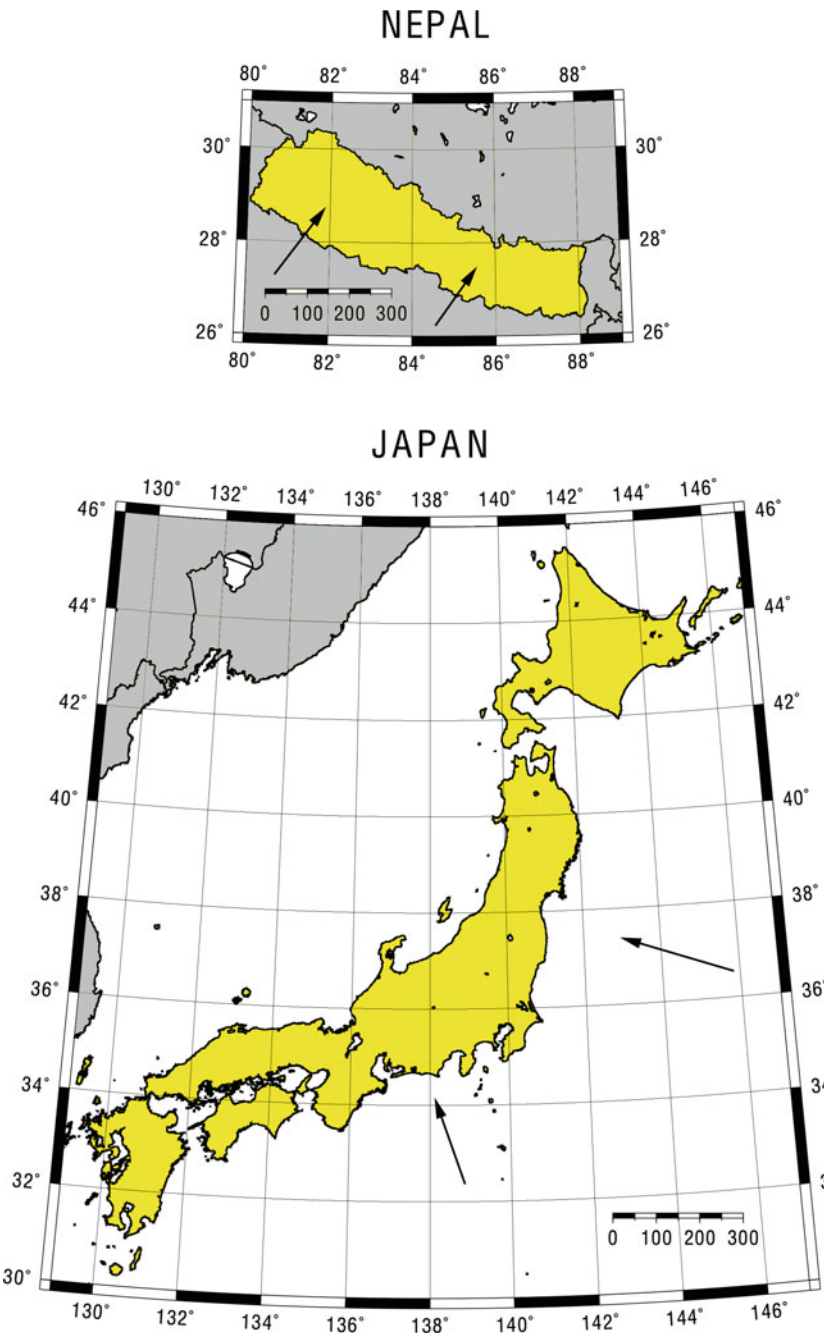


Fig. 6 Comparison of the geometry of Nepal and Japan, both of which are located on and parallel to a subduction boundary, making models of uniform hazard within them worth considering

6 Methodology

Our approach was based on similar issues in weather forecasting. Weather forecasts are routinely evaluated to assess how well their predictions matched what actually occurred. A key part of this assessment is adopting agreed metrics for "good" forecasts, so forecasters can assess how well different forecasts performed. Over the years, this process has improved forecasting methods and results, and yielded much better assessment of uncertainties.

Figure 7 shows an example, comparing the predictions of two models for the probability of rain at some place to the fraction of the time it actually rained. The National Weather Service forecasts are pretty accurate. However, a local television station's forecasts are less accurate, because they predict rain more often than actually occurs. Knowing how a forecast performs is useful: the better it has worked to date, the more we factor it into our daily plans.

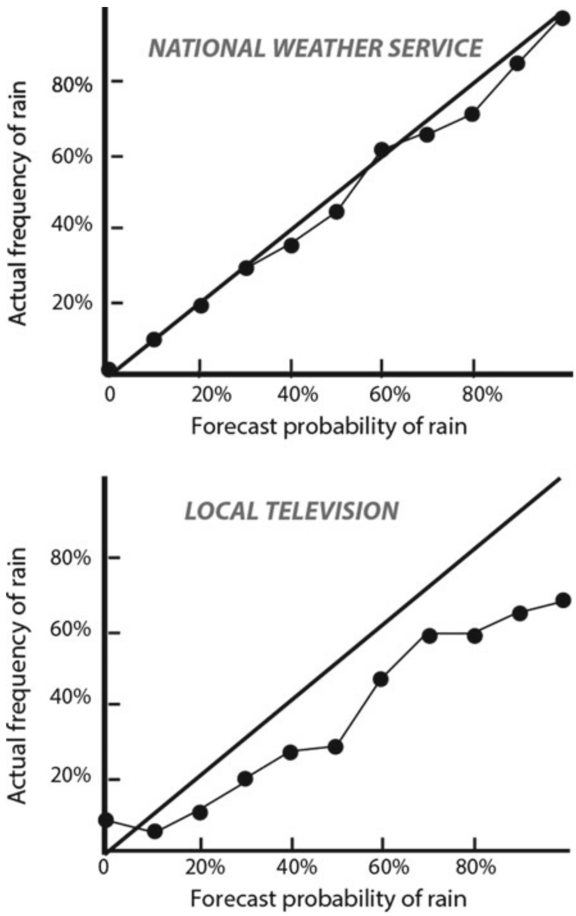


Fig. 7 Comparison of the predicted probability of rain to that actually observed in National Weather Service and a local television station's forecasts (Stein et al. 2015, after Silver 2012)

Similar analysis can be done for earthquake hazard maps, with two differences. One is that rainstorms happen often, so the predicted and observed frequency of rain at one place can be compared directly. However, large earthquakes are infrequent, so most places will not have experienced major shaking. To get around this, we can compare the maximum observed shaking over years of observations at many sites on the map to the predicted shaking at those sites (Ward 1995).

The second difference is that we can use several measures, or metrics, to assess how well a map performed. This is because the predictions of most seismic hazard maps are given in terms of probabilities. Maps are made for a return period of T years, and the value shown at a point on a map is a level of shaking which, during t years of observations, has a probability p of being exceeded once. T, t, and p are related by $p = 1 - \exp(-t/T)$ (Field 2010). This equation (Fig. 8a) shows that a map with a 475-year return period gives the level of shaking that should be exceeded at 10% of the sites in 50 years and at 63% of the sites in 475 years. Plots like Fig. 8b, c shows at which sites shaking exceeded the mapped value, which are the ones above the 45° line along which the observed and predicted shaking are equal.

The most direct way to assess how well a map is doing is using the fractional exceedance metric $M0 = |f - p|$, where p is the predicted fraction of sites where shaking is higher than the mapped value, and f is the actual fraction of such sites. If f is close to p, $M0$ is small, and by this metric the map did well. $M0$ measures how well a probabilistic map does what it's supposed to do. However, this measure doesn't consider the size of the differences between the observed and predicted shaking, which is also important. To see this, consider two different hazard maps.

In Fig. 8b, the predicted and observed fractions p and f are both 10%, so $M0 = 0$ and the map is perfect by this metric. However, many points are far from the 45° line, which is bad. Points far above the 45° line show underpredicted shaking, that would have exposed buildings to major damage. Points far below the 45° line show overpredicted shaking, that would have caused structures to be overdesigned and thus wasted resources. Viewed this way, the map did poorly.

Conversely, in Fig. 8c, the predicted and observed fractions are 10% and 20%, so $M0 = 0.1$, showing that by this metric the map didn't do well. However, most points are close to the 45° line, so the maximum actual shaking generally plots close to that predicted—which is good. The shaking wasn't significantly underpredicted or overpredicted, so in this sense the map did well.

How close points are to the 45° line is described by the squared misfit metric, $M1$, which measures the difference between the predicted and observed shaking, summed over all the sites. The map in Fig. 8b does well as measured by the $M0$ metric and poorly by the $M1$ metric, whereas that in Fig. 8c does poorly by the $M0$ metric and well by $M1$. Each metric measures different aspects of a map's performance. $M1$ measures something the hazard map isn't designed to do, but is like a visual comparison of a hazard map to the shaking that occurred (e.g., Geller 2011).

Using several metrics to measure hazard map performance makes sense. In general, assessing any system's performance involves looking at multiple aspects. This concept is familiar in sports, where players are evaluated in different ways. For

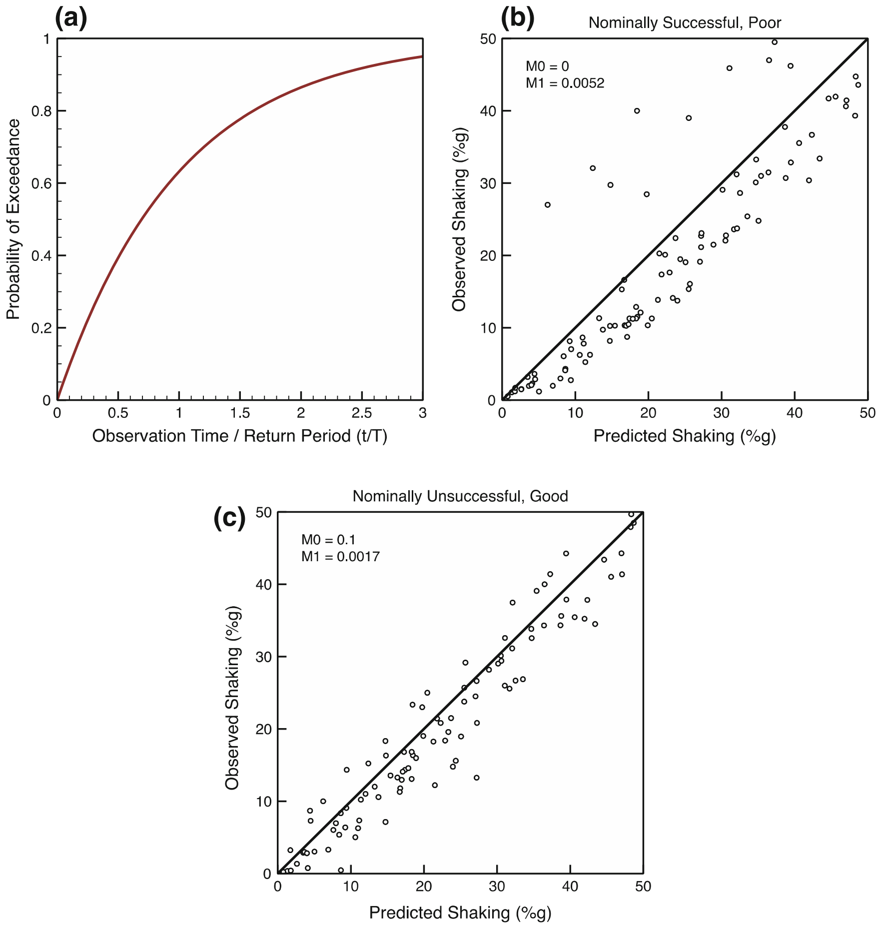


Fig. 8 **a** Assumed probability *p* that during a *t*-year-long observation period, shaking at a site will exceed a value that is expected on average once in a *T*-year return period. **b**–**c** Comparison of the results of two hazard maps. That in **b** is nominally successful as measured by the fractional exceedance metric, but significantly underpredicts the shaking at many sites and overpredicts that at others. That in **c** is nominally unsuccessful as measured by the fractional site exceedance metric, but better predicts the shaking at most sites (Stein et al. 2015)

example, how good a baseball player Babe Ruth was depends on the metric used. In many seasons Ruth led the league in both home runs and in the number of times he struck out. By one metric he did very well, and by another, very poorly. Similarly, a baseball player may be an average hitter, but valuable to a team because he is an outstanding fielder.

The short time period since hazard maps began to be made poses a challenge for assessing how well they work. If, during the 10 years after a 10%-in-50-yrs map was made, large earthquakes produced shaking at 40% of the sites that exceeded the predicted values, the map may not be performing well. However, if no higher shaking occurred at these sites in the subsequent 465 years, the map would be performing as designed. Given this problem, various studies examine how well maps describe past shaking. Although looking backwards in time—hindcasting—is not the same as evaluating a forecast with observations after the forecast was made, it gives useful insight.

7 Results

Using this approach, we compared the 510-year-long record of earthquake shaking to both the Japanese national hazard map (JNH) and smoother versions (Fig. 9). The smoothest version is a uniform hazard map with hazard at all sites set equal to the median of the JNH map. Using the misfit metric $M1$, the JNH map did better than

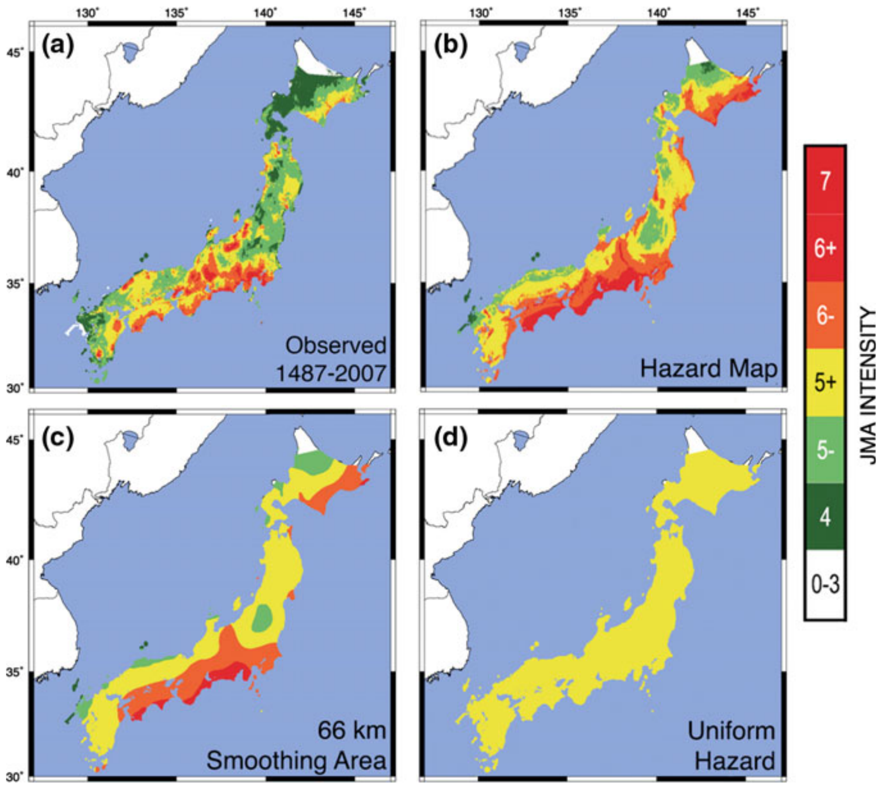


Fig. 9 **a** Map of largest known shaking on the Japan Meteorological Agency intensity scale in 510 years (Miyazawa and Mori 2009). **b** Probabilistic seismic hazard map for 975 year return period (J-SHIS 2015) **c** Smoothed hazard map derived by smoothing **b** over 66-km window (Brooks et al. 2016a). **d** Uniform hazard map derived by smoothing **b** over all of Japan (Brooks et al. 2016b)

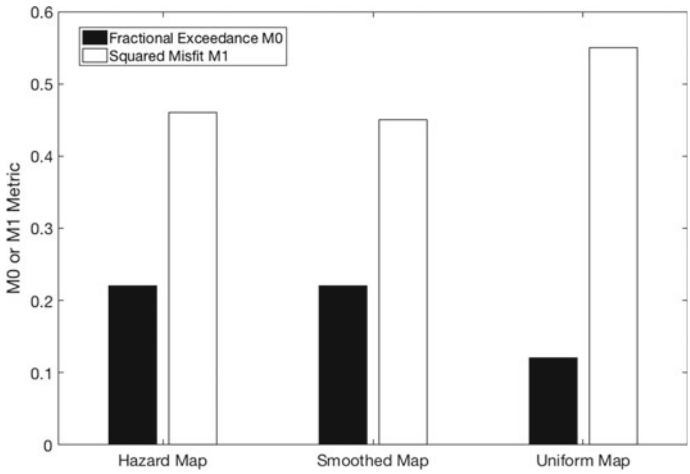


Fig. 10 Performance of the three hazard maps for Japan shown in Fig. 9, as measured by the fractional exceedance metric M0 and squared misfit metric, M1

the uniform map (Fig. 10). This is because *M*1 depends mostly on similar the patterns are in space, which is what we see when we compare two maps. However, as measured by the *M*0 metric, the uniform hazard map did better. This is because *M*0 depends mostly on how similar the average predicted and observed shaking levels are, and it turns out that the maps systematically overpredicted the observed shaking.

The uniform map averages over the whole country, so all the details are lost. An intermediate approach is to smooth the hazard map over different areas, which removes some but not all detail. The fractional exceedance metric *M*0 generally improved as the smoothing area increases, consistent with the observation that smoothing over all of Japan produced uniform maps that performed better than the JNH map as measured by *M*0. As measured by the *M*1 metric, map performance improved somewhat up to about 50–100 km of smoothing and then decreased substantially with further smoothing.

The observation that different maps do better by one metric and worse by another reflects the fact that a map's performance has multiple aspects, and so using several metrics to measure it makes sense. M0 is more sensitive to average shaking levels, whereas M1 is more sensitive to spatial variations. It seems that although the JNH maps are designed to predict shaking levels that should be exceeded at a certain fraction of the sites, the process by which their parameters are chosen tends to make the mapped shaking more closely resemble the maximum observed.

Our point is not that the Japan results would directly apply for Nepal. These results are for a particular area and for a particular set of maps and data. Rather, we think they indicate the value of doing similar analyses for Nepal. For this purpose, a long historical shaking dataset would be very valuable. We suspect that the results would favor smoother maps and—especially for longer return periods—higher hazard levels.

8 Implications for Hazard Mitigation

The goal of hazard maps is to reduce losses in future earthquakes via choosing an appropriate level of hazard mitigation, primarily via earthquake-resistant construction. The total cost of earthquakes to a community is the sum of the expected loss in future disasters and the cost of mitigation. Conceptually, estimating the loss depends on the estimated hazard, because the expected loss is the sum of the loss in individual future earthquakes multiplied assumed probability. A probabilistic hazard map includes this information in the shaking levels it predicts with different probabilities.

The total cost to a community of earthquakes depends on the amount of mitigation, shown schematically by the U-shaped curve in Fig. 11. If a community undertakes no mitigation, it has no mitigation costs (left side of the curve) but will expect high losses—so it makes sense to invest more in mitigation. Increased mitigation should decrease losses, so the curve goes down. Eventually, however, the cost of more mitigation exceeds the reduction in losses, and the curve rises again—the additional resources required would do more good if invested otherwise. The optimum amount of mitigation is the “sweet spot” at the bottom of the curve.

Such graphs are schematic ways to guide our thinking, rather than precisely computed equations, for two major reasons. First, there are large uncertainties in our ability to assess the earthquake hazard—our focus here—and the resulting losses. As shown in Fig. 12, inaccurate hazard and loss (damage) estimates would produce nonoptimal mitigation. Thus it would be unrealistic to claim we can actually find a single optimum strategy. Moreover, even without these uncertainties, mitigation is unlikely to be less than optimal because of limited resources and other societal needs for these resources. This is true even for developed nations, and

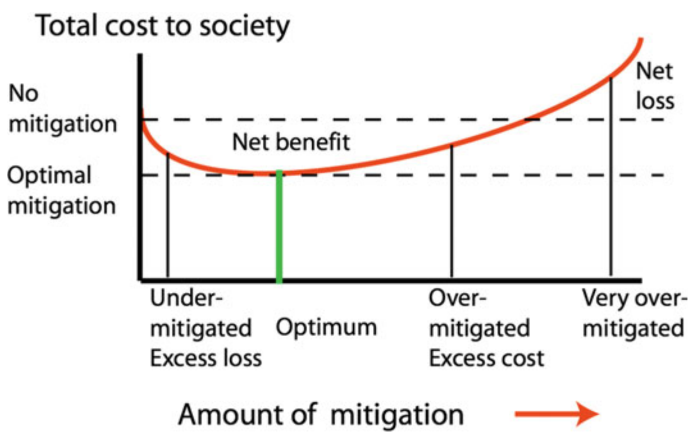


Fig. 11 Curve showing how the total cost to society of earthquakes depends on the amount of mitigation. The optimal mitigation level minimizes the total cost, the sum of the expected loss and the mitigation cost (Stein and Stein 2012)

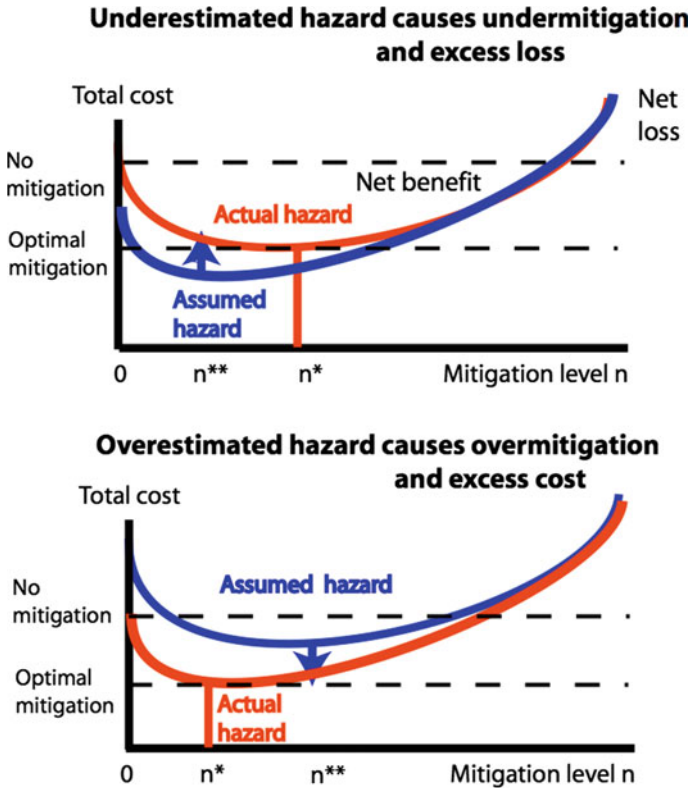


Fig. 12 Comparison of total cost curves for two estimated hazard levels. For each, the optimal mitigation level, n^*, minimizes the total cost, the sum of expected loss and mitigation cost. If the hazard is assumed to be described by one curve but actually described by the other, the assumed optimal mitigation level causes non-optimal mitigation, and thus excess expected loss or excess mitigation cost (Stein and Stein 2013)

especially the case in developing nations like Nepal. However, so long as the total cost is below the loss for no mitigation, less-than-optimal mitigation is better than none.

9 Conclusions

We suggest that given present knowledge, all of Nepal may be better regarded as equally hazardous and perhaps vulnerable to much larger earthquakes than those currently known, with long recurrence times. It seems worthwhile exploring alternative hazard maps, ideally with a long historical shaking dataset, and using new geological data as they become available. We suspect that the results would favor smoother maps and—especially for longer return periods—higher hazard levels.

Nonetheless, we would not expect any hazard map to perform perfectly. Aspects of future earthquakes may behave differently from past earthquakes, the details of which are only partly known. Some of the assumed details of future earthquake behavior will differ from what actually occurs. Nonetheless, improved maps could help in choosing better mitigation strategies. Hazard maps, like any natural-hazard forecasts, do not need be perfect—or even that good—to be useful in making policy (Stein and Stein 2014; Field 2015). The better they are, the more effectively they can be used.

References

Ader T, Avouac JP, Liu-Zeng J, Lyon-Caen H, Bollinger L, Galetzka J, Genrich J, Thomas M, Chanard K, Sapkota SN, Rajaure S (2012) Convergence rate across the Nepal Himalaya and interseismic coupling on the Main Himalayan Thrust: Implications for seismic hazard. J Geophys Res Solid Earth, 117(B4)

Avouac JP, Meng L, Wei S, Wang T, Ampuero JP (2015) Lower edge of locked Main Himalayan Thrust unzipped by the 2015 Gorkha earthquake. Nat Geosci 8:708–711

Bilham R, Ambraseys N (2005) Apparent Himalayan slip deficit from the summation of seismic moments for Himalayan earthquakes, 1500–2000. Curr Sci 88(10):1658–1663

Bilham R, Gaur VK, Molnar P (2001) Himalayan seismic hazard. Science 293(5534):1442–1444

Bollinger L, Avouac JP, Cattin R, Pandey MR (2004) Stress buildup in the Himalaya. J Geophys Res 109:B11405. doi:10.1029/2003JB002911

Bollinger L, Sapkota SN, Tapponnier P, Klinger Y, Rizza M, Van der Woerd J, Tiwari DR, Pandey R, Bitri A, Bes de Berc S (2014) Estimating the return times of great Himalayan earthquakes in eastern Nepal: evidence from the Patu and Bardibas strands of the main frontal thrust. J Geophys Res Solid Earth 119:7123–7163. doi:10.1002/2014JB010970

Box GEP (1979) Robustness in the strategy of scientific model building. Robustness Stat 1:201–236

Brooks EM, Stein S, Spencer BD (2016a) Investigating the effects of smoothing on the performance of earthquake hazard maps, Northwestern University Institute for Policy Research working paper

Brooks EM, Stein S, Spencer BD (2016b) Comparing the performance of Japan's earthquake hazard maps to uniform and randomized maps. Seismol Res Lett 87:90–102

Chaulagain H, Rodrigues H, Silva V, Spacone E, Varum H (2015) Seismic risk assessment and hazard mapping in Nepal. Nat Hazards 78:583–602

Field EH (2010) Probabilistic seismic hazard analysis: a primer. http://www.opensha.org/. Last accessed 27 May 2014

Field EH (2015) All models are wrong, but some are useful. Seismol Res Lett 86(2A):291–293

Geller RJ (2011) Shake-up time for Japanese seismology. Nature 472:407–409

Goda K, Kiyota T, Pokhrel R, Chiaro G, Katagiri T, Sharma K, Wilkinson S (2015) The 2015 Gorkha Nepal earthquake: insights from earthquake damage survey. Front Built Environ 1 (8):1–15. doi:10.3389/fbuil.2015.00008

Government of Nepal, National Planning Commission (2015) Post Disaster Needs Assessment

Hayes GP, Briggs RW, Barnhart WD, Yeck WL, McNamara DE, Wald DJ, Nealy JL, Benz HM, Gold RD, Jaiswal KS, Marano K (2015) Rapid characterization of the 2015 Mw 7.8 Gorkha, Nepal, earthquake sequence and its seismotectonic context. Seismol Res Lett 86(6):1557–1567

Japanese Seismic Hazard Information Station (J-SHIS) (2015) http://www.j-shis.bosai.go.jp/map/JSHIS2/download.html?lang=en. Last accessed May 2015
Kumar S, Wesnousky SG, Rockwell TK, Briggs R, Thakur VC, Jayangondaperumal R (2006) Paleoseismic evidence of great surface-rupture earthquakes along the Indian Himalaya. J Geophys Res 111 (B03304). doi:10.1029/2004JB003309
Kumar S, Wesnousky SG, Jayangondaperumal R, Nakata T, Kumahara Y, Singh V (2010) Paleoseismological evidence of surface faulting along the northeastern Himalayan front, India: Timing, size, and spatial extent of great earthquakes. J Geophys Res 115 (B12422). doi:10.1029/2009JB006789
Loveless JP, Meade BJ (2011) Spatial correlation of interseismic coupling and coseismic rupture extent of the 2011 Mw = 9.0 Tohoku-oki earthquake. Geophys Res Lett 38 (L17306). doi:10.1029/2011GL048561
Martin SS, Hough SE, Hung C (2015) Ground motions from the 2015 Mw 7.8 Gorkha, Nepal, earthquake constrained by a detailed assessment of macroseismic data. Seismol Res Lett 86 (6):1524–1532
Miyazawa M, Mori J (2009) Test of seismic hazard map from 500 years of recorded intensity data in Japan. Bull Seismol Soc Am 99:3140–3149
Moreno M, Rosenau M, Oncken O (2010) Maule earthquake slip correlates with pre-seismic locking of Andean subduction zone. Nature 467:198–202
Mugnier JL, Gajurel A, Huyghe P, Jayangondaperumal R, Jouanne F, Upreti B (2013) Structural interpretation of the great earthquakes of the last millennium in the central Himalaya. Earth Sci Rev 127:30–47. doi:10.1016/Jearscirev.2013.09.003
Newman A, Schneider J, Stein S, Mendez A (2001) Uncertainties in seismic hazard maps for the New Madrid seismic zone and implications for seismic hazard communication. Seismol Res Lett 72(6):647–663
Protti M, González V, Newman AV, Dixon TH, Schwartz SY, Marshall JS, Feng L, Walter JI, Malservisi R, Owen SE (2014) Nicoya earthquake rupture anticipated by geodetic measurement of the locked plate interface. Nat Geosci 7(2):117–121
Ram TD, Guoxin W (2013) Probabilistic seismic hazard analysis in Nepal. Earthq Eng Eng Vibr 12:577–586
Parker RL (1977) Understanding inverse theory. Annu Rev Earth Planet Sci 5:35–64
Silver N (2012) The signal and the noise: why so many predictions fail-but some don't. Penguin, New York
Stein S, Geller RJ, Liu M (2012) Why earthquake hazard maps often fail and what to do about it. Tectonophysics 562:1–25
Stein S, Friedrich AM (2014) How much can we clear the crystal ball? Astron Geophys 55(2):2–11
Stein J, Stein S (2012) Rebuilding Tohoku: a joint geophysical and economic framework for hazard mitigation. GSA Today 22(10):42–44
Stein S, Stein J (2014) Playing against nature: integrating science and economics to mitigate natural hazards in an uncertain world. AGU/Wiley-Blackwell
Stein S, Stein J (2013) How good do natural hazard assessments need to be? GSA Today 23(4/5). doi:10.1130/GSATG167GW.1
Stein S, Spencer BD, Brooks EM (2015) Metrics for assessing earthquake hazard map performance. Bull Seismol Soc Am 105(4). doi:10.1785/0120140164
Stevens VL, Avouac JP (2016) Millenary Mw > 9.0 earthquakes required by geodetic strain in the Himalaya. Geophys Res Lett, 43: doi:10.1002/2015GL067336
Ward S (1995) Area-based tests of long-term seismic hazard predictions. Bull Seismol Soc Am 85:1285–1298

Analysis of Landslides Triggered by the 2015 Gorkha Earthquake, Nepal

Prem Bahadur Thapa

Abstract On 25 April 2015, 7.8 Mw earthquake "Gorkha earthquake" struck central Nepal. Its epicenter was located 77 km northwest of Kathmandu near Barpak village in Gorkha District. The focus of the Gorkha earthquake was at a depth of approx. 15 km (considered shallow and therefore more damaging). On May 12, 2015, a major aftershock of 7.3 Mw followed the main shock. The Gorkha earthquake and its aftershocks caused thousands of human casualties and extensive damages, and triggered a large number of landslides of various types, including highly disrupted shallow slides, rock falls, and large-scale avalanches. An avalanche at Mount Everest killed at least 19 and another huge avalanche in the Langtang Valley killed about 350 people. The widespread landslides occurrence is posing a great threat to post-earthquake reconstruction. Field investigations and image interpretation identified thousands of landslides in affected districts of central Nepal. This provides a basis for better understanding and illustrating the distribution pattern of landslides triggered by the Gorkha earthquake and of the hazards related to them. The coseismic landslides were analyzed with respect to landslide causing and triggering factors, in order to characterize the spatial characteristics of landslides and to highlight the future hazard and risk. Slope angle and geology are the most significant parameters and potential ground acceleration values reflect an anomalous correlation with respect to landslide locations. The frequency ratio method was adopted for landslide susceptibility or hazard modelling. A landslide hazard map was generated and classified into five categories: very low, low, medium, high, and very high. 39.1% of the most affected areas belongs to very low and low classes with corresponding 5.9% of the inventoried landslides. Medium hazard zone makes up 37.1% of the area with 29.7% of the landslides. The rest of the area is classified into high and very high levels, which makes up 23.7% of the area with corresponding 64.3% of the total landslides. The verification of results indicates satisfactory agreement between the presumptive hazard map and the existing data on landslide locations. Consequently, there is a good correlation

P.B. Thapa (✉)
Department of Geology, Tri-Chandra Multiple Campus, Tribhuvan University, Kathmandu, Nepal
e-mail: thapagisinfo@gmail.com

J.H. Kruhl et al. (eds.), *Living Under the Threat of Earthquakes*,
Springer Natural Hazards, https://doi.org/10.1007/978-3-319-68044-6_3

between areas defined as representing “high” hazard and the known landslides. The hazard map not only reveals the likelihood of future landslides and debris flows. It is also helpful for the relocation of displaced people and for reconstruction strategies.

Keywords Gorkha earthquake · Landslide · Spatial characteristics
Hazard and risk · Nepal

1 Introduction

Nepal Himalaya is located in the seismo-tectonically active belt with rugged topography, complex geology, and frequent occurrence of extreme weather events. Pronounced tectonic and climatic forcing, manifested in high rock uplift rates, recurring large earthquakes, orographically enhanced precipitation, and high rates of mass wasting, erosion, and sediment transport create landscapes of high topographic relief and steep slopes (Korup and Clague 2009). Extreme events, such as high magnitude earthquakes, trigger landslides and induce significant morphological changes to large areas, particularly when the epicenter is located in a mountainous terrain (Jibson et al. 2006; Yin et al. 2009; Gorum et al. 2011; Wartman et al. 2013). In medieval times, large earthquakes in Nepal unleashed massive changes upon the landscape (Schwanghart et al. 2016).

Steep slopes produced by rapid tectonic uplift create high landslide hazard in Nepal even in the absence of ground shaking. The rugged terrain, unstable soils, heavy rains, and haphazard road construction in mountain areas combine to make Nepal as one of the world’s landslide hotspots (Witze 2015). Under normal conditions, the annual wet season in Nepal triggers landslides on the highly susceptible slopes in many parts of the country. Landscape disturbance by the 2015 Nepal earthquake and its aftershocks could significantly increase the landslide susceptibility or hazard in future monsoons, for a period of at least a few years because ground cracking and incipient landsliding occurred in many places (Collins and Jibson 2015).

1.1 Geological Setting and Seismicity in the Himalaya

The geological setting of the Himalaya comprises several faults (thrusts) that evolved and propagated from the north towards the south, amongst them three northerly dipping major thrusts—from south to north the Main Frontal Thrust (MFT), the Main Boundary Thrust (MBT), and the Main Central Thrust (MCT). These major thrust faults in the Nepal Himalaya sole at depth into the Main Himalayan Thrust (MHT). They clearly separate the major tectonostratigraphic units of the Nepal Himalaya (Figs. 1 and 2). The MFT separates the Quaternary

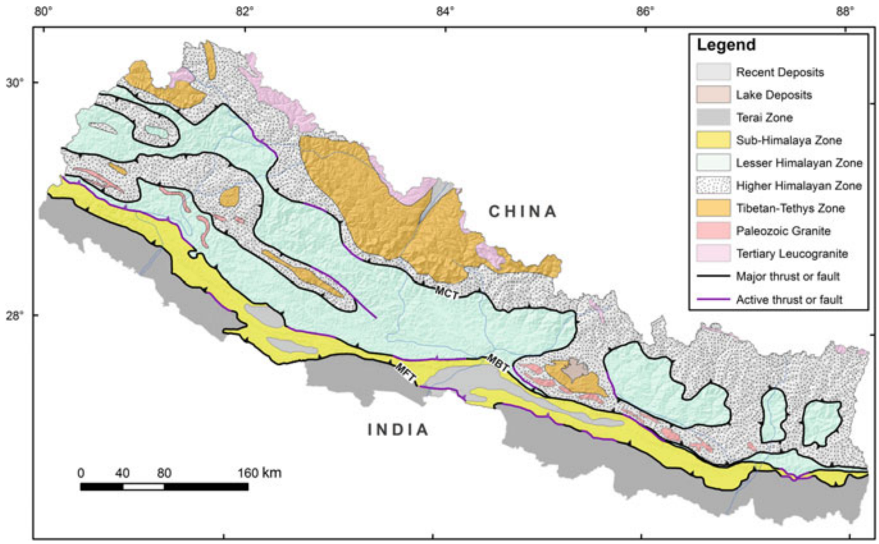


Fig. 1 Litho-tectonics of the Nepal Himalaya with active thrusts or faults. (Modified after Amatya and Janawali 1994; Nakata 1982)

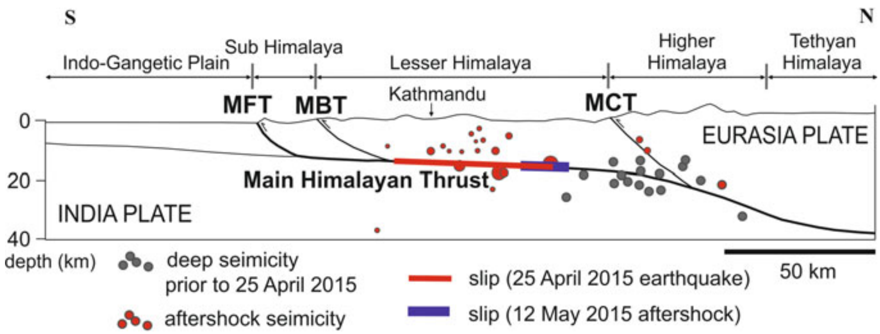


Fig. 2 Redrawn generalized cross section through the central Nepal Himalaya and the modelled slip of the Gorkha earthquake and of the May 12, 2015, aftershock. USGS (United States Geological Survey) 2015 compiled by GEER (Geotechnical Extreme Events Reconnaissance) (2015)

alluvium of the Indo-Gangetic Plain from the Sub-Himalaya (Siwalik Group). The MBT separates the Sub-Himalaya from the Lesser Himalaya and the MCT lies between high-grade metamorphic rocks of the Higher Himalayan Zone over the low-grade metamorphic rocks of the Lesser Himalayan Zone. The MCT is the oldest and successively followed by the MBT and the MFT. Among them, the MFT is considered as a southern tip of the MHT with flat-ramp-flat geometry dipping less than 10° (Ader et al. 2012). It represents a plate boundary thrust between the colliding plates, which has been found to be active and produce seismicity (catastrophic earthquakes) along the Himalaya. Thus, seismicity in the Himalaya is inherently linked with the geological setting of a major thrusts/faults system, which is inferred to be active in different segments (Nakata 1982). Historically, Nepal hosted several large earthquakes (Ambraseys and Douglas 2004; Bilham 2004) including the recent 2015 earthquake. Thus, the earthquakes in the Himalaya result from the collision between the Indian and Eurasian plates, which started about 55 million years ago (Molnar 1986). At the junction of the Indian and Eurasian tectonic plates an immense amount of energy builds up as the Indian plate continuously moves under the Eurasian plate at an average rate of 20 mm/year (Bettinelli et al. 2006; Bilham et al. 1997, etc.). This region accommodates approximately half of the tectonic convergence between these two plates (Avouac 2003; Ader et al. 2012). The built-up of energy has given rise to the highest mountains in the world (Mt. Everest); however, it also makes the Himalayan region seismically hazardous (Molden et al. 2016).

1.2 Gorkha Earthquake and Its Impacts

On 25 April 2015 at 11:56 AM, Nepal Standard Time, the Himalayan country of Nepal was struck by the catastrophic 7.8 Mw (USGS) earthquake. Its epicenter was located 77 km northwest of Kathmandu near Barpak village in Gorkha District. The focus of the Gorkha earthquake was at a depth of approx. 15 km and the main shock was followed by a major aftershock of 7.3 Mw on 12 May 2015. The 2015 Nepal earthquake is also known as “Gorkha earthquake” and considered as one of the most destructive earthquakes of Nepal Himalaya since the great 1934 Nepal-Bihar Earthquake. The Gorkha earthquake uplifted the Kathmandu valley by 1 m and mountainous regions north of Kathmandu subsided by 1.5 m (Bilham 2015; Lindsey et al. 2015). However, there was no surface rupture during the earthquake (GEER 2015; Kargel et al. 2016; Angster et al. 2015; Zhang et al. 2016). More than 469 aftershocks greater than 4.0 Mw were recorded as on 13 September 2016 (NSC 2016).

The Gorkha earthquake and its aftershocks had a devastating impact in Nepal, which resulted in a death toll of 8773 (Fig. 3), 23,304 injuries, more than 785,000 homes damaged or destroyed, and about 2.8 million people displaced (Molden et al. 2016). Most damages to homes and human settlement were seen in the rural areas, including many remote and inaccessible mountain communities. However, emerging cities and several neighborhoods in the Kathmandu Valley also saw severe damage to housing and human settlements (Molden et al. 2016). Numerous monuments of historical and cultural significance, some more than a couple of centuries old, were either destroyed or substantially damaged. Many of the heritage sites were extensively damaged, and some major monuments in Kathmandu’s seven

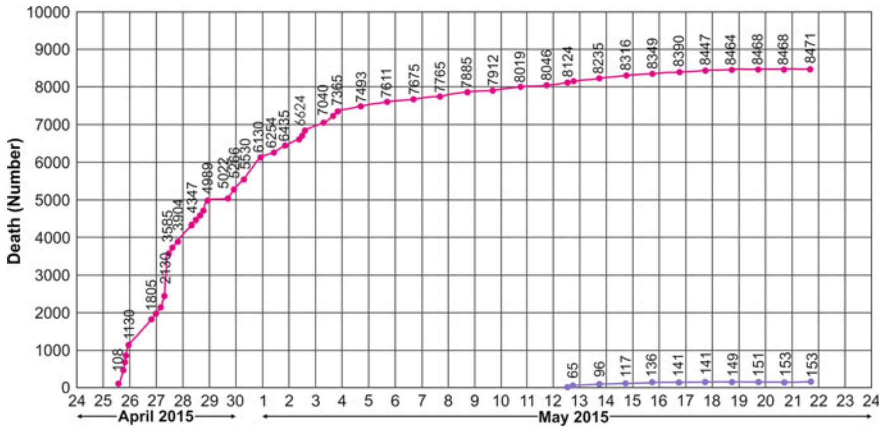


Fig. 3 Death toll due to 2015 Gorkha earthquake in Nepal. *Source* Nepal police and NEOC (National Emergency Operation Center) death toll counts in CATDAT (earthquake loss database) compiled by CEDIM (Center for Disaster Management and Risk Reduction Technology)

World Heritage Monument Zones were comprehensively damaged (NPC 2015a, b). Almost all sectors—social (housing and human settlements, health, education, and cultural heritage), productive (agriculture, irrigation, commerce, industry, tourism, and finance), infrastructure (electricity, communications, community infrastructure, transport, and water and sanitation), and cross-cutting (governance, disaster risk reduction, and environment and forestry) were seriously affected (Shrestha et al. 2016).

Apart from taking lives, damaging homes, and displacing people, the total value of the damage and loss caused by the earthquake is estimated at USD 7 billion (USD 1 ~ NPR 100), which is equivalent to about a third of Nepal's Gross Domestic Product (NPC 2015b). The total loss in the agriculture sector, the main source of livelihood in most earthquake-affected areas, is estimated at around NPR 28.4 billion (USD 284 million). NPR 16.4 billion (58%) of this amount is related to direct damages (NPC 2015b). With economic losses estimated at several billion US dollars, the financial impact to Nepal is severe and the rebuilding phase will likely span many years (GEER 2015). Thus, the 2015 earthquakes will have grave long-term socioeconomic impact on people and communities in Nepal (UN-OCHA 2015). The earthquakes pushed an additional 2.5–3.5% of the Nepalese population into poverty in 2015/2016—more than 700,000 people (NPC 2015b). Many homes and public buildings sustained less immediately apparent structural damage, some of which may not yet have been recognized and/or recorded. Such properties will have increased vulnerability to any future earthquake activity (Shrestha et al. 2016). The Post Disaster Needs Assessment (PDNA) Report (NPC 2015a) of the National Planning Commission (NPC) identified 14 affected districts (Sindhupalchok, Kathmandu, Dolakha, Kabhrepalanchok, Lalitpur, Dhading, Gorkha, Bhaktapur, Nuwakot, Rasuwa, Sindhuli, Kaski, Parbat, Okhaldhunga) of the country's

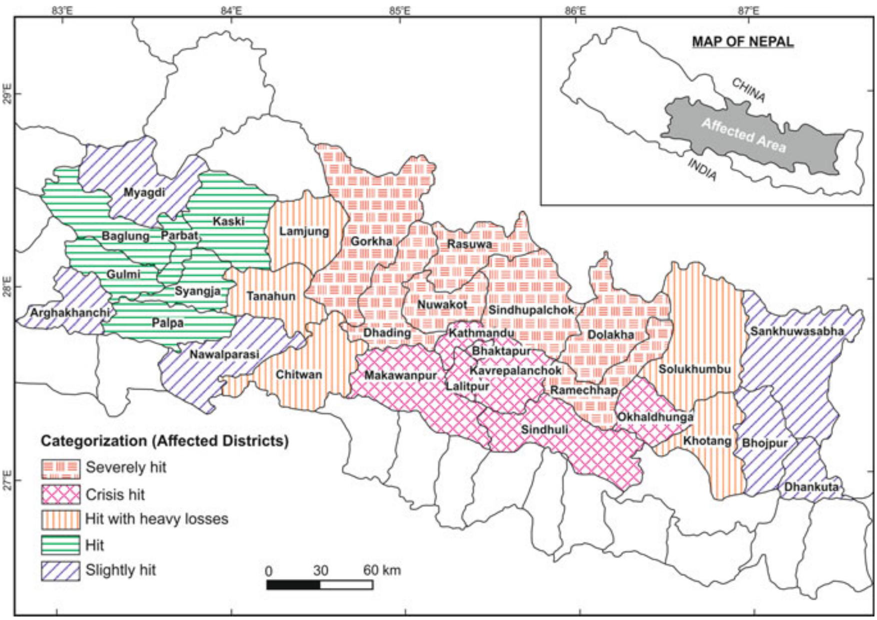


Fig. 4 Districts affected by the 25 April 2015 Gorkha earthquake and its major aftershock on 12 May 2015 (After NPC 2015b)

75 districts, of which seven were declared ‘severely hit’ (the worst category) and seven ‘crisis-hit’ (Fig. 4). Among the districts affected, loss of life was the highest in Sindhupalchok to the east with more than 3438 people killed according to the record of the Government of Nepal (GoN). The other districts were slightly or moderately affected. The Gorkha earthquake caused extensive loss of life and property because Nepal had not experienced earthquakes of this magnitude for more than 80 years and, therefore, people and state authorities were less prepared for such an incident (Moss et al. 2015).

The earthquake also triggered numerous secondary geo-hazards, including landslide-dammed rivers, mass movements (landslides/debris flows), glacial lake moraine failures, and avalanches (Molden et al. 2016). The nature of geo-hazards caused by the earthquake is unevenly distributed. Hundreds of fatalities were caused by landslides, including the particularly destructive Langtang debris avalanche (Collins and Jibson 2015; Kargel et al. 2016; Lacroix 2016). The 2015 Gorkha earthquake and its aftershocks induced slope movements. These had adverse effects on the local population, buildings and infrastructure, including burial and destruction of several villages, hundreds of fatalities, partial or total destruction of roads and natural damming of rivers posing significant hazard due to landslide dam burst and consequent catastrophic downstream flooding (Moss et al. 2015).

2 Landslides Triggered by the Gorkha Earthquake

The mountainous area of Nepal is generally prone to landslides, but the Gorkha earthquake and its aftershocks triggered many new landslides, often in locations not previously affected (Shrestha et al. 2016). Landslides triggered during the main shock and aftershocks blocked roads, dammed rivers and villages, causing hundreds of fatalities. These earthquake-induced landslides were mapped by a volunteer group from the University of Arizona, International Centre for Integrated Mountain Development (ICIMOD), National Aeronautics and Space Administration and United States Geological Survey (NASA-USGS), Interagency Earthquake Response Team, British Geological Survey, Durham University, Chinese Academy of Sciences (CAS), Indian Space Research Organization (ISRO), German Research Centre for Geosciences (GFZ), and others because the landslide inventory provides location information of landslide phenomena, types, volume, and damage (van Westen et al. 2008). Number of landslides mapped by different researchers are not matching. Kargel et al. (2016) identified 4312 landslides triggered by the Gorkha earthquake and aftershocks. Gnyawali et al. (2016) and others mapped some more thousands of landslides, etc. Such mismatch can be due to unavailability of cloud free images or skill of interpreters or mixing of pre-seismic or co-seismic landslides. The landslide map produced by the international volunteer team provided a rapid assessment in the form of a point or line features map (instead of polygon map) that were used to identify sites for immediate investigation and action in the aftermath of the earthquake. However, mapping of the landslide forms in terms of their actual shape and size is preferred for better understanding of their spatial relationship with terrain and ground shaking parameters (Harp et al. 2011; Xu et al. 2013). Thus, field-updated landslide inventory is required because formulating and documenting landslide maps is essential to define landslide susceptibility, hazard and risk and to survey types, patterns, distributions, and statistics of slope failures (Olyazadeh et al. 2016).

A zone of widespread and intense landslide incidence is found to run east–west, approximately parallel to the transition between the Lesser and High Himalayas (Fig. 5). The landslide concentrations of the Gorkha earthquake were highest near the epicenter but significant landslide concentrations extended about twice as far to the east than to the west (Collins and Jibson 2015). This likely was the result of the eastward-directed fault rupture of the main shock as well as the occurrence of the 7.3 Mw aftershock east of the main shock (Collins and Jibson 2015). The area of landslides triggered by the aftershock overlaps with the eastern end of the area affected by the Gorkha earthquake triggered landslides but distinction of landslides caused by the Gorkha Earthquake and its major aftershock could not be clearly separated out due to limited time span between these events during hardly hit time of disaster relief operation. Several important valley-blocking landslides also occurred, the most notable of which buried the village of Baisari on the Kali Gandaki River several weeks after the main shock (Moss et al. 2015). The largest and most destructive landslide triggered by the Gorkha earthquake occurred in the

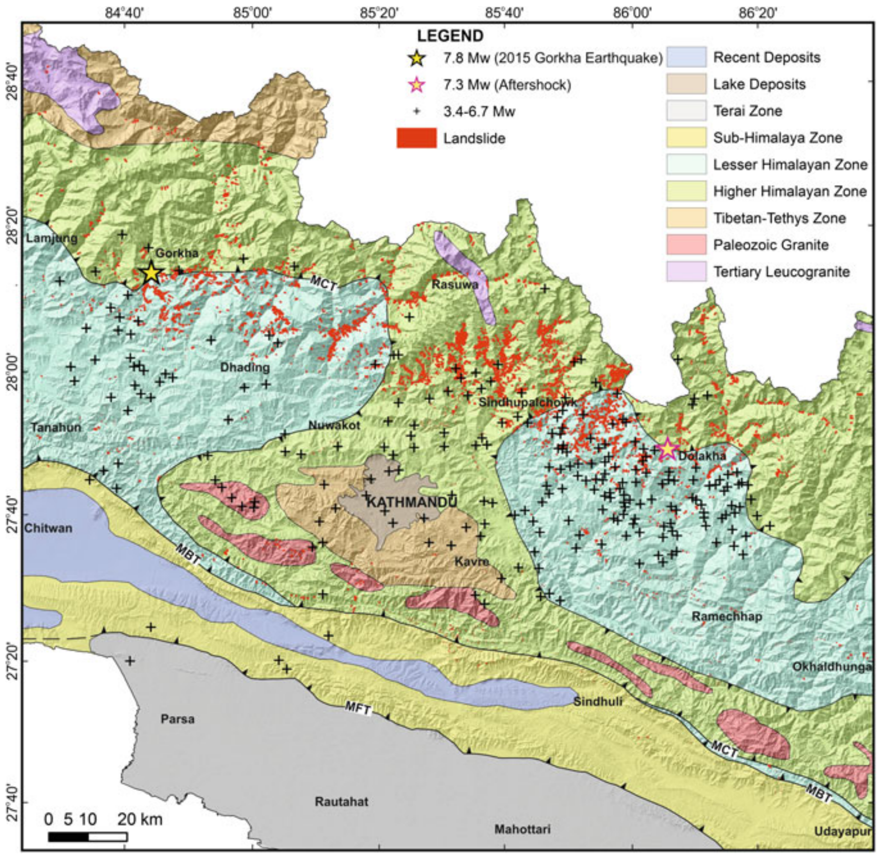


Fig. 5 Generalized geology and spatial distribution of landslides triggered by the 2015 Gorkha earthquake and its aftershocks in central Nepal Himalaya. *MFT* (Main Frontal Thrust), *MBT* (Main Boundary Thrust), *MCT* (Main Central Thrust)

Langtang Valley, where the shaking triggered a debris avalanche composed of ice, snow, and soil, burying several villages, and killing at least 350 people (Collins and Jibson 2015; Kargel et al. 2016).

2.1 Spatial Characteristics of Landslides

An analysis was carried out in relatively large geographical areas that were affected by the 2015 Gorkha earthquake and its aftershocks. The spatial relationships among mapped landslides and their causative factors provided the characteristics of landslide in the particular geo-environment by evaluating the variables contributing to the triggering of landslides, based on field evidences and spatial statistics by using geographic information system (GIS). The landslides triggered by the Gorkha earthquake were partly highly disrupted shallow-seated and partly delivered dry debris (Fig. 6a) and occurred in higher elevated regions (Fig. 6b). Consequently, ridge-top shatterings are hotspots of landslides. Most of the landslides were falls and slides of rock and soil. This is consistent with observations from other worldwide earthquakes (Keefer 2002). Spatial correlation of landslides with slope gradient shows that the maximum of landslides is related to topographic slopes greater than 35° (Fig. 6c). This indicates that steep slopes have a greater control on

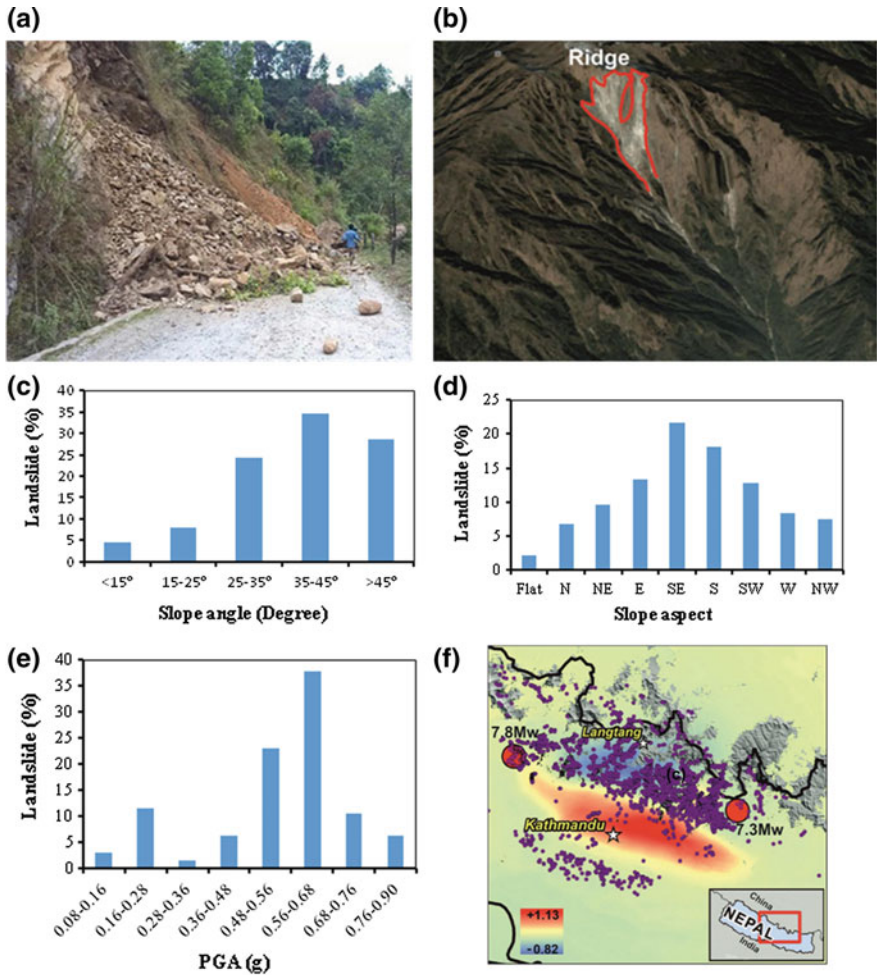


Fig. 6 Characteristics of landslides triggered by the 2015 Gorkha earthquake and its aftershocks in central Nepal. **a** shallow and dry slides along the Araniko Highway, **b** ridge-top shattering, Bhotekoshi River watershed, **c** slope angle, **d** slope aspect, **e** potential ground acceleration (PGA) values, **f** ground movement (Kargel et al. 2016)

landslide occurrences due to earthquakes (Martha et al. 2016). Shaking during the Gorkha earthquake was amplified on steep, convex slopes and the majority of landslides occurred in areas comprising fractured, weathered and thus unstable geological material susceptible to failure along steep slopes (Moss et al. 2015). In terms of slope aspect, comparatively more landslides occurred at south facing slopes (Fig. 5d). A local clustering of landslides was found, which is attributed to spatial variability in rock strength, bedrock fracturing, extent of weathering conditions, dip-slope condition, presence of granular soil in steep slope, and land cover. Exceptionally, the Langtang debris avalanche began as a snow and ice avalanche and entrained debris before becoming airborne off a 500 m-tall cliff. Estimates of the velocity of the airborne landslide debris approach 100 m/s. The estimated volume of the Langtang landslide is 2,000,000 m^3 (Collins and Jibson 2015).

The ground motion intensity, an important parameter in the landslide triggering (Meunier et al. 2007; Lacroix et al. 2015), was possibly smaller for the Gorkha earthquake than for previous large Himalayan earthquakes, due to the steady rupture velocity (Grandin et al. 2015; Galetzka et al. 2015) or the deeper source compared with other recent Himalayan earthquakes that broke the surface (Lacroix 2016). Among the shaking parameters, potential ground acceleration (PGA) is one of the factors that may control whether landslides occur in response to an earthquake. The specific frequency content, shake duration, PGA direction, and recurrent shocks also may be important (Ogata 1988). Based on the reports of Tajika et al. (1994a), many of the landslides occurred in hilly areas where the PGA was 0.306 g (acceleration due to Earth's gravity) or higher. Most slope failures occurred with PGA values of greater than 0.255 'g' (Tajika et al. 1994b). But the Gorkha earthquake-induced landslides have an anomalous correlation with increasing PGA values, with some correlation of PGA values between 0.48 and 0.68 'g' and landslide occurrences (Fig. 6e). This indicates that there are other ground parameters that controlled landslide occurrences, along with the ground acceleration, which is similar to that seen previously in the case of large earthquake-induced landslides (Wartman et al. 2013). Another key earthquake phenomenon is the wide-field land surface deformation pattern, which appears to have influenced the distribution of landslides. According to Kargel et al. (2016), an unexpected pattern of landslide distribution is found during the 2015 Gorkha earthquake in terms of locations and severity of landslides. Most of the documented landslides occurred in areas where the ground surface dropped down, rather than in areas where the ground was uplifted (Fig. 6f).

Each factor likely contributes in landslides occurrence but lithology is a common significant parameter. Landslide density is highest roughly in the middle between the epicenters of the main shock and the main aftershock (Fig. 5). Whereas this cluster's proximity to the Gorkha earthquake epicenter is evident, the pattern defined by the cluster is closely correlated with the outcrop of the upper Lesser Himalayan rocks (phyllite, meta-sandstone) which is bounded to the north by the MCT (Fig. 5). Near the thrusted contact, many landslides were found. Notably, these occur on either side of the MCT and thus fault structures may have exerted indirect control for clustering of landslides (Kargel et al. 2016). Moreover, landslides triggered by strong shaking were the dominant geotechnical effect of the recent earthquakes in Nepal (Moss et al. 2015).

2.2 *Future Hazard and Risk*

Proper identification of landslides locations can predict where the ground might be unstable and prone to future hazard and risk. The highest densities of earthquake-related landslides are distributed in a broad swath between the two largest shocks, where many aftershocks also occurred (Fig. 5). These areas must be viewed as having a very high risk of slope failures during the successive monsoons. The 2015 Gorkha earthquake triggered thousands of landslides that were equivalent to several hundred years of 'normal' monsoon-triggered landslide activity in affected districts (Rosser et al. 2016). The zone of intense earthquake-induced landslides approximately coincides with those areas with the highest annual fatalities due to rainfall-triggered landslides. Consequently, it is to be feared that the heavy rainfall in the successive monsoon reactivates many landslides and triggers a host of new failures as well (Petley 2015). The 2015 and 2016 monsoons already led to a large numbers of landslides and extensive fatalities. Numerous additional landslides, many times greater than typically caused by a normal monsoon, could in future occur in the areas that were hardest-hit during the earthquake. Certainly, the nature of landslide hazard will evolve in rainstorms. The worst water-induced landslide in Nepal's history happened in 1993, claimed 1336 lives and destroyed numerous public facilities. The 1993 landslide and flooding hazard was a periodic extreme event and is not so unlikely or uncommon in Nepal (Dhital et al. 1993). Extreme weather events in the future might have disastrous effects. In addition, extensive ridge-top fracturing as well as the ground cracking at many locations at steep slopes will facilitate increased infiltration of rainfall runoff (Fig. 7a). This, in turn, leads to an increase in pore water pressure within these slopes, which substantially decreases their stability and increases the likelihood of landsliding. The partially detached landslide masses that did not move all the way to valley bottoms could be reactivated in wetter conditions and move downslope to block valleys (Collins and Jibson 2015). When such masses become saturated during monsoon rains, they could remobilize into potentially damaging debris flows that can travel rapidly for long distances. Regions downstream of areas of pervasive landsliding could experience continuing debris flow hazard throughout the current as well as future monsoon seasons over the next several years because other areas struck by large earthquakes have experienced substantial increases in sedimentation rates on annual and decadal scales (e.g. Keefer 1994; Lin et al. 2004). Triggering thresholds significantly decreased after strong earthquake events (Yu et al. 2014) in high PGA value areas. Consequently, the meteorological thresholds for debris flows as loose sediments, deposited by the coseismic landslides, are lowered (Shieh et al. 2009). The debris flow activity in these earthquake-affected areas will be very high in the first 5–10 years period after the earthquake while the total period with an increased activity will last 20–40 years (Tang et al. 2009). The close association between dip slopes and landslides causes greatest risk of failure during times of intense rainfall (Fig. 7b). More than 60% of the villages in central Nepal, which are located on near-threshold or threshold dip slopes, are at high risk (Ojha and DeCelles 2015). Destabilized hillslopes and weakened soil horizons represent an ongoing threat (Andermann et al. 2015; Gallen et al. 2015). Low seismic PGAs at a few percent of 'g' may cause failures that lead to a landslide or avalanche if the materials are already near failure (Kargel et al. 2016). (i) Granular materials may accumulate near the angle of repose, making them susceptible to coseismic failure, due to an acceleration that would increase shear stress along incipient planes of failure or related to rapid coseismic vibration-induced creep (Chou et al. 2013). (ii) Seismic vibrations may cause liquefaction of water-saturated sediment, disturbances to the local hydrology, and coseismic or postseismic flow or rotational slumping (Chen et al. 2009).

Landslides triggered by large earthquakes pose immediate and prolonged hazards. Predictive modelling of regional landslide susceptibility maps is generally used to identify where landslides may occur in a given region. This is done on the basis of a set of relevant environmental characteristics, assuming that slope failures in the future will be more likely to occur under the conditions which led to past and present slope movements (Varnes 1984; Carrara et al. 1995). An analysis of the distribution of landslides induced by the Gorkha earthquake and its causative/triggering variables can predict future patterns of landsliding in the affected areas of central Nepal. PGA as seismic intensity data combined with geo-environmental variables (geology, slope angle, slope aspect, land use) were used to model Landslide Hazard Index (LHI) by the maximum likelihood function of frequency ratio method (FRM). The approach is based on the observed relationships between each variable and the distribution of landslides. Frequency ratio (FR) values for each variable class was calculated and then summed up

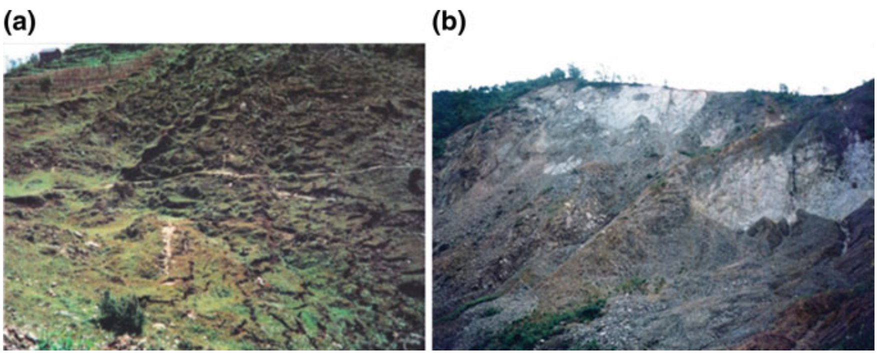


Fig. 7 Indicators of future hazard and risk: **a** tension cracks (ground cracking) at Chaubas village of Makwanapur, Nepal **b** dip-slope condition daylighting the hill-slope at Chhap village of Makwanpur, Nepal

(LHI = ΣFR) all ratio value maps to generate a landslide hazard map. Fr = 1 means that the variable class has a density of landslides proportionally to the size of the class in the map. A value which is greater than one indicates a high correlation and a value of less than one is lower correlation. The computed landslide hazard map was classified into five categories: very low, low, medium, high, and very high. 39.1% of the most affected areas belong to low and very low classes with corresponding 5.9% of the inventoried landslides. The medium hazard zone makes up 37.1% of the area with 29.7% of the landslides. The rest of the area was classified into high and very high categories, which makes up 23.7% of the area with corresponding 64.3% of the total landslides (Figs. 8 and 9a).

Hazard modelling shows that the overlapping zone between Gorkha earthquake (7.8 Mw) and its major aftershock (7.3 Mw) is a highly hazardous area for landslides. In fact, these locations already suffered from both high earthquake intensities that caused the widespread distribution of landslides (Figs. 5, 8). The result was verified and validated which is important in the modelling process. Such landslide hazard map validation has been already addressed in the past (Carrara et al. 1995; Chung et al. 1995; Luzi and Pergalani 1996; Chung and Fabbri 2003; Baeza et al. 2010 etc.). The verification of results indicates satisfactory agreement between the presumptive hazard map and the existing data on landslide locations, i.e., there is good correlation between areas defined as representing "high" hazard and the known landslides (Fig. 9a). Quantitative validation of the hazard model is done by calculating the success rate (Fig. 9b). The area under the curve (AUC) of 69.85% shows that the model is valid with a prediction accuracy of 50–100% (total area).

Landslide hazard caused by earthquakes can be primary or secondary. The primary hazard is situated high on hillslopes (typically above most settlements) and along valley floors. In addition, landslide material can be remobilized into debris flows (secondary hazard) that travel down along existing channels or gullies and affect valley floors (Rosser et al. 2016). Therefore, the potential exists for immense landslides and river blockages, which may pose the greatest mountain hazard in the

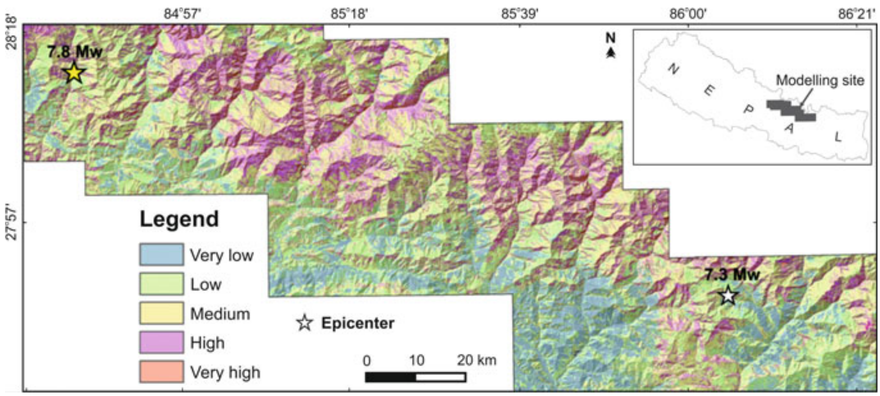


Fig. 8 Landslide hazard analysis across the region most affected by the 2015 Gorkha earthquake

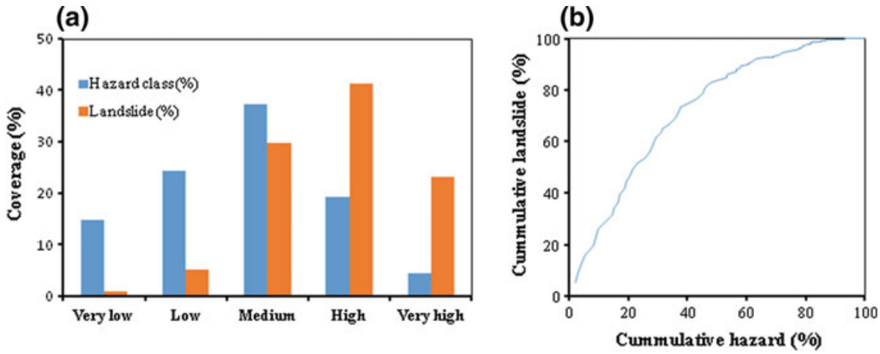


Fig. 9 Validation of landslide hazard; **a** frequency statistics and **b** success rate

affected areas. 2015 and 2016 monsoons rain already provided the clue to observe the development of new landslides as well as the reactivation of pre-existing landslides prompted by the subsequent rainfall. Some newer head scarps tend to develop retreating upward from pre-existing landslide scarps formed in already weathered rock or in rock loosened by the earthquake. In addition, a rainfall-induced debris flow was observed, with debris served from the upper slope, which run into a gully eroding the deposits along its course.

To safeguard from future hazard and risk, evaluation of suitable landslide risk reduction options is indispensable because the different types of hazards have varied impacts and require appropriate mitigation measures. Increase in pore water pressure is the main cause of landslides initiation in mountain hill-slope. The management of surface and subsurface water is the most efficient stabilization measures (Thapa 2015). Inclined horizontal drains can be used to lower groundwater level by discharging water as a function of gravity outlets. The combined effort of drainage, bioengineering, and structural measures are suitable wherever feasible from economic and engineering geological point of view.

3 Concluding Remarks

Taking into account serious impacts, the 2015 Gorkha earthquake is considered as the most destructive in central Nepal Himalaya since the 1934 Nepal–Bihar earthquake, with a long-term hazardous effect. The loss of life from the earthquake and its largest aftershocks was mainly due to poor construction of buildings, characterized by (i) insufficiency or absence of reinforcement and (ii) location of settlements in close proximity to unstable hill-slopes. The generation of geo-hazards, especially of numerous slope movements (landslide and debris flow) resulted in the devastation of residential areas mainly in the mountainous parts of the affected areas with rugged geomorphology. Nepal Himalaya is facing increasing risks from landslides because of large-scale earthquakes, frequent occurrence of extreme weather events, and human interventions.

Landslides triggered by the Gorkha earthquake are highly disrupted and shallow-seated (fall, slide) and tend to occur in higher elevated regions. Ridge-top shatterings are hotspots of landslides. In terms of slope geometry, more slides found to be in steeper and south facing slopes. The correlation of ground shaking with landslides is somewhat anomalous because other ground parameters, such as lithology and geological structure, are expected to control landslide occurrences along with the ground acceleration. The pattern of landslide distribution is unexpected in relation to locations and severity of landslides because most of the documented landslides during and after the Gorkha earthquake occurred in areas where the ground surface dropped down.

The close association between dip slopes and landslides and extensive ground cracking can put many locations in earthquake-affected regions into great risk of failure. Thus, slopes in the hilly terrain, severely weakened by the quake, are now more likely to slip after strong rains and aftershocks. Landslide masses, partially detached during earthquake, may remobilize into potentially damaging debris flows that can travel rapidly over long distances. Regions downstream of areas of pervasive landsliding could experience continuous debris-flow hazard throughout future monsoon seasons. Analysis of landslides characteristics, indicators of future risk, and hazard level zones computed in this study could be helpful for relocation of displaced people and any reconstruction strategies in Nepal. The predicted very high hazardous zones of landslides in the overlapping zone between the Gorkha earthquake and its major aftershock can be either avoided or implemented with suitable landslide mitigation options. Building community resilience to shocks can be cost effective. Humanitarian response and reconstruction also represent critical opportunities to build back better.

Acknowledgements The author is thankful to a reviewer who provided very constructive comments to improve the manuscript.

References

Ader T, Avouac J-P, Liu-Zeng J, Lyon-Caen H, Bollinger L, Galetzka J, Genrich J, Thomas M, Chanard K, Sapkota SN, Rajaure S, Shrestha P, Ding L, Flouzat M (2012) Convergence rate across the Nepal Himalaya and interseismic coupling on the Main Himalayan Thrust: implications for seismic hazard. J Geophys Res 117(B04403). doi:10.1029/2011JB009071

Amatya KM, Jnawali BM (1994) Geological map of Nepal, Scale:1:1,000,000. Department of Mines and Geology, International Centre for Integrated Mountain Development, Carl Duisberg Gesellschaft e. V., and United Nations Environment Programme

Ambraseys, NN, Douglas, J (2004) Magnitude calibration of north Indian earthquakes. Geophys J Int 159:165–206. doi:10.1111/j.1365-246X.2004.02323.x

Andermann C, Behling R, Cook KL, Emberson R, Hovius N, Marc O, Motagh M, Roessner S, Sens-Schoenfelder C, Turowski JM (2015) Landscape response to the Mw 7.9 Gorkha earthquake. Geol Soc Am Abstr Programs 47(7):105–112, abstract

Angster S, Fielding EJ, Wesnousky S, Pierce I, Chamlagain D, Gautam D, Upreti BN, Kumahara Y, Nakata T (2015) Field Reconnaissance after the 25 April 2015 M 7.8 Gorkha Earthquake. Seismol Res Lett 86(6):1506–1513. doi:10.1785/0220150135

Avouac J-P (2003) Mountain building, erosion and the seismic cycle in the Nepal Himalaya. Adv Geophys 46:1–80

Baeza C, Lantada N, Moya J (2010) Validation and evaluation of two multivariate statistical models for predictive shallow landslide susceptibility mapping of the Eastern Pyrenees (Spain). Environ Earth Sci 61:507–523

Bettinelli P, Avouac, JP, Flouzat M, Jouanne, F, Bollinger L, Willis P, Chitrakar GR (2006) Plate motion of India and interseismic strain in the Nepal Himalaya from GPS and DORIS measurements. J Geodesy 80(8–11):567–589. doi:10.1007/s00190-006-0030-3

Bilham R (2004) Earthquakes in India and the Himalaya: tectonics, geodesy and history. Ann Geophys 47:839–858. doi:10.4401/ag-3338

Bilham R (2015) Raising Kathmandu. Nat Geosci 8:582–584

Bilham R, Larson K, Freymuller J (1997) GPS measurements of present-day convergence across the Nepal Himalaya. Nature 386:61–64

Carrara A, Cardinali M, Guzzetti F, Reichenbach P (1995) GIS-based techniques for mapping landslide hazard. In: Carrara A, Guzzetti F (eds) Geographical information systems in assessing natural hazards, pp 135–176

CEDIM (Center for Disaster Management and Risk Reduction Technology). http://www.cedim.de/

Chen Y, Cao LXZ, Hou L, Sun R, Dong L, Wang W, Meng F, Chen H (2009) Liquefaction macrophenomena in the great Wenchuan earthquake. Earthq Eng Eng Vib 8(2):219–229. doi:10.1007/s11803-009-9033-4

Chou HT, Lee CF, Chen, SC (2013) The collapse process of Granular slopes under seismic forcing. In: Ugai K, Yagi H, Wakai A (eds) Earthquake-induced landslides: proceedings of the international symposium on earthquake-induced landslides, pp 45–57

Chung CF, Fabbri AG (2003) Validation of spatial prediction models for landslide hazard mapping. Nat Hazards 30:451–472

Chung CF, Fabbri, AG, van Westen CJ (1995) Multivariate regression analysis for landslide hazard zonation. In: Carrara A, Guzzetti F (eds) Geographic information systems in assessing natural hazards, pp 107–133

Collins BD, Jibson RW (2015) Assessment of existing and potential landslide hazards resulting from the April 25, 2015 Gorkha, Nepal earthquake sequence. U.S. geological survey open file report 2015-1142, Reston, VA

Dhital MR, Khanal N, Thapa KB (1993) The role of extreme weather events, mass movements, and land use changes in increasing natural hazards. A Report of the preliminary field assessment and workshop on causes of recent damage incurred in south-central Nepal, July 19–20 1993. ICIMOD publication, Kathmandu

Galetzka J, Melgar D, Genrich JF, Geng J, Owen S, Lindsey EO, Xu X, Bock Y, Avouac J-P, Adhikari LB, Upreti, BN, Pratt-Sitaula B, Bhattarai TN, Sitaula BP, Moore A, Hudnut KW, Szeliga W, Normandeau, J, Fend M, Flouzat M, Bollinger L, Shrestha P, Koirala B, Gautam U, Bhatterai M, Gupta R, Kandel T, Timsina C, Sapkota SN, Rajaure S, Maharjan N (2015) Slip pulse and resonance of the Kathmandu basin during the 2015 Gorkha earthquake, Nepal. Science 349(6252):1091–1095. doi:10.1126/science.aac6383

Gallen SF, Clark MK, Niemi N, Lupker M, Gajurel AP, West AJ, Lowe K, Roback K (2015) Coseismic landslide hazards and geomorphic consequences of the Mw 7.8 Gorkha earthquake, Nepal. Geol Soc Am Abstr Programs 47(7):105–111, abstract

GEER (2015) Geotechnical Field Reconnaissance: Gorkha (Nepal) Earthquake of April 25 2015 and Related Shaking Sequence. Geotechnical Extreme Event Reconnaissance (GEER), GEER Association Report No. GEER-040. Version 1.0

Gorum T, Fan X, van Westen CJ, Huang RQ, Xu Q, Tang C, Wang G (2011) Distribution pattern of earthquake-induced landslides triggered by the 12 May 2008 Wenchuan earthquake. Geomorphology 133:152–167

Grandin R, Vallée M, Satriano C, Lacassin R, Klinger Y, Simoes M, Bollinger L (2015) Rupture process of the Mw = 7.9 2015 Gorkha earthquake (Nepal): insights into Himalayan megathrust segmentation. Geophys Res Lett. doi:10.1002/2015GL066044

Gnyawali KR, Maka S, Adhikari, BR, Chamlagain D, Duwal S, Dhungana AR (2016) Spatial implications of earthquake induced landslides triggered by the april 25 Gorkha earthquake Mw 7.8: preliminary analysis and findings. International conference on earthquake engineering and post disaster reconstruction planning, Bhaktapur, Nepal, pp 50–58

Harp EL, Keefer DK, Sato HP, Yagi H (2011) Landslide inventories: the essential part of seismic hazard analyses. Eng Geo 122:9–12

Jibson RW, Harp EL, Schulz W, Keefer DK (2006) Large rock avalanches triggered by the M 7.9 Denali fault, Alaska, earthquake of 3 November 2002. Eng Geol 83:144–160

Kargel JS, Leonard GJ, Shugar DH, Haritashya UK, Bevington A, Fielding EJ, Fujita K, Geertsema, M, Miles ES, Steiner J, Anderson E, Bajracharya S, Bawden GW, Breashears,DF, Byers A, Collins B, Dhital MR, Donnellan A, Evans TL, Geai ML, Glasscoe MT, Green D, Gurung DR, Heijenk R, Hilborn A, Hudnut K, Huyck C, Immerzeel WW, Liming J, Jibson R, Kääb A, Khanal NR, Kirschbaum D, Kraaijenbrink PDA, Lamsal D, Shiyin L, Mingyang LV, McKinney D, Nahirnick NK, Zhuotong N, Ojha S, Olsenholler J, Painter TH, Pleasants M, KC P, Yuan Q, Raup BH, Regmi D, Rounce DR, Sakai A, Donghui S, Shea JM, Shrestha AB, Shukla A, Stumm D, van der Kooij M, Voss K, Xin W, Weihs B, Wolfe D, Lizong W, Xiaojun Y, Yoder MR, Young N (2016) Geomorphic and geologic controls of geohazards induced by Nepal's 2015 Gorkha earthquake. Science 351 (6269). doi:10.1126/science.aac8353

Keefer DK (1994) The importance of earthquake-induced landslides to long-term erosion and slope-failure hazards in seismically active areas. Geomorphology 10(1):265–284

Keefer DK (2002) Investigating landslides caused by earthquakes—a historical review. Surv Geophys 23:473–510. doi:10.1023/A:1021274710840

Korup O, Clague JJ (2009) Natural hazards, extreme events, and mountain topography. Quater Sci Rev 28:977–990

Lacroix P (2016) Landslides triggered by the Gorkha earthquake in the Langtang valley, volumes and initiation processes. Earth, Planets and Space 68:46

Lacroix P, Berthier E, Taipe Maquerhua E (2015) Earthquake-driven acceleration of slow-moving landslides in the Colca valley, Peru, detected from Pléiades images. Remote Sens Environ 165:148–158

Lin CW, Shieh CL, Yuan BD, Shieh YC, Liu SH, Lee SY (2004) Impact of Chi-Chi earthquake on the occurrence of landslides and debris flows; example from the Chenyulan River watershed, Nantou. Taiwan. Eng Geo 71(1–2):49–61

Lindsey EO, Natsuaki R, Xu X, Shimada M, Hashimoto M, Melgar D, Sandwell DT (2015) Line of sight displacement from ALOS-2 interferometry: Mw 7.8 Gorkha earthquake and Mw 7.3 aftershock. Geophys Res Lett 42:6655–6661

Luzi L, Pergalani F (1996) A methodology for slope instability zonation using a probabilistic method.—Actas VI Congreso Nacional y ConferenciaInternacional de GeologiaAmbiental y OrdenaciondelTerritorio 1:537–556

Martha TR, Roy PI, Mazumdar R, Govindharaj KB, Kumar KV (2016) Spatial characteristics of landslides triggered by the 2015 Mw 7.8 (Gorkha) and Mw 7.3 (Dolakha) earthquakes in Nepal. Landslides. doi:10.1007/s10346-016-0763-x

Meunier P, Hovius N, Haines AJ (2007) Regional patterns of earthquake-triggered landslides and their relation to ground motion. Geophys Res Lett 34:L20408. doi:10.1029/2007GL031337

Molden D, Sharma E, Acharya G (2016) Lessons from Nepal's Gorkha Earthquake 2015. In: Shingh SP, Khanal SC, Joshi M (eds) Lessons from Nepal's Earthquake for the Indian Himalayas and the Gangetic Plains, Central Himalayan Environment Association (CHEA):1–14

Molnar P (1986) The geologic history and structure of the Himalaya. Am Sci 74:114–154

Moss RES, Thompson EM, Kieffer DS, Tiwari B, Hashash YMA, Acharya I, Adhikari BR, Asimaki D, Clahan KB, Collins BD, Dahal S, Jibson RW, Khadka D, Macdonald A, Madugo CLM, Mason HB, Pehlivan M, Rayamajhi D, Uprety S (2015) Geotechnical Effects of the 2015 Magnitude 7.8 Gorkha, Nepal, Earthquake and Aftershocks. Seismol Res Lett 86 (6):1514–1523. doi:10.1785/0220150158

Nakata T (1982) A photogrammetric study on active faults, in the Nepal Himalayas. Jour Nepal Geol Soc 2:67–80

NPC (2015a) Post disaster needs assessment. Key findings. Government of Nepal, National Planning Commission (NPC), Kathmandu, Nepal, vol A

NPC (2015b) Post disaster needs assessment: sector reports. Government of Nepal, National Planning Commission (NPC), Kathmandu, Nepal, vol B

NSC (2016) National Seismological Center (NSC), Department of Mines and Geology, Kathmandu, Nepal. http://www.seismonepal.gov.np/

Ogata Y (1988) Statistical models for earthquake occurrences and residual analysis for point processes. Jour Amer Stat Assoc 83:9–27. doi:10.1080/01621459.1988.10478560

Ohja TP, DeCelles PG (2015) Landslide distribution before and after the 2015 Gorkha earthquakes in central Nepal: relationships with dip slopes and villages. Geological Soc Am Abstr Programs 47(7):105–110, abstract

Olyazadeh R, Sudmeier-Rieux K, Jaboyedoff M, Derron M-H, Devkota S (2016) An offline-online WebGIS android application for fast data acquisition of landslide hazard and risk. Nat Hazards Earth Syst Sci Discuss. doi:10.5194/nhess-2016-267

Petley D (2015) Landslides in Nepal and the impact of the SW Monsoon. AGU, the Landslide blog. http://blogs.agu.org/landslideblog/2015/05/18/nepal-and-the-sw-monsoon-1/

Rosser N, Densmore A, Oven K (2016) Landslides following the 2015 Gorkha earthquake: monsoon 2016. Earthquakes without Frontiers (EWF) blog Post. http://ewf.nerc.ac.uk/2016/06/15/landslides-following-2015-gorkha-earthquake-monsoon-2016/

Schwanghart W, Bernhardt A, Stolle A, Hoelzmann P, Adhikari BR, Andermann C, Tofelde S, Merchel S, Rugel G, Fort M, Korup O (2016) Repeated catastrophic valley infill following medieval earthquakes in the Nepal Himalaya. Science. doi:10.1126/science.aac9865

Shieh CL, Chen YS, Tsai YJ, Wu JH (2009) Variability in rainfall threshold for debris flow after the Chi-Chi earthquake in central Taiwan, China. Int J Sediment Res 24:177–188

Shrestha, AB, Bajracharya, SR, Kargel, JS, Khanal NR (2016) The impact of Nepal's 2015 Gorkha Earthquake-induced geohazards. International Centre for Integrated Mountain Development (ICIMOD), Research Report 2016/1

Tajika J, Fukami H, Okazaki N, Ozawa S, Endo Y, Kurosawa K, Ohtsu S, Ishimaru S, Akita F (1994a) Ground failures and disasters caused by the 1993 Kushiro-oki earthquake. Geological Survey of Hokkaido special report 23, Sapporo, Japan

Tajika J, Ito Y, Ishimaru S, Hirota T (1994b) Slope movements in Nemuro-Kushiro Region. In: Ground disasters caused by the Hokkaido Toho-oki earthquake of October, 1994, Geological Survey of Hokkaido special report 25:81–94, Sapporo, Japan

Tang C, Zhu J, Li W (2009) Rainfall-triggered debris flows following the Wenchuan earthquake. Bull Eng Geol Environ 68:187–194

Thapa PB (2015) Occurrence of landslides in Nepal and their mitigation options. J Nepal Geol Soc 49:17–28

UN-OCHA (2015) United Nations Office for the Coordination of Humanitarian Affairs (UN-OCHA). http://www.unocha.org/nepal

Van Westen CJ, Castellanos E, Kuriakose SL (2008) Spatial data for landslide susceptibility, hazard, and vulnerability assessment: an overview. Eng Geo 102:112–131

Varnes DJ (1984) Landslide hazard zonation: a review of principles and practice. UNESCO Press, Paris

Wartman J, Dunham L, Tiwari B, Pradel D (2013) Landslides in eastern Honshu induced by the 2011 Tōhoku earthquake. Bull Seismol Soc Am 103(2B):1503–1521

Witze A (2015) Mappers rush to pinpoint landslide risk in Nepal. Nature 521:133–134. doi:10.1038/521133a

Xu C, Xu X, Yu G (2013) Landslides triggered by slipping-fault generated earthquake on a plateau: an example of the 14 April 2010, Ms 7.1, Yushu, China earthquake. Landslides 10:421–431

Yin Y, Wang F, Sun P (2009) Landslide hazards triggered by the 2008 Wenchuan earthquake, Sichuan, China. Landslides 6:139–152

Yu B, Wu Y, Chu S (2014) Preliminary study of the effect of earthquakes on the rainfall threshold of debris flows. Eng Geo 182:130–135

Zhang L, Li J, Liao W, Wang Q (2016) Source rupture process of the 2015 Gorkha, Nepal Mw7.9 earthquake and its tectonic implications. Geode Geodyn 7(2):124–131

The 1985 (M8.1) Michoacán Earthquake and Its Effects in Mexico City

Alejandra Arciniega-Ceballos, Marcela Baena-Rivera and Francisco J. Sánchez-Sesma

Abstract The September 19, 1985 M8.1 earthquake west of Michoacán, Mexico, due to shallow subduction of Cocos plate beneath the North American plate. This mega-thrust inverse faulting event broke about 200 km along the boundary of the Mexican subduction zone in the Pacific coast of Michoacán. This earthquake consisted of two main sub-events at 16 km depth, separated 27s in time and about 95 km SE in distance. Thirty-six hours later, a major M7.5 aftershock occurred in the SE edge of the same area. The 1985 earthquake caused enormous damages, even at distances of up to 300 km from the epicenter. This was the case of Mexico City in which the maximum accelerations recorded reached 0.17 g, exceeding building codes limits (Anderson et al. in Science 233:1043–1049, 1986), and spectral amplifications and duration were unprecedented (Singh et al. in Bull Seism Soc Am 78:451–477, 1988). The official account reported more than six thousand buildings destroyed or seriously damaged and estimated between 10,000 and 35,000 persons missing or dead. After this earthquake, seismic monitoring systems have been developed and improved. The building codes are often revised and regular monitoring of structures is currently done after earthquakes to keep safer standards. In the same vein, a number of educational programs were developed to promote a culture of prevention. It is claimed that the 1985 earthquake generated a widespread solidarity and awareness among city dwellers. On September 19th, 2017, an intraplate earthquake M7.1, hit Central Mexico again, causing extensive building damage, testing the effectiveness of developed programs implemented after the 1985 earthquake.

A. Arciniega-Ceballos (✉)
Institute of Geophysics, National Autonomous University of Mexico (UNAM), Mexico City, Mexico
e-mail: maac@igeofisica.unam.mx

M. Baena-Rivera · F.J. Sánchez-Sesma
Institute of Engineering, National Autonomous University of Mexico (UNAM), Mexico City, Mexico
e-mail: mbaenar@iingen.unam.mx

F.J. Sánchez-Sesma
e-mail: sesma@unam.mx

J.H. Kruhl et al. (eds.), *Living Under the Threat of Earthquakes*,
Springer Natural Hazards, https://doi.org/10.1007/978-3-319-68044-6_4

Keywords Earthquake · Subduction zone · Soil amplification effects
Structural damage · Mexico

1 Introduction

A significant part of Mexican territory is shaken by earthquakes of different types engendered by the tectonic activity of the region. The Cocos and the North American plates at the Mexican subduction zone have a convergence rate of about 5 cm/year. This motion induces intraplate earthquakes ($M \leq 7$) on the North American plate, intermediate normal fault events on Cocos Plate ($M \sim 6$) and large subduction earthquakes ($M > 8$). However, the distribution of intensities and effects of these earthquakes differ. Among the most important subduction events occurred in twentieth century we count:

- The M7.6 earthquake of June 7, 1911 with a rupture area of ca. 60% the one of the 1985 earthquake (UNAM Seismology Group GRL 1986)
- The M7.8 earthquake of July 28, 1957
- The M7.4 Petatlan event of March 14, 1979 which ruptured essentially at the zone of the 1985 major aftershock
- The M7.3 Playa Azul shock that occurred in October 25, 1981 with a rupture area of about 40×20 km^2 (Havskov et al. 1983) (Fig. 1).

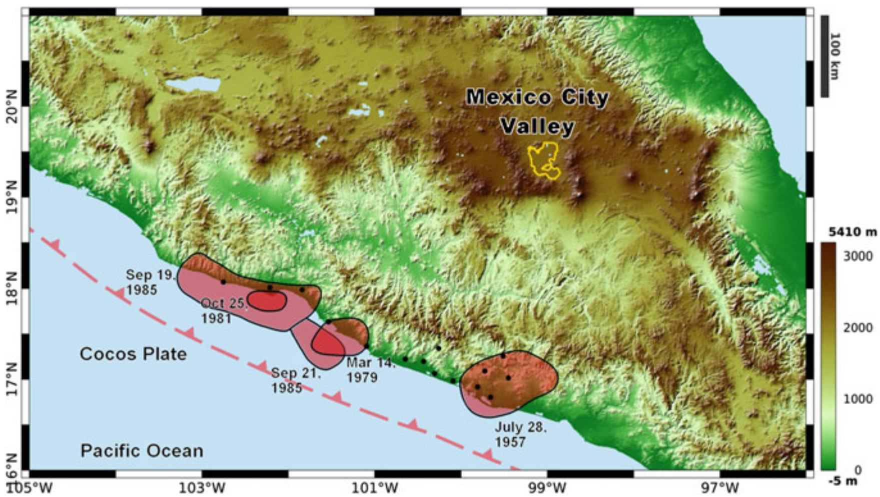


Fig. 1 Elevation map of central Mexico. Mexico City Valley is delineated with a *yellow line* in the middle of Trans Mexican Volcanic Belt. The estimated ruptures of five subduction events are shaded with *red* (from *left* to *right*: 09.19.85 M8.1; 10.25.81 M7.3; 09.21.85 M7.5; 03.14.79 M7.4; 07.28.57 M7.8). The *dashed red line* indicates the trench of Cocos and North American plates and the accelerometric stations of Guerrero Array are plotted with *black dots*

These earthquakes caused minor damage in Mexico City, which is roughly 300 km away from the subduction zone, in comparison with the damage caused by the 1985 earthquake.

Nowadays, although the 1957 and 1979 earthquakes could be seen as a kind of warnings because of conspicuous collapse of some buildings in Mexico City, the lack of reliable historical seismicity data led to minimize the seismic hazard, and therefore effects and intensity of the 1985 earthquakes could not be anticipated. Moreover, the occurrence of such events is considered rare and the systematic recording of earthquakes is relatively recent (Sánchez-Sesma and Crouse 2014). Regarding the 1985 Michoacan Earthquake, it exists a vast bibliography. Among them are the three special issues in *Earthquake Spectra* (1988, 1989). In this paper, a brief account of some relevant seismological facts and important actions taken as a consequence of the 1985 earthquake and its effects on Mexico City are highlighted. This may have some bearing on the reconstruction issues at the aftermath of the April 25, 2014 Nepal earthquake.

2 Geology Frame

The Mexico City Valley geological characteristics are unique. Mexico City is in a plateau at 2250 m.a.s.l., and covers a region of about 110 km N–S and 80 km E–W. Quaternary and Cenozoic volcanoes surround the Valley, and shallow lakes (Xaltocan, Zumpango, Texcoco, Xochimilco and Chalco) formed after the Pleistocene-Holocene Chichinautzin mountain range closed the Basin resulting in the formation of the lacustrine system on which the Mexico City is extended (Fig. 2) (Mooser et al. 1974; Padilla y Sánchez 1989). The City was founded in the fourteenth century and since then floodings were not rare. In the Prehispanic Aztec towns hydraulic control structures like channels and dikes proliferate. The *Chinampas* (kind of floating terrains that eventually became cultivated areas) were also common constructive systems. Since the sixteenth century, with the Spanish Colonization, the lakes started to be drained to avoid the recurrent floodings. Thereby, the City grew within a basin on loose layers of compound soil of clay, sand and volcanics, over the Mesozoic bedrock of marine sedimentary sequence.

The geology conditions of the region constrain the soil characteristics and determine the seismic response of Valley. Mexican engineers knew the peculiar soil conditions of the City and the special requirements were generated for the design of foundations and structures since the early 50s. Marsal and Mazari (1959) classified the soils of Mexico City in the three geotechnical zones depicted in Fig. 2. The Hill Zone, known also as the hard soil, extends on the higher elevations in the Valley, it is composed of lava flows and volcanic tuffs. The transition Zone presents alluvial sandy and silty layers with occasional intervals of clay, and surrounds with some volcanic craters. The Lake Zone, occupies the central area of the Basin, characterized by lacustrine soft-bed soil composed by highly compressible deposits with 20–80 m thickness over resistant sands.

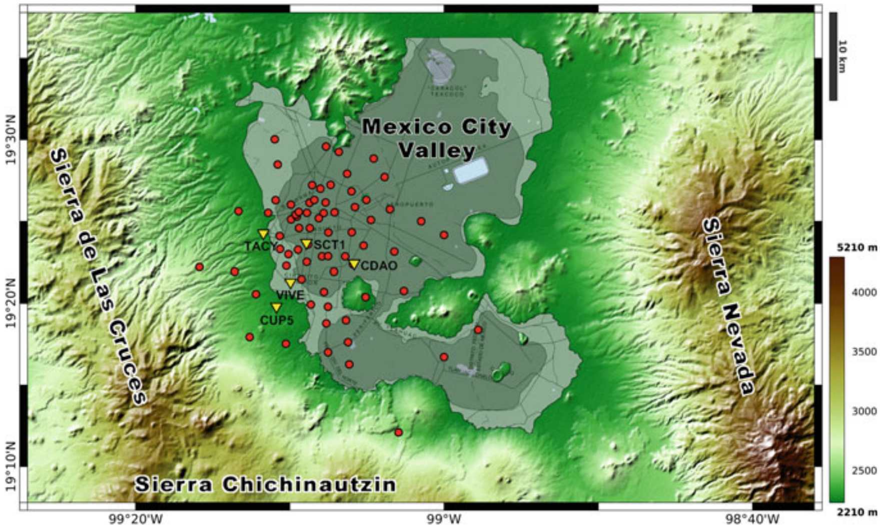


Fig. 2 Elevation map of Mexico City Valley and the mountain ranges that closed the basin: "Sierra de Las Cruces", "Sierra Chichinautzin" and "Sierra Nevada". Inside the basin is the Lake Zone characterized by soft lacustrine soils, shaded in *dark gray*. The Transition Zone is plotted in *light gray* and the Hill Zone (above 2300 masl) in *green*. The *red dots* indicate stations of the Accelerometric Network that operates since 1987 to the present. The *yellow triangles* denote accelerometer stations that recorded the 1985 earthquakes

This geotechnical classification has been useful to establish the building code regulations generated after the careful study of the recorded ground motion before and after 1985. However, this layered classification cannot explain alone the large amplitudes and long durations recorded at sites of the Valley during the Michoacan Earthquake. It is now generally accepted that to forecast the response of the Valley, a complete layered model should take into account the concatenation of source, path and site effects (e.g. Singh et al. 1988; Sánchez-Sesma et al. 1988; Campillo et al. 1989; Castro et al. 1990).

On the other hand, the water supply to the city has been an issue of major concern. Aqueducts provided water but since the mid-nineteenth century, wells were installed to extract the liquid from the aquifers (between the clay formations or below them). With time, the extreme exploitation of the aquifers produces subsidence and the ensuing changes of dominant period of the ground at some sites (Ovando-Shelley et al. 2007). All these effects combined make the Valley of Mexico highly vulnerable to the seismic threat despite of its long distance to the Pacific trench.

3 The 1985 Earthquake Characteristics

Since early 1985, seismologists were waiting for a big quake at the so called Guerrero Gap and a series of accelerometric recording stations have been installed along the Mexican Pacific coast in the Guerrero Array. In fact, the 19 September earthquake occurred in the Michoacán seismic gap, which had been identified as a zone with high seismic potential and was well recorded by the array. This mega-thrust earthquake was caused by subduction of the Cocos Plate beneath Mexico (Fig. 1). The station at Caleta de Campos was just above the epicenter (Anderson et al. 1986). On September 19, 1985, at 07:18 h (local time), a M8 earthquake of occurred with epicenter close to Pacific coast of Mexico, with some damage in the epicentral area and Ciudad Guzman, Jalisco. However, the damages in Mexico City were unprecedented.

The fault rupture area was of about 200 km length along the boundary of the Mexican subduction zone in the Pacific coast of Michoacán and a width of about 50 km. The thrust source mechanism had a 288° fault plane strike and a dip of 9° (Eissler et al. 1986). Strong ground motion investigations indicate that this major earthquake consisted of two main sub-events at 16 km depth, separated 27 s in time and about 95 km SE in distance (Fig. 1). The larger M7.5 aftershock occurred thirty-six hours later, in the SE edge of the same area. The total seismic moment was of about 11×10^{28} dyne-cm (Astiz et al. 1987) and the rupture area was of about 10^4 km^2 (see Fig. 1).

4 Effects of Soil Amplification and Structural Damage

The 1985 earthquake produced large intensities in Mexico City, in the Mercalli scale they reached level IX. Maximum accelerations reached 0.17 g, thus exceeding building codes limits (Anderson et al. 1986) and the spectral amplifications and durations were unprecedented (Singh et al. 1988). These features are quite unusual for an event which epicentral distance to the site is of about 400 km. The earthquake destroyed or severely damaged about six thousand buildings. The causalities are estimated to be between 10,000 and 35,000 people with tens of thousands injured or homeless. The cost of damages has been estimated to be larger than the 2% of the gross domestic product in 1985.

The influence of soft soil on the seismic response of alluvial valleys may produce significant amplifications of the ground motion. This problem has been the subject of numerous studies (e.g. Bard and Bouchon 1980a, b; Sánchez-Sesma 1987; Aki 1988; Kawase and Aki 1989; Campillo et al. 1989). The large amplitude ground motion and long duration records in the lacustrine plain sites in the Valley of Mexico result from the combination of significant source, path and site effects (e.g. Singh et al. 1988; Sánchez-Sesma et al. 1988; Campillo et al. 1989; Castro et al. 1990). Ordaz and Singh (1992) discovered a large regional amplification. They demonstrated, using a data set of seismograms from stations located both inland and along the cost, that seismic waves at hill zone sites in Mexico City are amplified. Such amplifications at the so called “hard zone” are remarkable as they reach at least 10 times at critical frequencies for Mexico City soil conditions (1–5s). Considering that the uppermost soft layers trap the seismic wave energy causing significant ground motion amplifications, reaching 10–50 times, in lake-bed sites with respect to the hill sites at periods between 1 and 5 s. This results in an amplification of 100–500 with respect to the hard sites with similar hypocentral distances, located inland or along the coast. Moreover, their study shows that the amplification effects and damages seem to be independent from the earthquake magnitude. These observations strongly suggest that amplification effects in Mexico City are not only due to the lacustrine soil characteristics. The mechanisms are still to be elucidated as amplifications that are beyond the levels predicted by simple 1D models (Sánchez-Sesma et al. 1988; Singh et al. 1998). All this brings on the validity of the term ‘site amplification’ to adequately explain the observed devastation.

In addition, the number of Pre-Hispanic structures (e.g. channels, tunnels, temples), under which have been built modern structures is unknown. Their condition may cause important effects in the seismic response during earthquakes. Padilla y Sánchez (1989) showed a link between more than 2000 collapsed and damaged buildings and Pre-Hispanic and Colonial structures, during the 1985 earthquake.

Many of the structural collapses were buildings that fulfilled the requirements of the Complementary Technical Standards (NTC) 1976 of the Building Regulations of the Federal District (effective in 1985). This was due to the large values of peak ground acceleration in the Lake Zone (Fig. 2) as compared to the expected values. Ductility factors (Q) was allowed to reach 6, which further decreased the design acceleration.

On the other hand, the duration of ground motion imposes critical conditions to structural response. Based on recorded data Reinoso and Ordaz (2001) proposed expressions to estimate duration in Mexico City in terms of magnitude distance and the dominant period of site. In some sites the duration of strong ground motion in 1985 exceeded 5 min., particularly in the lakebed zone (Fig. 2). This subjected the structures to lasting oscillations, which in some cases may had caused resonance and/or structural failure due to the loss of strength after many cycles of load (Ordaz and Singh 1992). The slab punching by columns revealed lack of shear reinforcement and many systems, particularly reinforced concrete structures, but also those of steel, showed lack of strength and ductility when their periods were close to the site period.

5 New Building Code Regulations

Besides source, paths of seismic waves and the geological and subsoil conditions, irregular settlements in difficult soil conditions and poor enforcement of building regulations contributed to the collapse or failure of hundreds of structures. After the 1985 earthquake, the building codes are often revised and regular monitoring of structures is done after earthquakes to keep safer standards.

Several studies helped to characterize in detail the Mexico City subsoil; results from geotechnical and geophysical prospecting campaigns updated the shallow structure model in some areas inside the Mexico City Valley (Auvinet and Juárez 2011). Imaging investigations for subsidence monitoring and for ground water extraction are taken into account for improving the design of foundations and underground structures (Cabral et al. 2008).

Relying upon the acceleration records at many points in the City an empirical model was developed to evaluate site effects and the response of the Valley (Ordaz et al. 1994). First attempts regarding on spectral ratios were calculated with respect to a reference station at the Hill Zone (CU at UNAM's main campus). Spectral ratios showed remarkable stability for most events, regardless their origin, their source mechanism and their magnitude (Rosenblueth and Arciniega 1992; Arciniega-Ceballos 1990). Applying some averaging techniques and interpolation scheme (Pérez-Rocha 1998) the representative spectral ratio of at each point was obtained. Then, assuming smooth spatial variation of the dominant period and applying random vibration theory (Boore 1983) the response spectra was estimated at any point within the accelerometric array.

Regarding the dominant periods of soil sites, it has recently been discovered that the frequency characteristics of the sites change with time. For instance, the site SCT had 2.0s in 1985 and now is 1.6s (Avilés and Pérez-Rocha 2010). These might be attributed to several factors that alter the soils conditions and their elastic properties (Ovando-Shelley et al. 2007). For those construction systems that are vulnerable to long lasting resonant ground motion, the emergency regulations (released just after the 1985 earthquake and the subsequent versions), included increases in steel reinforcement, like stirrups and joints. Significant strength requirements, regarding sections of columns, walls and beams, were introduced. That leads to increases in stiffness as well. Systems with rigid flat-slabs and frames without walls have now stronger requirements in both strength and ductility. Moreover, slenderness and irregular geometries were restricted. They are however not free of controversy as they leave to designers some freedom to choose, as some simplifications require higher coefficients, while more costly and detailed procedures allow weaker constrains. These specifications and other design parameters have been modified in the 1993 and 2004 versions that are currently used where the seismic coefficient of maximum design acceleration is 0.45 g.

6 Accelerometric Network, Alert System and Institutional Outreach

In 1985 the Mexico City Accelerometric Network (MCAN) had only 9 stations (marked with stars in Fig. 2). Few years after the earthquake, the monitoring systems improved increasing the MCAN around 80 in the free field (Fig. 2). Nowadays the MCAN resulted from joint efforts of collaboration between the Institutes of Engineering and Geophysics, UNAM and Centro de Instrumentación y

Registro Sísmico (CIRES—a private non-profit organization). In addition, around the Valley there are 31 short-period seismometers, operated by the National Seismic Survey, which nowadays counts with a network of 56 broadband STS-2 and 9 short-period seismometers distributed around the country (see http://www.ssn.unam.mx/acerca-de/estaciones/).

A Seismic Alarm System for Mexico City, developed by CIRES, was implemented for earthquakes with magnitudes larger than M6 occurring along the Guerrero and Michoacán coast. This system gives about 50-s warning before the shear waves arrive to the Valley.

In 1988, the National Disaster Prevention Center was established; first, sponsored by the Japanese International Cooperation Agency and later by the Mexican Ministry of Interior. In the last few years an independent organism was created: The Institute for Building Safety which aim is to promote criteria to enforce the fulfillment of code requirements. This requires close collaboration with professional engineering organizations. The widespread damage after the 1985 quake, was enormous and the nature of the causes, initially was a mystery for most of the population, therefore a number of educational actions were developed to promote the culture of prevention: regular simulacrums, insurance information, formation of well-trained emergency search and rescue brigades, are all among the preventive measures adopted.

7 Conclusions

The Valley of Mexico grew on loose layers of compound soil of clay, sand and volcanics. The unconsolidated thick layers of lake sediments (circa 100 m), together with the excess draining of the aquifer, subject the City to severe processes of subsidence. These local characteristics in addition with tectonic and regional settings favor the amplification of seismic waves and long lasting codas.

It is well known that earthquakes cannot be predicted and it is as well difficult to anticipate their intensities. Specially, in the case of complex earthquakes like Michoacán 1985 and Tohoku 2011. These types of events are considered rare and our knowledge about such earthquakes is still limited regarding that the necessary dense seismic networks are relatively recent.

The study of the 1985 Michoacán earthquake and its effects in Mexico City brought on new impetus and several studies have served as an example to the world contributing to our understanding on the seismic response in basins with lacustrine and sand conditions (e.g. San Francisco Bay, CA in 1989). More recent investigations include analyses and modeling of site effects, mechanical and geometrical characteristics of the strata and subsoil and the damage distribution caused by a strong-motion event (Baena et al. 2016 and references here in).

In the same vein, the recently created Institute for Building Safety by the City government may contribute to guarantee structural safety by rigorous code enforcement. The maximum design acceleration were increased, the values of the ductility factor (Q) for different types of structures and building materials were restricted, and increases the steel reinforcement. All these actions are established to implement practical criteria for the adequate assessment of future ground motion levels and seismic risk mitigation. Nevertheless, more efforts have to be done to create awareness among public, architects, engineers planners and policy makers about the implications on living in a region with high rates of seismicity.

8 Addendum

The effectiveness of the developed programs was tested exactly 32 years after the M8.1 1985 Michoacán event by the occurrence of two intraplate earthquakes: the first, M8.2, on September 7th, 2017, in Tehuantepec, at a distance of about 600 km to Mexico City, and the second, M7.1, ironically again on September 19th, between Puebla and Morelos States, only 120 km away from Mexico City. Both events had an extensional mechanism and about the same depth of 57 km, causing considerable damage within a radius of approximately 200 km. During the M8.2 earthquake, maximum accelerations (Amax) did not exceed the values recorded in 1985, causing almost no damage in Mexico City, while during the M7.1 earthquake, Amax in hard zone (57 cm/s2), doubled the response recorded in 1985 (30 cm/s2). Damage not only happened in the soft-lake zone, also many buildings (3 to 8 floors) collapsed in the transition zone. This might be attributed to the high frequency content of the almost vertically incoming waves motion.

It is clear that this recent seismic activity put to the test the programs implemented after 1985. Building codes for different earthquakes scenarios have to be revised as well as the strict supervision of regulations by qualified and uncorrupted authorities.

The Seismic Alert System (SAS) worked during the M8.2 quake as expected but during the M7.1 event the SAS triggered late. This happened because SAS is designed for earthquakes coming from the Pacific coast. Fortunately, the M7.1 earthquake took place 2:15 hours after the annual simulacrum exercise, mitigating considerably the casualties (about 500 nationwide) compared with about 10,000 casualties of the 1985 Michoacán earthquake. This experience states the urgent revision of civil protection programs, in order to strengthen education and routinely practice simulacrum exercises. In addition, a nationwide coverage of the warning system should be achieved.

Acknowledgements Thanks are given to Roberto Meli and Mario Rodriguez for their comments and suggestions. Ana L Ruiz provided some station coordinates. The help of Elizabeth Plata and Guillermina Sánchez and their team of USI-II UNAM was useful to locate references. This work was partially supported by AXA Research Fund, by DGAPA-UNAM, Grants Numbers IN104712, IN106111, IN105716, and by CONACYT 101515.

References

Aki K (1988) Local site effects on strong ground motion. In: Von Thun JL (ed) Earthquake engineering and soil dynamics II: recent advances in ground motion evaluation, Geotechnical Special Publication Am Soc Civil Eng, New York, 20:103–155

Anderson JG, Bodin P, Brune JN, Prince J, Singh SK, Quass R, Onate M (1986) Strong Ground Motion from the Michoacan, Mexico Earthquake. Science 233:1043–1049

Arciniega-Ceballos A (1990) Modelo semi-empírico para estimar espectros de respuesta sísmicos en el valle de México. Thesis, National Autonomous University of Mexico

Astiz L, Kanamori H, Eissler H (1987) Source characteristics of earthquakes in the Michoacan Seismic gap in Mexico. Bull Seism Soc Am 77:1326–1346

Auvinet G, Juárez M (2011) Geotechnical characterization of Mexico City subsoil. In: Proceedings of the 14th Pan-American conference on soil mechanics and geotechnical engineering http://geoserver.ing.puc.cl/info/conferences/PanAm2011/panam2011/pdfs/GEO11Paper1204.pdf

Avilés J, Pérez-Rocha LE (2010) Regional subsidence of Mexico City and its effects on seismic response. Soil Dyn Earthq Eng 30(10):981–989

Baena-Rivera M, Perton M, Sánchez-Sesma FJ (2016) Surface-wave retrieval from generalized diffuse fields in 2D synthetic models of alluvial valleys. Bull Seism Soc Am 106(6):2811–2816. doi:10.1785/0120160084

Bard PY, Bouchon M (1980a) The seismic response of sediment filled valleys. Part 1: the case of incident SH waves. Bull Seism Soc Am 70:1263–1286

Bard PY, Bouchon M (1980b) The seismic response of sediment filled valleys. Part 2: the case of incident P and SV waves. Bull Seism Soc Am 70:1921–1941

Boore D (1983) Stochastic simulation of high-frequency ground motions based on seismological models of the radiated spectra. Bull Seism Soc Am 73(6):1865–1894

Cabral-Cano E, Dixon TH, Mirelles-Wilhelm F, Sánchez-Zamora O, Diaz-Molina O, Carande R (2008) Space geodetic imaging of rapid ground subsidence in Mexico City. Bull Geol Soc Am 120(11/12):1556–1566. doi:10.1130/B26001.1

Campillo M, Bard BY, Nicollin F, Sánchez-Sesma FJ (1988) The Mexico earthquake of September 19, 1985. The incident wave field in Mexico City during the great Michoacan earthquake and its interaction with deep basin. Earthq Spectra 4:591–608

Campillo M, Gariel JC, Aki K, Sánchez-Sesma FJ (1989) Destructive strong ground motion in Mexico City: source, path and site effects during the great 1985 Michoacán earthquake. Bull Seism Soc Am 79:1718–1735

Castro R, Anderson JG, Singh SK (1990) Site response, attenuation and source spectra of S waves along the Guerrero, Mexico, subduction zone. Bull Seism Soc Am 80(6A):1481–1503

Eissler HL, Astiz S, Kanamori H (1986) Tectonic settings and source parameters of the September 1985 Michoacan, Mexico, earthquake. Geophys Res Lett 13:569–572

Havskov J, Singh SK, Nava E, Domínguez T, Rodriguez M (1983) Playa Azul, Michoacan, Mexico, earthquake of 25 October, 1981 (Ms = 7.3). Bull Seism Soc Am 73:449–458

Kawase H, Aki K (1989) A study on the response of a soft basin for incident S, P, and Rayleigh waves with special reference to the long duration observed in Mexico City. Bull Seism Soc Am 79:1361–1382

Marsal RJ, Mazari, M (1959) El subsuelo de la Ciudad de México. Instituto de Ingeniería. Universidad Nacional Autónoma de México

Mooser F, Nairn AEM, Negendank JFW (1974) Palaeomagnetic investigations of the tertiary and quaternary igneous rocks: VIII a palaeomagnetic and petrologic study of volcanics of the Valley of Mexico. Geol Rundsch 63(2):451–483

Ordaz M, Singh SK (1992) Source spectra and spectral attenuation of seismic waves from Mexican earthquakes, and evidence of amplification in the hill zone of Mexico City. Bull Seism Soc Am 82:24–43

Ordaz M, Singh SK, Arciniega-Ceballos A (1994) Bayesian attenuation regressions: an application to Mexico City. Geophys J Int 117:335–344

Ovando-Shelley E, Ossa A, Romo MP (2007) The sinking of Mexico City: its effects on soil properties and seismic response. Soil Dynamics and Earthquake Engineering 27:333–343

Padilla y Sánchez RJ (1989) Geology and tectonics of the basin of Mexico and their relationship with the damage caused by the earthquakes of september 1985. Int J Min Geol Eng 7(1):17–28

Pérez-Rocha LE (1998) Respuesta Sísmica Estructural: Efectos de Sitio e Interacción Suelo-Estructura (aplicaciones al Valle de México). Ph.D. thesis School of Engineering Universidad Nacional Autónoma de México, Mexico

Reinoso E, Ordaz M (2001) Duration of strong ground motion during Mexican earthquakes in terms of magnitude, distance to the rupture area and dominant site period. Earthq Eng Struct Dynam 30:653–673

Rosenblueth E, Arciniega A (1992) Response spectral ratios. Earthq Eng Struct Dys 21:483–492

Sanchez-Sesma FJ (1987) Site effects on strong ground motion. Soil Dyn Earthq Eng 6:124–132

Sánchez-Sesma FJ, Chávez-Pérez S, Suárez M, Bravo MA, Pérez-Rocha LE (1988) The Mexico earthquake of september 19, 1985: on the seismic response of the Valley of Mexico. Earthq Spectra 4:569–589

Sánchez-Sesma FJ, Crouse CB (2014) Effects of site geology on seismic ground motion: early history. Earthq Eng Struct Dyn. doi:10.1002/eqe.2503 (published online in Wiley Online Library)

Singh SK, Mena E, Castro R (1988) Some aspects of the source characteristics and the ground amplifications in and near Mexico City from the acceleration data of september 1985 Michoacan Earthquake. Bull Seism Soc Am 78:451–477

Singh SK, Lermo J, Dominguez T, Ordaz M, Espinosa JM, Mena E, Quaas R (1998) The Mexico earthquake of september 1985 a study of seismic waves in the Valley of Mexico with respect to a hill zone site. Earthq Spectra 4:653–673

UNAM Seismology Group (1986) The September 1985 Michoacan earthquakes: aftershock distribution and history of rupture. Geophys Res Lett 13:573–576

Part II
Damage, Prevention, Restoration

Lessons from Building Damage Patterns During April 25, 2015 Gorkha Earthquake in Nepal

Ramesh Guragain, Surya Narayan Shrestha, Dev Kumar Maharjan and Suman Pradhan

Abstract The April 25, 2015 Gorkha Earthquake of Magnitude 7.8 in Nepal damaged about seven hundred thousand buildings. The main typologies of buildings in the affected area are stone masonry with mud mortar, some buildings with stone and brick masonry with cement/sand mortar and few reinforced concrete buildings with masonry infill. Among the damaged buildings, about 96% of the buildings were masonry and about 4% reinforced concrete buildings with masonry infill. This study conducted detailed damage assessment of over 150,000 buildings of different type of masonry and reinforced concrete (rc) buildings in Nepal. First, the buildings were classified according to different structural types like adobe, stone in mud, brick in mud, stone in cement, brick in cement, wood, bamboo, rc and others. Other important parameters like type of floors and roofs and occupancy of the buildings were noted before starting the detailed damage assessment of structural elements. Damage to overall building as well as to different structural/non-structural elements was categorized into four different categories mainly overall hazard, structural hazard, non-structural hazard and geotechnical hazard. The damage level to different structural/non-structural elements was assigned from insignificant damage to extreme damage in three categories considering the severity of damage like crack widths, delamination, tilting etc. In addition to the severity of damage, extent of damage to that particular element of different severity was also noted. Each type of damage with different severity was estimated in terms of extent like less than 1/3rd of the total area, 1/3rd–2/3rd and more than 2/3rd. Considering

R. Guragain (✉) · S.N. Shrestha · D.K. Maharjan · S. Pradhan
National Society for Earthquake Technology-Nepal (NSET), Karyabinayak, Nepal
e-mail: rguragain@nset.org.np

S.N. Shrestha
e-mail: sshrestha@nset.org.np

D.K. Maharjan
e-mail: dmaharjan@nset.org.np

S. Pradhan
e-mail: spradhan@nset.org.np

J.H. Kruhl et al. (eds.), *Living Under the Threat of Earthquakes*,
Springer Natural Hazards, https://doi.org/10.1007/978-3-319-68044-6_5

the damage severity and extent, overall damage grade to the building was assigned. Finally, based on the damage grade and extent of damage, recommendation for the building, either to demolish, repair and retrofit or just repair was recommended. This study further analyzes the main type of damage to different categories of the buildings and finds out critical factors to be considered for making them earthquake resistant. Existing traditional earthquake resistant elements like wooden bands and their effectiveness on earthquake safety of masonry buildings are further studied. It is found that, corner separation, diagonal cracking, out of plane failure, in-plane flexural failure and delamination are the main type of damage to masonry buildings while soft-story damage, joint failure, lap splice, columns shear failure, beam failure and infill walls failure are the main types of damages to non-engineered rc-buildings.

Keywords Low strength masonry · Non-engineered buildings · Damage patterns

1 Introduction

The April 25, 2015 Gorkha Earthquake of Magnitude 7.8 in Nepal damaged about 700,000 buildings. The main typologies of buildings in the affected area are stone masonry with mud mortar, some buildings with stone and brick masonry with cement/sand mortar and few reinforced concrete buildings with masonry infill. Figure 1 shows the building typology distribution in 31 districts, which were affected by the April 25, 2015 earthquake in Nepal. It shows that about 58% of the buildings are mud based masonry, i.e. stone in mud, adobe or brick in mud; 21% are cement based masonry either stone with cement-sand mortar or brick with cement-sand mortar and about 15% are reinforced concrete with masonry infill. There are other types of buildings that are only about 6%.

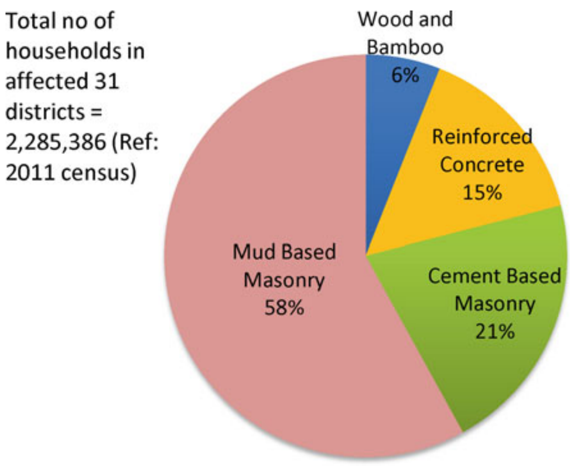


Fig. 1 Overall building typology distribution in the affected area of April 25, Nepal earthquake (CBS 2011)

Large numbers of the residential buildings in developing countries in seismic area are non-engineered type owner-built masonry. Unreinforced stone masonry buildings are common in mountain areas in seismic countries around the world. Stone masonry has been constructed for different use starting from simple residential buildings to palaces, temples and monuments. Bothara and Brzev (2011) have discussed different types of stone masonry buildings in earthquake prone countries and their performance during earthquakes. The performance of masonry buildings during earthquake is very poor. The breakdown of the casualties due to earthquakes in the period of 1900–1990 shows about 75% of the fatalities attributed to earthquakes are caused due to collapse of buildings and the greatest proportion of it is from the collapse of masonry buildings (Coburn and Spence 2002). The performance of stone masonry buildings in different earthquakes shows random shaped stone masonry buildings are more vulnerable than other type of masonry buildings (Spence 2007). Damage to random shaped stone masonry buildings was highest in the 2005 Kashmir earthquake in Pakistan (EERI 2006; Rossetto and Peiris 2009).

Among the damaged buildings, about 96% of the buildings were masonry and about 4% reinforced concrete buildings with masonry infill based on preliminary analysis conducted for preliminary damage and need assessment (PDNA 2015).

The April 25th 2015 Gorkha Earthquake in Nepal caused 8450 deaths and more than 700,000 buildings were severely damaged with a significant number of them collapsed. Most of the death and injuries were caused by the collapse of buildings. Just after the earthquake, though mainly in Kathmandu valley, many organizations provided rapid visual assessment of the buildings and advised people on the possibility of continued use of the buildings or whether evacuation is required.

However, the information on the possibility of repair/retrofit or demolition was not provided by the rapid visual assessment. So, detailed damage assessment of the building is necessary so that reasonable suggestions can be provided to the people in need. Further, the local governments can use the detailed damage assessment information for development of a reconstruction strategy within their territory. In addition, the detailed damage assessment helps to understand the main reason for damage to buildings, and the lessons learned will be beneficial for designing future strategies for disaster risk reduction. In this context, a detailed damage assessment targeting more than 200,000 buildings was conducted by the National Society for Earthquake Technology-Nepal (NSET) after the April 25, 2015 Gorkha Earthquake. This paper highlights the objectives and methodology of the detailed damage assessment, locations and scope of the detailed damage assessment and initial findings and results of the detailed damage assessment.

2 Objectives and Methodology of the Detailed Damage Assessment

2.1 Objectives

The overall objective of the study was to understand the main failure mechanism of different type of buildings, so that the mitigation measures can be optimized in the long run. However, for the immediate benefit for the reconstruction, the specific objectives were to:

- Assess and collect the building damage information in a systematic way
- Provide possible solutions to the affected communities
- Provide references for the policymakers for reconstruction planning based on the results gained from the assessments.

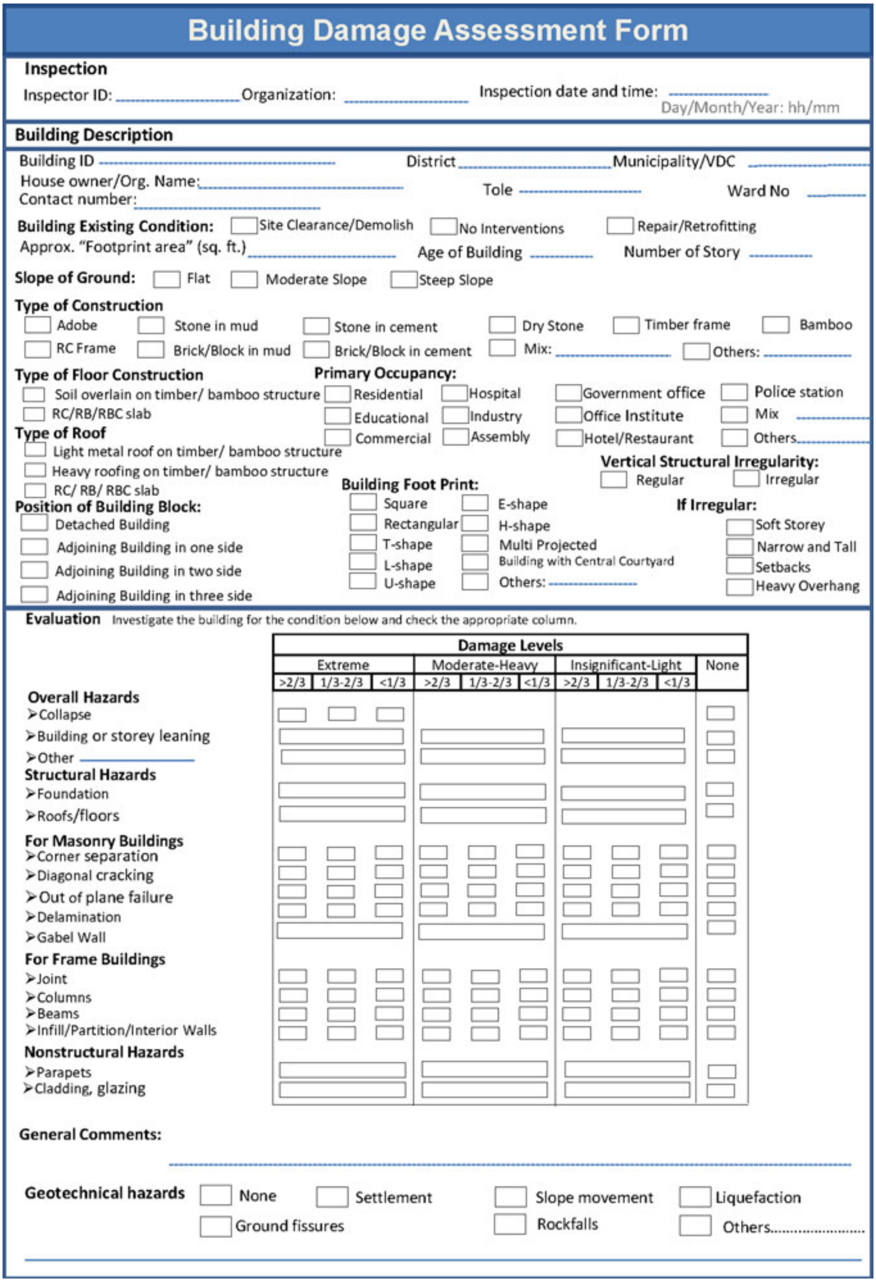
2.2 Methodology

The overall methodology adopted in this study is as follows:

- Development of damage assessment format: The post disaster damage assessment guidelines published by the Department of Urban Development & Building Construction (DUDBC), Government of Nepal, was used to develop the damage assessment format. Figures 2 and 3 show the detailed damage assessment form used for the study.
- Use of IT tools for the survey: An Android application was developed to collect the data.
- Train surveyors: A training curricula was developed to enhance the skills of surveyors to understand the technical and social issues concerning the detailed damage assessment of the buildings.
- Conduct the detailed damage assessment and analyze the data.

First, the buildings were classified according to different structural types like adobe, stone in mud, brick in mud, stone in cement, brick in cement, wood, bamboo, rc and others. Other important parameters like type of floors and roofs and occupancy of the buildings were noted before starting the detailed damage assessment of structural elements.

Damage to the overall building as well as to different structural/non-structural elements was categorized into four different categories namely overall hazard, structural hazard, non-structural hazard and geotechnical hazard. The damage level of different structural/non-structural elements was assigned from insignificant damage to extreme damage in three categories, considering the severity of damage like crack widths, delamination, tilting etc. In addition to the severity of damage, extent of damage to that particular element of different severity was also noted.



Building Damage Assessment Form

Inspection

Inspector ID: ____________ Organization: ____________ Inspection date and time: ____________ Day/Month/Year: hh/mm

Building Description

Building ID ____________ District ____________ Municipality/VDC ____________

House owner/Org. Name: ____________ Tole ____________ Ward No ____________

Contact number: ____________

Building Existing Condition: ☐ Site Clearance/Demolish ☐ No Interventions ☐ Repair/Retrofitting

Approx. "Footprint area" (sq. ft.) ____________ Age of Building ________ Number of Story ________

Slope of Ground: ☐ Flat ☐ Moderate Slope ☐ Steep Slope

Type of Construction

☐ Adobe ☐ Stone in mud ☐ Stone in cement ☐ Dry Stone ☐ Timber frame ☐ Bamboo

☐ RC Frame ☐ Brick/Block in mud ☐ Brick/Block in cement ☐ Mix: ____________ ☐ Others: ____________

Type of Floor Construction

☐ Soil overlain on timber/ bamboo structure

☐ RC/RB/RBC slab

Type of Roof

☐ Light metal roof on timber/ bamboo structure

☐ Heavy roofing on timber/ bamboo structure

☐ RC/ RB/ RBC slab

Position of Building Block:

☐ Detached Building

☐ Adjoining Building in one side

☐ Adjoining Building in two side

☐ Adjoining Building in three side

Primary Occupancy:

☐ Residential ☐ Hospital ☐ Government office ☐ Police station

☐ Educational ☐ Industry ☐ Office Institute ☐ Mix ________

☐ Commercial ☐ Assembly ☐ Hotel/Restaurant ☐ Others ________

Building Foot Print:

☐ Square ☐ E-shape

☐ Rectangular ☐ H-shape

☐ T-shape ☐ Multi Projected

☐ L-shape ☐ Building with Central Courtyard

☐ U-shape ☐ Others: ____________

Vertical Structural Irregularity:

☐ Regular ☐ Irregular

If Irregular:

☐ Soft Storey

☐ Narrow and Tall

☐ Setbacks

☐ Heavy Overhang

Evaluation Investigate the building for the condition below and check the appropriate column.

	Damage Levels									
	Extreme			Moderate-Heavy			Insignificant-Light			None
	>2/3	1/3-2/3	<1/3	>2/3	1/3-2/3	<1/3	>2/3	1/3-2/3	<1/3	
Overall Hazards										
➢Collapse	☐	☐	☐							☐
➢Building or storey leaning	☐			☐			☐			☐
➢Other ________	☐			☐			☐			☐
Structural Hazards										
➢Foundation	☐			☐			☐			☐
➢Roofs/floors	☐			☐			☐			☐
For Masonry Buildings										
➢Corner separation	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
➢Diagonal cracking	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
➢Out of plane failure	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
➢Delamination	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
➢Gabel Wall	☐			☐			☐			☐
For Frame Buildings										
➢Joint	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
➢Columns	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
➢Beams	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
➢Infill/Partition/Interior Walls	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Nonstructural Hazards										
➢Parapets	☐			☐			☐			☐
➢Cladding, glazing	☐			☐			☐			☐

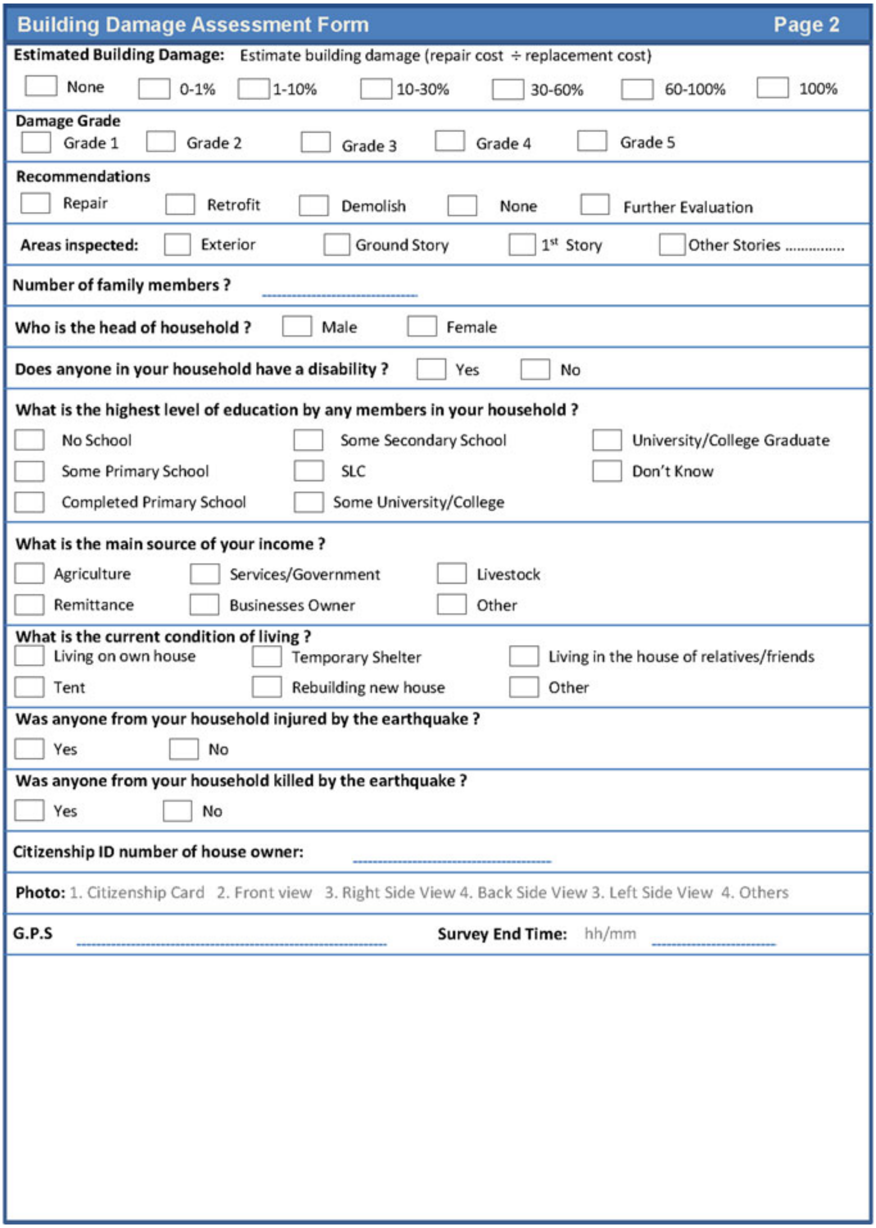
General Comments:

____

Geotechnical hazards ☐ None ☐ Settlement ☐ Slope movement ☐ Liquefaction

☐ Ground fissures ☐ Rockfalls ☐ Others........................

Fig. 2 Detailed damage assessment form (1/2)



Building Damage Assessment Form **Page 2**

Estimated Building Damage: Estimate building damage (repair cost ÷ replacement cost)

☐ None ☐ 0-1% ☐ 1-10% ☐ 10-30% ☐ 30-60% ☐ 60-100% ☐ 100%

Damage Grade

☐ Grade 1 ☐ Grade 2 ☐ Grade 3 ☐ Grade 4 ☐ Grade 5

Recommendations

☐ Repair ☐ Retrofit ☐ Demolish ☐ None ☐ Further Evaluation

Areas inspected: ☐ Exterior ☐ Ground Story ☐ 1st Story ☐ Other Stories ....

Number of family members ? ------------------------------

Who is the head of household ? ☐ Male ☐ Female

Does anyone in your household have a disability ? ☐ Yes ☐ No

What is the highest level of education by any members in your household ?

☐ No School ☐ Some Secondary School ☐ University/College Graduate

☐ Some Primary School ☐ SLC ☐ Don't Know

☐ Completed Primary School ☐ Some University/College

What is the main source of your income ?

☐ Agriculture ☐ Services/Government ☐ Livestock

☐ Remittance ☐ Businesses Owner ☐ Other

What is the current condition of living ?

☐ Living on own house ☐ Temporary Shelter ☐ Living in the house of relatives/friends

☐ Tent ☐ Rebuilding new house ☐ Other

Was anyone from your household injured by the earthquake ?

☐ Yes ☐ No

Was anyone from your household killed by the earthquake ?

☐ Yes ☐ No

Citizenship ID number of house owner: --

Photo: 1. Citizenship Card 2. Front view 3. Right Side View 4. Back Side View 3. Left Side View 4. Others

G.P.S -- **Survey End Time:** hh/mm -------------------------

Fig. 3 Detailed damage assessment form (2/2)

Each type of damage with different severity was estimated in terms of extent like less than 1/3rd of the total area, 1/3rd–2/3rd and more than 2/3rd. Considering the damage severity and extent, an overall damage grade was assigned to the building.

Finally, based on the damage grade and extent of damage, it was recommended either to demolish, repair and retrofit or just repair the building.

3 Study Area and Scope

Figure 4 shows the targeted locations for the detailed damage assessment. This paper presents the preliminary result of about 80,000 buildings already surveyed and analyzed. The number of buildings surveyed and analyzed in different locations is given in Table 1.

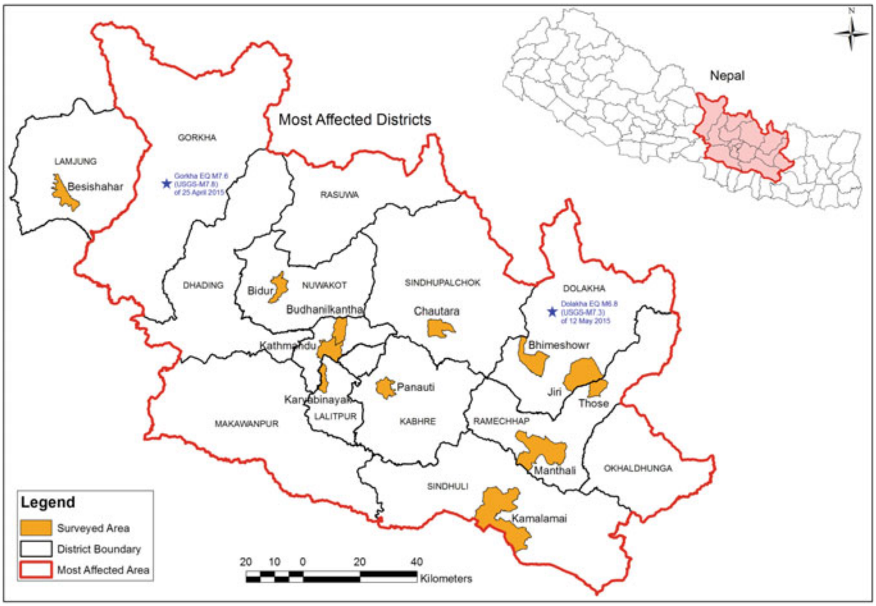


Fig. 4 Locations of the area surveyed for building damage assessment

Table 1 Location and number of buildings surveyed and analyzed

Location	Number of buildings	Location	Number of buildings
Chautara	4308	Jiri	3997
Kamalamai	8575	Panauti	6928
Thosey	754	Manthali	8295
Bidur	6760	Kathmandu	8216
Lalitpur	6630	Bhimeshor	6035
Budhanilkantha	12,723	Besisahar	5597
Total buildings analyzed: 78,918			

4 Preliminary Results

This section highlights the preliminary findings of the analysis of the damage assessment results.

4.1 Building Typology and Number of Story

Figure 5 shows the distribution of buildings with number of stories. The surveyed area was mainly municipalities where more than 92% of the buildings have less than 3 stories. This clearly indicates that, any strategy for risk reduction should focus on low-rise buildings to solve the majority of problems.

Figure 6 shows the distribution of building typology versus number of stories. The interesting fact is that, the 2-story stone-in-mud buildings are found highest in

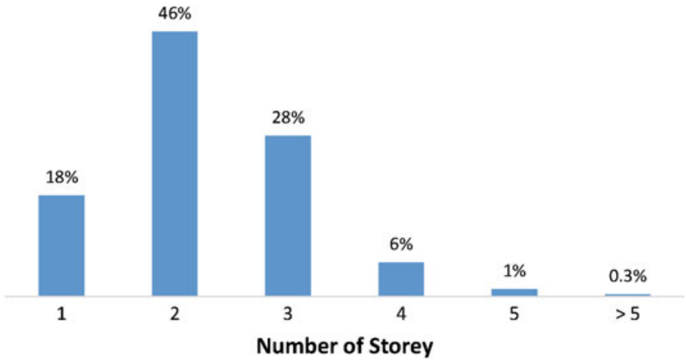


Fig. 5 Distribution of buildings with number of stories

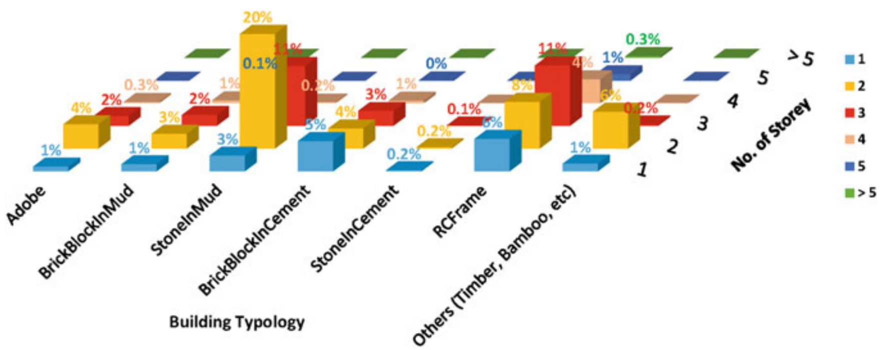


Fig. 6 Building typology versus number of stories from the field survey

number. Among the total of about 80,000 buildings surveyed, 36% are stone-in-mud and 20% of the total are 2-story stone-in-mud buildings. So, on one hand it is clear that earthquake risk reduction should focus on low rise buildings and on the other hand, a safe solution for the construction of 2-story stone-in-mud buildings needs to be developed.

The other important finding is that existing stone-in-cement buildings are less than 1% in total. The study area was in municipalities. If the survey is conducted in rural areas, the ratio of stone-in-cement buildings would be less than this.

4.2 Building Typology and Age Distribution

Figure 7 shows the building typology vs number of stories. The reinforced concrete buildings show very clearly that, these buildings are new and the percentage is higher for recent buildings with ages less than 10 years. However, stone-in-mud buildings show almost uniform distribution among the ages with less than 10 years, 10–20 years and 20–30 years. This fact also indicates that people are still constructing stone-in-mud buildings with very little overall change to other building types.

4.3 Overall Building Damage

Figure 8 shows the overall damage grade distribution of the buildings assessed, while Fig. 9 shows the distribution of damage grades versus building typology. From the grade 5 damage, which is 15% of the total building stock, 11% is stone-in-mud buildings, which is about 75% of the total collapsed buildings. Other categories with major damage are brick-in-mud and adobe.

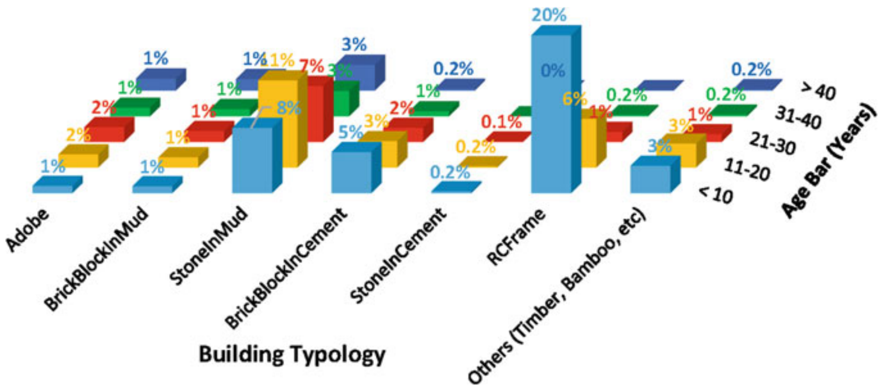


Fig. 7 Building typology versus age distribution

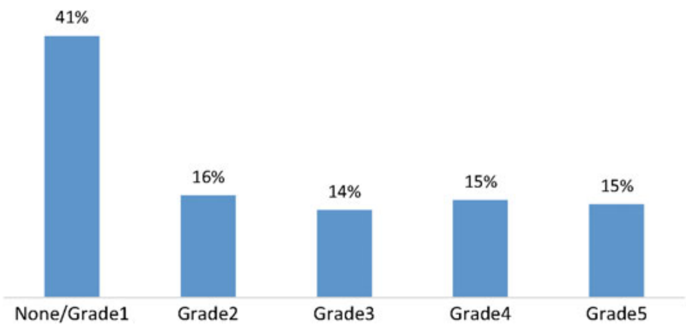


Fig. 8 Overall damage grade distribution

Cleary, very little damage is seen in reinforced concrete buildings. Stone-in-cement and brick-in-cement masonry buildings are also found less vulnerable in comparison to mud-based construction.

4.4 *Overall Building Damage*

Figures 10 and 11 show the comparison of different types of damage to stone-in-mud and brick-in-cement buildings. In stone-in-mud buildings, diagonal cracking and corner separation are found to be the major type of damage. Though delamination is generally considered one of the major problems in stone masonry buildings, relatively minor delamination was observed in those buildings that were still standing. This might be due to the reason that the delaminated buildings collapsed either partially or completely or suffered out-of-plane failure.

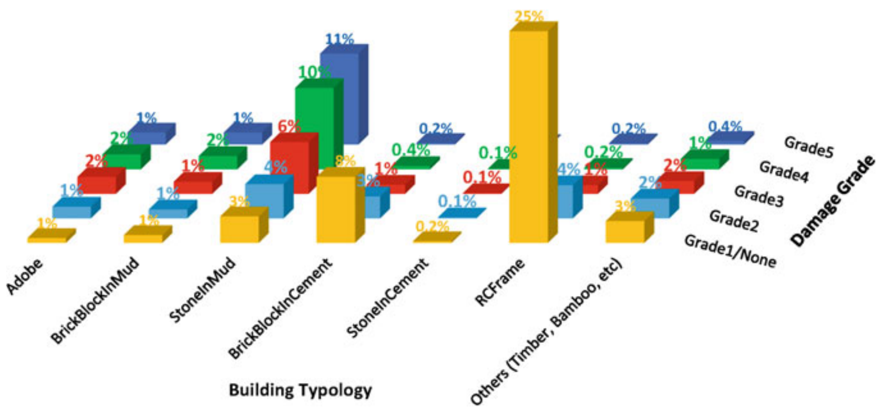


Fig. 9 Overall damage grade distribution versus building typology

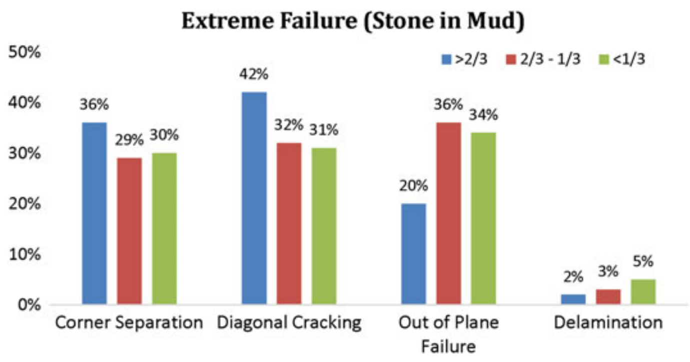


Fig. 10 Different types of damage in stone-in-mud buildings

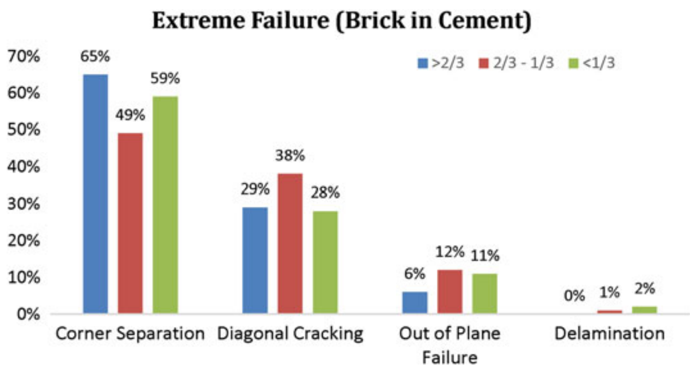


Fig. 11 Different types of damage in brick-in-cement buildings

In brick-in-cement buildings, corner separation and diagonal cracking are the major damage pattern observed in buildings that are still standing. Relatively minor out-of-plane failure was observed and delamination is negligible for this category of buildings.

Figure 12 shows different types of damage to reinforced concrete buildings. Damage to infill walls is the highest. However, this damage can be categorized as tnon-structural damage. The remaining major damage is found in columns and joints, while damage to beams is relatively minor.

4.5 Comparison of Damage to Previous Studies

Fragility functions for different types of masonry buildings in Nepal are provided by Guragain (2015). The Gorkha Earthquake provided accelerometer records in the

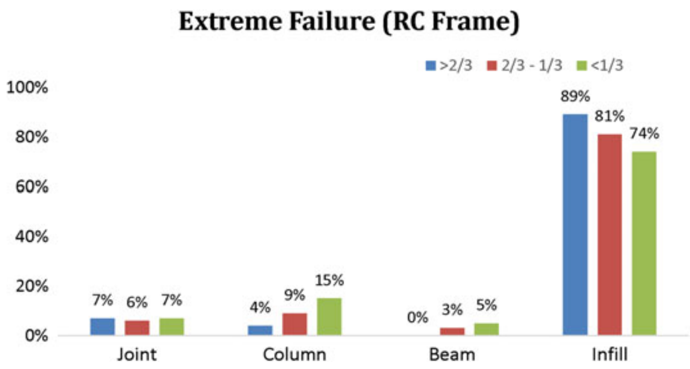
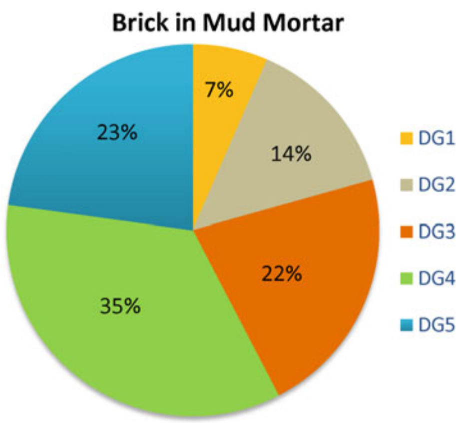


Fig. 12 Different types of damage in rc-buildings with masonry infill

Kathmandu Valley only. So, it was possible to compare the ratio of different grades of damage only in Kathmandu Valley. The average peak ground acceleration in Kathmandu Valley was about 0.2 g. Figure 13 gives different levels of damage to brick-in-mud buildings in Karyabinayak Municipality in Kathmandu Valley and Fig. 14 gives the fragility functions for brickin-mud buildings by Guragain (2015), with the ratio of damage obtained from a field survey. The fragility function shows 50% of buidlings completele damaged (which includes partial and fully collapsed buildings) at 0.2 g, while the damage ratio obtained from the field survey is 56% for complete damage. For moderate damage the fragility function gives 25% compared to 22% from the field survey. Similarly, it is 25% and 21% for slight damage. This comparison shows thtat, the fragility functions by Guragain (2015) are near to the damage ratio obtained in the field. The damage grade definitions are:

- DG1—slight structural damage
- DG2—moderate structural damage
- DG3—significant structural damage

Fig. 13 Percentage of brick-in-mud buildings with damage grades in Karyabinayak municipality



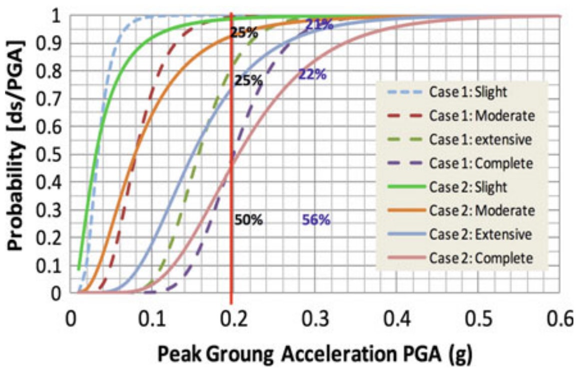


Fig. 14 Fragility function for brick-in-mud buildings by Guragain (2015) with ratio of damage obtained from the field survey at 0.2 g. The percentage values with *black font* are from numerical simulations and with *blue font* are from the field survey

- DG4—partial collapse
- DG5—collapse of the building

Case 1 and case 2 in Fig. 13 represent the numerical simulation results. Case 1 represents simulation results using only the average mortar strengths, while case 2 represents simulation results including very poor mortar strength and very strong mortar strengths as well.

5 Key Lessons for Reconstruction from Damage Assessment

Analysing the damage statistics, the lessons for reconstruction are as follows:

a. **We should focus on appropriate technology:** Most of the buildings damaged during the Gorkha earthquake are masonry non-engineered buildings. It is difficult to transport modern construction materials into remote areas. Even in recent years, people are constructing stone-in-mud buildings. So, it is recommended that the reconstruction techniques should cover stone-in-mud buildings and focus on locally available materials.
b. **Technical Assistance is key for safer construction:** Widespread damage of non-engineered buildings indicates that the construction workers do not know about earthquake resistant techniques. So, it is recommended to plan a massive training program and plan for the training of currently active masons. At the same time, it may be necessary to train new masons, as the need for reconstruction is much higher than for regular construction.
c. **A comprehensive program considering different aspects of technical support is important:** The technical support should be comprehensive, covering awareness of homeowners, capacity building of construction workforce and assist in establishing a system for compliance checks during reconstruction at local government level. The awareness of homeowners can help create demand

for safer construction, as homeowners will control the construction of houses. A trained construction workforce will fulfil this demand and the local government can make the process sustainable with a comprehensive checking system in place.

6 Conclusions

Detailed damage assessment of over 150,000 buildings of different types of masonry and reinforced concrete buildings damaged in the April 25, 2015 Gorkha earthquake in Nepal was conducted and the analysis of about 80,000 buildings is presented in this paper.

This study analyzes the main types of damage to different categories of buildings and identifies critical factors to be considered for making them earthquake resistant. It is found that, corner separation, diagonal cracking, out-of-plane failure, in-plane flexural failure and delamination are the main types of damage to masonry buildings, while joint failure, column shear failure, beam failure and infill wall failure are the main types of damages to non-engineered rc-buildings.

Analyzing the building typology and age of the buildings it is found that, mud-based construction, specially stone-in-mud, is uniformly distributed among the different age categories. This shows the importance of developing an earthquake-safe technology for constructing this type of buildings. The distribution of the number of stories indicates the need for focusing on low-rise buildings, and the highest priority must be given to the development of earthquake-safe 2–3 story stone-in-mud masonry buildings, if the existing construction practice and life style of the people are to survive.

Development and transfer of appropriate technologies, training of construction workforce, awareness of homeowners and institutionalization of safer construction practices in local governments are the important key lessons from this damage assessment of buildings.

References

Bothara J, Brzev S (2011) A tutorial: Improving the seismic performance of stone masonry buildings, Earthquake Engineering Research Institute, EERI Publication Number WHE-2011-01, Oakland, CA, USA

CBS (2011) Report on census survey-2011. Central Bureau of Statistics, The Government of Nepal

Coburn A, Spence R (2002) Earthquake protection. Wiley, New Jersey

EERI (2006). Learning from earthquakes, The Kashmir Earthquake of October 8, 2005: Impacts in Pakistan. EERI special earthquake report, EERI, 94612-1934 Oakland, CA, USA

Guragain R (2015) Development of earthquake risk assessment system for Nepal. Ph.D. dissertation, The University of Tokyo
PDNA (2015) Preliminary damage and need assessment report. World Bank, Nepal
Rossetto T, Peiris N (2009) Observations of damage due to the Kashmir Earthquake of October 8, 2005 and study of current seismic provisions for buildings in Pakistan. Bull Earthq Eng 7:681–699
Spence R (2007) Saving lives in earthquakes: successes and failures in seismic protection since 1960. Bull Earthq Eng 5(2):139–251

Nepal Post Earthquake Cultural Heritage Rehabilitation

Christian Manhart

Abstract This article shows UNESCO's experience in Nepal during and after the 2015 earthquakes in the protection and rehabilitation of the country's rich cultural heritage. It explains the technical and administrative challenges, as well as the actions UNESCO undertook in 2015/16.

Keywords Earthquake · Cultural heritage reconstruction · UNESCO Nepal

Over a year following the two devastating earthquakes in April and May 2015 that hit Nepal, not many of the collapsed temples and historical monuments have been reconstructed. Several critical questions from the people and the media have emerged in this regard. The government and UNESCO have often been asked why they have not been able to undertake reconstruction faster and to do more.

In this article I will explain the reasons behind the slow restoration process and what has been done so far.

I personally experienced both earthquakes. During the first violent shaking of the ground I was in my house in Patan and thanks to the several UN earthquake drills I had participated to, I knew immediately that it was a major one. I was however quite shocked by a number of factors: by the violence of the movements—my house shifted about 50 cm back and forth- by the loud noise provoked by the moving house, soil and falling furniture, as well as the long duration of the quake, it lasted approximately 2 min, which then seemed to be an eternity. It was remarkable that 30 min after the earthquake, mobile phones and the internet functioned rather well, allowing me to inform my headquarters in Paris and my family in Germany that I was alive.

Following a first damage assessment at my residence, I went to the office to proceed with the staff count. One member of our UNESCO team went missing for more than a week as she was on vacation in a northwestern remote area, which was totally cut off. Then I went to the streets, which mainly were covered by rubble and

C. Manhart (✉)
UNESCO, Office to Nepal, Lalitpur, Kathmandu, Nepal
e-mail: c.manhart@unesco.org

J.H. Kruhl et al. (eds.), *Living Under the Threat of Earthquakes*,
Springer Natural Hazards, https://doi.org/10.1007/978-3-319-68044-6_6

to Patan Durbar Square. Here I was again surprised by well-organized local communities which pulled out living and dead bodies from the rubble while moving out and bringing to security in the inner courtyards unique architectural elements including statues and carved wooden beams.

The Department of Archaeology (DoA) assigned to UNESCO a coordination role for all heritage relief work. We organized an initial coordination meeting just a few days after the first earthquake, to which we invited all possible stakeholders and experts, in order to gather information on the damage to heritage sites and draw up priorities.

Jointly with the DoA, we immediately started the assessment of damage, a task in which we were assisted by many volunteers, Nepali and internationals. Many of them came spontaneously to us.

During this process we were closely assisted by our headquarters in Paris which transferred emergency funding, enabling us to pay our volunteers, to employ up to 10 additional staff for our Culture Unit (structural engineers, architects, archaeologists), and to carry out first emergency work for several monuments. The post-earthquake activities represented a boost for the office as many new activities in the fields of culture and education were introduced.

In the first weeks after the earthquakes, we got dozens of media interview requests every day, our team had to mobilize and coordinate volunteers, experts and visitors and UNESCO constantly cooperated with the Department of Archaeology and other stakeholders.

We soon started with the emergency consolidation of buildings, which were still standing, but at risk of collapse due to heavy damage.

At the World Heritage Site of Swayambhu, with the help of a Japanese team from Kyoto University, we evaluated the landslide risks at the south slope of the hill. Just three months prior to the earthquake, a landslide expert had issued a warning on the landslide risk zones in the area. Fortunately the earthquake did not trigger a landslide at the site, the cracks on the south slope of the hill had however widened. A team of experts covered them with tarpaulins to prevent water penetration during the monsoon season. We also secured and inventoried all cultural materials found in the rubble—mainly wooden beams, sculptures and temple items. We excavated the basis of the collapsed small Tashi Gomang Stupa with the aim of consolidating it before reconstruction. Among the rubble we found 9 sculptures, jewelry, gold and silver coins mostly of nineteenth century and thousands of small —2 to 3 cm—clay votive stupas. All the artifacts were inventoried and put in a secure place located in a priest's house. All materials have been placed back into the stupa during reconstruction. We also sealed the cracks of the main stupa to make it water proof for the monsoon period which was quickly approaching. All activities were carried out with the help of the local priests, as laymen are not allowed to step in the stupa. We safeguarded and restored the mural paintings of the Shantipur Temple with the help of an internationally renowned expert from Italy, who came twice for a month. He also organized trainings for national specialists in murals conservation. The Shantipur Temple, which was badly damaged with several collapsed walls, was shored all around, and we are now preparing a detailed plan on how to reconstruct it.

The Hanumandhoka Museum at Kathmandu Durbar Square was badly damaged and the walls of two buildings resulted totally shaky after the earthquake. However, they still contained 6000 cultural objects, which had to be taken out urgently. We were provided assistance from a team of ICOM,[1] ICCROM[2] and ICOMOS,[3] which carried out a series of vital training sessions with national experts, in shoring, as well as packing, removing and conserving museum objects. The damaged walls of the museum collapsed shortly after the rainy season in 2015, and we are preparing a plan together with the DoA tackling how to safeguard and restore the remaining parts of the museum structure. Since autumn 2015 we have collected architectural features from the destroyed temples within and beyond the Kathmandu Durbar Square—notably wooden beams, which had been removed by bulldozers just after the earthquake and placed in 26 different so-called “dumping sites”. These elements were recorded, analyzed, cleaned and restored, in order to be reused in their original locations.

Several institutions found out that much more historical structures collapsed compared to concrete ones and concluded that everything should be reconstructed now in reinforced concrete, to be resistant to the next earthquake. Some even recommended to build temples in concrete and to paste historically looking facades in the front. It is indeed interesting to analyze the reasons behind the collapse of innumerable historical structures, public buildings as well as private houses. Most historical buildings are a mix of brick and sal wood, giving them strength and at the same time the flexibility to move horizontally in the case of an earthquake. We identified two reasons for collapse: first the fact that many historical buildings were rebuilt after the 1934 earthquake in a quick and cheap way, mainly reducing the amount of expensive sal wood used. Second the lack of maintenance. When it comes to the maintenance of temples, it is necessary to prevent water penetration from the roof and the bottom as well as exchanging deteriorated parts in order to keep buildings strong and resistant.

Overall, less concrete buildings collapsed because most of them were relatively new—Kathmandu’s population has risen within the last 10 years from 600,000 to 3 million. It is common knowledge that concrete has a life expectancy normally limited to 50–70 years—a period, too short for heritage buildings. We therefore plead in the context of Nepali heritage buildings using as far as possible traditional building methods, which can be adapted on a case-to-case basis, and to systematically invest in the maintenance of buildings.

I began the article, by asking what were the reasons for the delay in rebuilding cultural heritage. The first is that the proclamation of the Constitution in September

[1]ICOM: International Council of Museums.

[2]ICCROM: International Centre for the Study of the Preservation and Restoration of Cultural Property.

[3]ICOMOS: International Council on Monuments and Sites.

2015 triggered the blockade of the border with India for six months, resulting in severe shortage of imported goods and in particular a major fuel crises. This stopped most reconstruction projects. The rather unstable political situation and lengthy bureaucratic government approval procedures are another factor. Furthermore, heritage restoration mostly requires long preparations, such as excavations to see whether the foundations are stable, inventory and analysis of architectural elements, which can be re-used. An individual rebuilding plan has to be prepared for each monument, as each has its particular problems.

UNESCO participated in revising the heritage building codes, with the purpose of rebuilding better and earthquake resilient structures while respecting traditional building materials and techniques—for the moment only available in Nepali language.

In the fields of Education and Culture, UNESCO Kathmandu participated in the Post Disaster Needs Assessment, PDNA, which was a major challenge, not only due to the short timeframe—one-week preparation plus 3 weeks work—but also because of the lack of much needed information. The needs assessment was the basis for the donors' conference held on 25 June 2015, and the establishment of the government budget.

The assessment found that out of 691 damaged historic buildings in 16 districts—131 fully collapsed and 560 were partially damaged. Total needs identified by PDNA in the field of Culture were over $200 million. This included not only the reconstruction of collapsed buildings, but also the consolidation of still standing structures, the strengthening of the Department of Archaeology, the restoration of damaged monasteries (which are often no historical buildings), the rehabilitation of intangible heritage and valorization of the arts and crafts.

Since then, it has been a challenge to integrate PDNA results into policy and implementation in the present context of Nepal. The National Reconstruction Authority with a mandate to coordinate structural assessments and reconstruction, formed by the Cabinet, took many months to become operational and underwent many structural and staff changes. Another concern for UNESCO is the government's bidding process, which has to be applied to modern and historical structures, and which awards the contract to the lowest bidder, who cannot ensure best quality standards. This is not suitable for cultural heritage buildings and UNESCO is advocating for a change in the bidding rules and respect of international conservation standards.

The culture sector in Nepal is recognized by politicians, the media and certain donors an essential development factor—mainly through tourism and employment generation—as well as a source of national pride. There is also quite a lot of donor interest in the field of culture after the earthquakes that hit the country. So far, UNESCO has obtained funds-in-trust from the governments of Japan and Flanders, as well as from the Hong Kong based Fok Foundation and the Chinese province of Hainan. Many other donors have established bilateral collaborations with UNESCO including the USA, Germany, Austria, India, China, the US based Global Heritage Fund and others. UNESCO cooperates with most of these donors, provides technical advice to them and the government. In parallel UNESCO continues implementing own consolidation and restoration projects at Swayambhu, Hanumandhoka, Jagarnath, Gopinath, Patan and Changu Narayan. If funding will be available, we intend to carry out a pilot restoration project in Sankhu, a medieval Newari city in the east of Katmandu, which is on the tentative list for World Heritage inscription (UNESCO 2017). Jointly with the Department of Archaeology, UNESCO has initiated a large documentation project for the creation of a holistic cultural heritage inventory, run on the Arches platform. UNESCO has also close cooperation with international institutions, such as ICOMOS, ICOM, SOAS,[4] ICCROM.

What is more, we have obtained excellent documentation of most monuments with old photographs, drawings, plans and measurements. Many architectural elements have survived the earthquake including statues, sculptures, carved wooden beams, corner stones, lintels and so forth. Despite the challenges, we remain optimistic that through collective efforts, Nepal's historical buildings will be reconstructed and consolidated. As the saying of people affected by the disaster was, Nepal will rise again.

References

National Planning Commission: Government of Nepal (2015) Post Disaster Needs Assessment. Volume B: Sector Reports, Singha Durbar, Kathmandu. http://un.org.np/sites/default/files/PDNA-volume-B.pdf. Accessed 10 Feb 2017

UNESCO (2017) UNESCO Tentative Lists. http://whc.unesco.org/en/tentativelists/. Accessed 10 Feb 2017

[4]SOAS: School of Oriental and African Studies, University of London.

Heritage and Reconstruction: Different Perspectives

Luigi Petti, Claudia Trillo and Martina Di Mauro

Abstract Heritage is the physical expression of the cultural identity of local communities and in most cases it is a key factor supporting the development of the local economy. Due to its own nature, heritage is a non-renewable patrimony to protect for the future generations. The purpose of this paper is to describe reconstruction issues for urban conservation in historic cities, which have been led to destruction by accident, because of flooding, earthquakes, storm, fires, and also war, pointing out the association between conservation and development. In so doing, the paper will focus on the case study of a city listed in the World Heritage List, Kathmandu. A further matter concerns the controversial approach of reconstruction: while restoration aims to bring a monument back to its original state or preserve from further damage, reconstruction instead is accomplished on buildings that are destroyed or constituted of just limited ruins, sometimes even requiring the construction of a new building. After the Second World War the patrimony of the European historic cities was severely damaged, making the population aware of their loss of cultural and national identity and opening the international debate on the proper techniques and theories that should be applied. When it comes to historical cities, rather than a single monument, it does not involve just the physical appearance and the historical value but might allow to reinstate the socio-economic condition and the cultural identity of a place after a period of decline.

Keywords Reconstruction · Cultural heritage · Criteria · Strategies

L. Petti (✉) · M. Di Mauro
Department of Civil Engineering, University of Salerno, Salerno, Italy
e-mail: petti@unisa.it

M. Di Mauro
e-mail: dimauro.martina@gmail.com

C. Trillo
School of Built Environment, University of Salford, Salford, UK
e-mail: c.trillo2@salford.ac.uk

J.H. Kruhl et al. (eds.), *Living Under the Threat of Earthquakes*,
Springer Natural Hazards, https://doi.org/10.1007/978-3-319-68044-6_7

1 Reconstruction: An Approach for Conservation

According to current theories, reconstruction is an acceptable approach in heritage conservation when it concerns the rebuilding of monuments and sites that have been destroyed by accident, by natural calamity such as an earthquake, or by war referring to tangible proof (Petzet 2004). Especially the repercussions of the First and Second World Wars and the destruction of the historic part of the cities spread across the inhabitants the awareness of the loss of their heritage and the need of recovering their past (Smets 1987) allowed the legitimization of reconstruction and the diffusion of several rebuilding works.

Remarkable examples are the Horyu-ji Temple at Nara in Japan, destroyed by a fire in 1949 and rebuilt in 1954, the reconstruction in 1908 of the Campanile of San Marco in Venice after its sudden structural collapse, the Old Bridge at Mostar destroyed in 1993 due to the war of Balkans and the Frauenkirche in Dresden destroyed during the Second World War (Stanley-Price 2006).

The term "reconstruction" owes its negative sense to the several restorations of ruins made in the 19th century and based on Viollet-le-Duc's theory. According to his concept of restoration, based on the monument's integrity and the achievement of the "stylistic unity" to restore a building is "not to maintain it, repair it or refurbish it, it means to re-establish it to a state of completeness that may have never existed, at any given moment" (Viollet-le-Duc 1990) even including those parts designed by the previous architect but never actually realized and also adding new parts of his own design. This attitude has been severely criticized not only by his contemporaries, such as the art critic John Ruskin whose theories supported the conservation of the monument's historical matter in order to preserve its authenticity (Vieira 2004), but also by twentieth-century critics and restorers who believed that his restorations were mainly creative and based on his personal ideal of Middle ages instead of historical evidences.

In Italy, the architect and art critic Camillo Boito, with his theoretical approach known as philological restoration, can be considered a mediator between the conceptions of his contemporaries on architectural restoration. His theory is exposed in the document called "Prima carta del Restauro" presented at the III Conference of Architects and Civil Engineers of Rome in 1883. In brief, he criticized the "misconstruction" of the monument, which should be considered as "a book, that I want to read without cuts, retouching and rehashes". He asserted that the only way to avoid imitation was to make noticeable the new intervention "so that everyone can recognize it as a modern work" (Piazza and Riggio 2007). His position has been recorded in article 12 of the Venice Charter. In 1933, *the Charter of Athens* referred to the technique of anastylosis, a sort of reconstruction applicable in the occurrence of archaeological sites: "In the case of ruins…steps should be taken to reinstate any original fragment that may be recovered (anastylosis) wherever this is possible" (CIAM 1993).

Also The *Charter of Venic*e of 1964, which is still one of the most influential conservation document internationally accepted (ICOMOS 1990), allows this method concerning archeologic ruins in art. 15: “All reconstruction work should however be ruled out a priori. Only anastylosis, that is to say, the reassembling of existing but dismembered parts can be permitted. The material used for integration should always be recognizable and its use should be the least that will ensure the conservation of a monument and the reinstatement of its form.” However, the chart still maintains a restrict attitude regarding reconstruction in general as conservation should “respect for original material and authentic documents. It must stop at the point where conjecture begins, and in this case moreover any extra work which is indispensable must be distinct from the architectural composition and must bear a contemporary stamp. The restoration in any case must be preceded and followed by an archaeological and historical study of the monument” (art. 9) and “replacements of missing parts must integrate harmoniously with the whole, but at the same time must be distinguishable from the original so that restoration does not falsify the artistic or historic evidence.” (art. 12)

The cautious approach reconstruction proposed with the Venice Charter has been evoked in the numerous following documents. Actually, in the document of the World Heritage Convention of 1972 which sets the criteria of inscription of cultural properties in the World Heritage List of the UNESCO is stated “that reconstruction is only acceptable if it is carried out on the basis of complete and detailed documentation on the original and to no extent to the conjecture” (§ 73.9. b.2 World Heritage criteria).

Another example is the revised version of the Burra Charter of Australia ICOMOS of 1999, originally developed in Australia but internationally considered valid (Stanley-Price 2009) and appropriate, which states that:

> Article 1.8.
>
> Reconstruction means returning a place to a known earlier state and is distinguished from restoration by the introduction of new material into the fabric.
>
> Article 20. Reconstruction.
>
> 20.1. Reconstruction is appropriate only where a place is incomplete through damage or alteration, and only where there is sufficient evidence to reproduce an earlier state of the fabric. In rare cases, reconstruction may also be appropriate as part of a use or practice that retains the cultural significance of the place.
>
> 20.2. Reconstruction should be identifiable on close inspection or through additional interpretation.

The common principle which led all the charters is still valid in the most recent World Heritage Operational Guidelines of July 2015 that consider “reconstruction of archaeological remains or historic buildings or districts is justifiable only in exceptional circumstances” and “is acceptable only on the basis of complete and detailed documentation and to no extent on conjecture.”

In any case, it cannot be considered a simple action of rebuilding. While reconstruction, considered a proper restauration technique, has philological bases (iconographic, written, or material evidence) rebuilding does not necessarily take into account evidences of the previous state (Piazza and Riggio 2007). In order to avoid improper interventions realized in spite of the lack of evidence, the matter of authenticity has become of increasing importance in the recent past years.

The Venice Charter in 1964 was the first international document to mention the concept of authenticity in the field of cultural heritage (Nezhad et al. 2015) in its preamble declares that: “The common responsibility to safeguard them (the monuments) for future generations is recognized. It is our duty to hand them on in the full richness of their authenticity”.

Later, in 1977 the World Heritage Committee of UNESCO stated authenticity as a requirement for the inscription in the World Heritage List introducing a “test” for the assessment explained in article 9 of the Operational Guidelines made up of four different criteria: Design, Materials, Workmanship and Setting. It is relevant to point out that these four attributes are concerning just tangible aspects of the heritage (Denyer 2011). The first serious discussions and analyses regarding intangible heritage emerged just in 1994 with the World Heritage Convention held in Nara (Japan), which stated in article 7 of its declaration that: “All cultures and societies are rooted in the particular forms and means of tangible and intangible expression which constitute their heritage, and these should be respected.” On these basis, Japan was the first nation in the world to institute in its legislation the legal protection for intangible cultural heritage with the Japanese Law for Protection of Cultural Properties in 1998 (Jokilehto 2006).

Concerning reconstruction Japan has always had a different attitude compared to the Western society: the best examples are the temples in Ise, which are demolished and completely rebuilt every twenty years, symbolizing the renewal of the imperial family (Adams 2013). These religious traditions have led to a different approach regarding authenticity (Hourbart and Dawans 2011).

Consistently the Nara Document asserted that the assessment of authenticity could not be regulated by fixed criteria but had to take into account cultural differences and peculiarities (Jokilehto 2013):

> Art.11: All judgements about values attributed to cultural properties as well as the credibility of related information sources may differ from culture to culture, and even within the same culture. It is thus not possible to base judgements of values and authenticity within fixed criteria. On the contrary, the respect due to all cultures requires that heritage properties must be considered and judged within the cultural contexts to which they belong.
>
> Art.12: Therefore, it is of the highest importance and urgency that, within each culture, recognition be accorded to the specific nature of its heritage values and the credibility and truthfulness of related information sources.

Likewise, in 2000 the *Charter of Riga on authenticity and historical reconstruction in relationship to cultural heritage* has declared in article 6 that reconstruction could be acceptable in exceptional circumstances, such as a human or natural disaster (Hourbart and Dawans 2011) “when the monument concerned has outstanding artistic, symbolic or environmental (whether urban or rural) significance for regional history and cultures; provided that:

- appropriate survey and historical documentation is available (including iconographic, archival or material evidence);
- the reconstruction does not falsify the overall urban or landscape context; and
- existing significant historic fabric will not be damaged; and
- providing always that the need for reconstruction has been established through full and open consultations among national and local authorities and the community concerned."

Basically, the charter of Riga laid the theoretical groundwork in order to justify a more permissive approach compared to the attitude set in the chart of Venice and establishing a new philosophy based on more permissive criteria (Dushkina 2005).

Contemporary to the Riga Charter, in 2000 the *Charter of Cracow* recognised for the first time the legitimate use of a reconstructive approach to restoration in case of damage caused by war: "Reconstruction of an entire building, destroyed by armed conflict or natural disaster, is only acceptable if there are exceptional social or cultural motives that are related to the identity of the entire community." (András 2002).

Having discussed the principles stated in the most important and international documents, it is possible to identify the common criteria that legitimate reconstruction as an appropriate approach in heritage conservation, which is legitimate when:

- Occurred rare and calamitous events;
- Monuments are completely destroyed, testified by very bare remining tangible matter;
- Consistent documentation is available in order to lead the reconstruction process (Stanley-Price 2006).
- The following table summarises the principles stated in the most important and international documents (Table 1).

2 Reconstruction as a Tool for Cultural and Economic Regeneration

The previous paragraph has exhaustively examined the physical process of rebuilding. However, when the action of reconstructing depends on the event of a natural disaster, such as an earthquake, or of an armed conflict its effects are not limited to tangible matter of the heritage but it implies the regeneration of the social- economic condition of an area and the cultural identity of the local population after a crisis (Jokilehto 2013).

After the Second World War the patrimony of the European historic cities was severely damaged and in some cases such as London, Dresden, Warsaw and Florence extensively destroyed. Therefore, the restauration could be explained not only by cultural and intellectual reasons but also psychological motivations.

In those exceptional cases the principles of the philological restoration based on the minimal intervention and the neutral addition stated in the document called

Table 1 Summary of the principles stated in the most important and international documents

Charter	Proposed policy and recommendation on reconstruction
Charter of Athens (1933)	"In the case of ruins, scrupulous conservation is necessary, and steps should be taken to reinstate any original fragments that may be recovered (anastylosis); the new materials used for this purpose should in all cases be recognisable"
Charter of Venice (1964)	(art. 15) "All reconstruction work should however be ruled out a priori. Only anastylosis, that is to say, the reassembling of existing but dismembered parts can be permitted. The material used for integration should always be recognizable and its use should be the least that will ensure the conservation of a monument and the reinstatement of its form" (art. 9) "respect for original material and authentic documents. It must stop at the point where conjecture begins, and in this case moreover any extra work which is indispensable must be distinct from the architectural composition and must bear a contemporary stamp. The restoration in any case must be preceded and followed by an archaeological and historical study of the monument" (art. 12) "replacements of missing parts must integrate harmoniously with the whole, but at the same time must be distinguishable from the original so that restoration does not falsify the artistic or historic evidence"
WH Convention (1972)	'That reconstruction is only acceptable if it is carried out on the basis of complete and detailed documentation on the original and to no extent to the conjecture''
Burra Charter of Australia ICOMOS (1999)	"Article 1.8: Reconstruction means returning a place to a known earlier state and is distinguished from restoration by the introduction of new material into the fabric Article 20. Reconstruction 20.1. Reconstruction is appropriate only where a place is incomplete through damage or alteration, and only where there is sufficient evidence to reproduce an earlier state of the fabric. In rare cases, reconstruction may also be appropriate as part of a use or practice that retains the cultural significance of the place 20.2. Reconstruction should be identifiable on close inspection or through additional interpretation"
Charter of Riga (2000)	(art.6) Reconstruction could be acceptable in exceptional circumstances, such as a human or natural disaster "when the monument concerned has outstanding artistic, symbolic or environmental (whether urban or rural) significance for regional history and cultures; provided that: (1) appropriate survey and historical documentation is available (including iconographic, archival or material evidence); (2) the reconstruction does not falsify the overall urban or landscape context; and (3) existing significant historic fabric will not be damaged; and

(continued)

Table 1 (continued)

Charter	Proposed policy and recommendation on reconstruction
	(4) providing always that the need for reconstruction has been established through full and open consultations among national and local authorities and the community concerned"
Charter of Cracow (2000)	"Reconstruction of an entire building, destroyed by armed conflict or natural disaster, is only acceptable if there are exceptional social or cultural motives that are related to the identity of the entire community"
World Heritage Operational Guidelines (2015)	"Reconstruction of archaeological remains or historic buildings or districts is justifiable only in exceptional circumstances" and "is acceptable only on the basis of complete and detailed documentation and to no extent on conjecture"

Source Authors' elaboration

"Prima carta del Restauro" in 1883 and reaffirmed in 1931 in the charter of Athens were completely inadequate as the reconstruction would have affected vast urban areas, not only small parts of an individual monument (Varagnoli 2015).

As a result of the absence of an appropriate regulation different approaches have been used in each city. The analysis of disparate interpretations of the reconstruction issue given in Italy, Poland and Germany (the countries most effected by the war destruction) may be considered the base on which the modern theories on restauration and reconstruction of the historic cities have been built.

In Dresden, where 85% of the town was destroyed by allied bombing in 1945, monuments were rebuilt in order to imitate the previous image of the historic center tied to sentimental connection with the destroyed heritage.

In Warsaw, the Old Town was destroyed by the enemy, aspiring to the cancellation of the Polish cultural identity. That is why it was rebuilt not as it appeared just before the war but in its eighteenth-century image, when the town was free from the invaders and living its most prosperous period in order to re-establish the Polish national identity (Talò 2012).

In Florence, the German army destroyed five of the six bridges of the town. The only one to be saved was Ponte Vecchio, nevertheless the historic buildings on the river sides was severely damaged. The bridges have been rebuilt as they were before the attack, instead the urban area has been reconstructed according to the lost volume but in modern forms, due to providing new houses and improving the living conditions (Larkham et al. 2014).

Different was the case of London, where the war destruction has been considered as an opportunity of change (Bullock 2002): the design of new buildings took inspiration from modern style although the still standing old churches were kept as an element of continuity in this new urban context (Jokilehto 2013).

In spite of these famous examples, in all Europe inappropriate reconstruction activities have been conducted led by the population's awareness of their loss of cultural and national identity, opening the international debate on the proper techniques and theories that should have been applied.

In 1976, the UNESCO Recommendation concerning the Safeguarding and Contemporary Role of Historic Areas emphasized that "throughout the world, under the pretext of expansion or modernization, demolition ignorant of what it is demolishing and irrational and inappropriate reconstruction work is causing serious damage to this historic heritage" (UNESCO 1976).

Later, the matter of appropriate reconstruction of historic heritage wrecked by war was discussed in the ICOMOS symposium in Dresden in November 1982 (Jokilehto 2013), which produced a document in form of operative guidelines whose article 8 sets "The complete reconstruction of severely damaged monuments must be regarded as an exceptional circumstance which is justified only for special reasons resulting from the destruction of a monument of great significance by war. Such a reconstruction must be based on reliable documentation of its condition before destruction."

When it is applied according to the appropriate approach reconstruction is not only a way to restore the cultural identity but also to led a process of economic regeneration since heritage has an important economic impact because it "constitutes a powerful driving force of inclusive local and regional development and creates considerable externalities, in particular through the enhancement of sustainable cultural tourism" (Council of the European Union 2014) and produces an economic benefit for the public or private authorities that manage it (Stanley-Price 2006) adding tangible economic value to cultural resources (UNEP 2005).

The relationship between national identity and tourism promotion can be clarified looking at the experiences in Easter Europe had after the war of political separation of Yugoslavia (1991–2001) where reconstruction had the double aim of recreating the national identity and the economic conditions, in order to renovate the importance as a touristic attraction held by Yugoslavia in the previous decade (Hall 2002).

The attack on Dubrovnik, Croatia, is a distinct case compared to the other destructions made in the Balkans: it had the clear intention of reducing the touristic potential of the destination, famous to be the image of Croatia in Western Europe, and prevent its economic income (Wise and Mulec 2015).

For this reason, the restoration that involved of the roof line of Dubrovnik is considered a remarkable example of economic regeneration.

The town old Dubrovnik was born in the thirteenth century but widely developed only during the fourteenth and fifteenth when it prospered as the capital of the maritime Republic of Ragusa. It had been completely destroyed on the 6th April 1667 and successively rebuilt in baroque style.

Other two earthquakes on 15 April 1979 and 25 May 1979 caused damage to 1071 structures (UNESCO 1993) and several others were completely destroyed. In the same year, it became a World Heritage Site and the restoration continued until it had to stop in October 1991 because of the civil war of Yugoslavia. The bombardments, protracted until June 1992, worsen the damage owed to the earthquake of 1979. The worst shelling took place on 6 December 1991 and in the same month Dubrovnik was added to the list of World Heritage in Danger.

The bombing damaged around 69% of the rooftops for an overall surface of 40,693 m^2 (UNESCO 1993). These architectural elements, made of brick tiles, have always characterized the visual impression of the town, needed an immediate rebuilding.

The recostuction precess started right after the shelling by virtue of UNESCO founding. The selected approach followed the stylistic type of restauration: the new building elements of the roofes were chosen in order to recreate as close as possible the 'Dubrovnik-type', both the new tiles and the stone eaves (UNESCO 1993).

On the 15th December 1995, the pace was signed in Paris. In the following summer of 1996 started a period of healing and recovering beyond, focusing on tourism. By the summer of 1998, tourisms resurgence began as visitor increased, demonstrating that the efforts to recreate the landscape using original, or similar, materials could be successful (Wise and Mulec 2015).

3 The Case Study: The Historical City of Kathmandu, Nepal

In the first decades of the twentieth century Nepal was mostly constituted of rural areas and the issue of heritage conservation was not sufficiently evaluated.

The Department of Archaeology was established just in 1952 (Chapagain 2008), carrying out several works of repair and maintenance on the cultural heritage, and the site of the Kathmandu Valley was declared a protected monument zone under the national Ancient Monument Preservation Act of 1956.

In 1978, Nepal became part of the UNESCO's Convention for the Protection of the World Cultural and Natural Heritage and subsequently Nepal's application seven monument sites in the Valley (the three Durbar Squares, Pashupatinath, Bouddha, Changu Narayan and Swoyambhu) were enlisted in the World Heritage Sites in 1979. Nevertheless, since the first years right after the inscription, the sudden economic development and demographic pressure have threatened its integrity and authenticity: just few monuments of the Malla and Shah dynasties (VX–XVIII centuries) survived while their urban setting was destroyed by the illegal demolitions and reconstructions of buildings in reinforced concrete (Rossato 2008).

In 1992, Kathmandu has been the setting of the Wood Committee of the ICOMOS meeting regarding the restoration of the Baha Bahi monastery, bringing forward the discussion which led to the Nara Document of Authenticity in 1994 (UNESCO 2015).

In 1993, the World Heritage Committee at its seventeenth session declared its concern about the state of conservation of Kathmandu Valley site and considered to include the site in the List of World Heritage "for the ongoing degradation and demolition of monuments and historic buildings in the Kathmandu Valley, due to weak legislation and lack of adequate protective measures, as required in the

Convention" (UNESCO 1993). Actually, the decision was formalized only in 2003, after several reports of conservation, as "the traditional elements of heritage of six of the seven Monument Zones had been partially or significantly lost since the time of inscription, resulting in a general loss of authenticity and integrity of the property as a whole" and "the threat of uncontrolled development has persisted, which continuously decreases the urban landscape and architectural fabric of the property" (UNESCO 2003).

When Kathmandu Valley was placed on the List of World Heritage in Danger, the World Heritage Committee demanded Nepal to draft an Integrated Management Plan (IMP) in order to "redefine the core and support zones of all Monument Zones, accompanied with management mechanisms to adequately conserve the remaining World Heritage value of the property in the long term" (UNESCO 2003), redefining boundaries and creating buffer zones.

The IMP was edited between 2004 and 2007, when it became effective. This then led to the removal of Kathmandu Valley from the List of World Heritage in Danger in 2007.

The 'Nepali' architecture, also known as the 'Newari', differs considerably from the typical style of the neighboring cultures, although the remarkable influence of the Indian culture with whom it shares the religion.

The Kathmandu valley has always supplied clay to product bricks and shingles and at the same time the blooming woods of surrounding hills are a source of wood (Marino and Pietrammellara 2007). The traditional architecture is symbolized by the high building structure known as "Pagoda". It is multi-tiered roofed temple (Dixit et al. 2004), built during the period of Malla dynasty (1200–1768) (Shakya et al. 2014) affecting the constructions of analogous structures in India and China.

The concept of restauration valid in the Eastern cultures, including the Nepali, is considerably different from the principles and ideals developed in Europe as discussed in the second paragraph. The aim is to maintain it over the centuries the use of a certain monument as its custom was rather than to preserve it as an authentic evidence of the past. This is strictly related to the religious belief in reincarnation: as the human being will be reincarnated, the monument will be re-built in the same shape and with the same materials.

This is a "destructive" approach to conservation. The demolition of the original building and the consequent reconstruction is considered a valid way to ensure its survival in the same shape and use, replicating the original model in the same materials and techniques (Marino and Pietrammellara 2007).

This methodology implies that most of the heritage recovered according to this approach cannot be considered authentic as this definition, in its Western meaning, is attributed to the original building.

The choose of Nepal as a case study is completely appropriate as its heritage has been gone through several modifications and reconstructions during its history, due to both the materials of its construction, which turned out to be not particularly resistant to the weather conditions needing periodical replacement, and its setting as the Kathmandu valley is placed in an earthquake prone area (Tiwari 2012). Just the most recent are: the magnitude 6.9 earthquake on the 18th September 2011

(Shakya et al. 2013) and the 7.8 magnitude earthquake on the 25th April 2015, with the epicenter in Gorkha district, 80 km northwest of Kathmandu.

There are also evidences of occurred earthquakes for at least each century, such as the ones of 1833 and 1934. Each destructive event has led to a phase of reconstruction or 'Cyclical Renewal' in order to recovery from the effects of the earthquake. In particular, after the great earthquake of 1934 most of the monuments of the Valley have been restored: some of them have been re-built reproducing their original form, some of them reconstructed adopting variation (e.g. the Chaturmukhalinga Mahadev Temple in Hanuman Dhoka and the Fasi Dega Temple in Bhaktapur) and moreover few of the destroyed ones have never been re-built (e.g. the Hari Shankar Temple in Bhaktapur) (UNESCO 2015).

An example of how reconstruction was usually realized is the case of the '55-Window Palace'. This monument, built in 1697 a.D., suffered of the collapse of the wood frame of its second floor due to the earthquake of 1934. The restauration was managed using wood elements and windows works rescued from the ruins (Govinda Sherestha 2006), more likely in order to deal with the lack of material to build new structures than for the will of preserving their authenticity (Tiwari 2016).

The works had been done in the shortest time possible but during the following works of restauration of the palace "it was found that many wooden elements that were reused after the hasty reconstruction in 1934 were replaced in the wrong position or direction, contrary to traditional construction practice. It was decided to rectify this during the restoration process" (UNESCO 2015).

In some occasions, instead of restauration, the used approach dealt with the replacement of an entire building. An example is the god-house of the goddess Tripurasundari in Bhaktapur.

The monument, until the beginning of the 2000s, was made up of nine different structures: one original dating back to the eighteenth century, four reconstructed after the 1934 earthquake and other three demolished and renovated in the 1970s due to a plan of refurbishment and restoration supported by German founding (Gutschow 2016).

Nevertheless, the site was included in the World Heritage List in 1979 as "the authenticity of the ensembles has not been affected, even though there are some illegal constructions" and "ensembles represent an exceptional testimony to the traditional civilization of Kathmandu Valley in Nepal. The coexistence and amalgamation of Hinduism and Buddhism with animist rituals and Tantrism is considered unique. ICOMOS considers that this criterion could continue to be valid for some of the original areas and revised areas" (UNESCO 2007).

The god-house of the goddess Tripurasundari was dismissed and rebuilt during the years 2006–2008 by the local municipal heritage office. The intervention, which realized a building "four feet higher and more elaborate than its predecessor" (Glendinning 2013), was supported by touristic incomes and found its theoretical motivation in the criteria of 'spirit and feeling' (Gutschow 2016) stated in the art 82 of the 2005 World Heritage Operational Guidelines as: "Depending on the type of cultural heritage, and its cultural context, properties may be understood to meet the conditions of authenticity if their cultural value (as recognized in the nomination criteria proposed) are truthfully and credibly expressed through a variety of attributes including: form and design; materials and substance; use and function; traditions, techniques and management systems; location and setting; language, and other forms of intangible heritage; spirit and feeling; other internal and external factors."

4 Remarks and Recommendations

In recent years, conservation of historical urban landscape is gaining significant attention, also elicited by the World Heritage Committee work. The international conference on World Heritage and Contemporary Architecture—Managing the Historic Urban Landscape held in Vienna in May 2005 played an important role in this process. As a major result of this conference, the document called 'Vienna Memorandum' was adopted. This document introduced a new concept, by recommending sustainable development of the new urban developments in order to preserve the integrity of the historic urban landscape (UNESCO 2010).

Between 2005 and 2010, several regional meetings on historic urban landscapes followed the Vienna conference. After five years of debate, the UNESCO adopted a new recommendation on the subject of conservation of historic urban landscapes, i.e. the Recommendation on the Historic Urban Landscape on the 10th November 2011, which sets in article 22 some important guidelines for the interventions: "Conservation of the urban heritage should be integrated into general policy planning and practices and those related to the broader urban context. Policies should provide mechanisms for balancing conservation and sustainability in the short and long terms. Special emphasis should be placed on the harmonious, integration of contemporary interventions into the historic urban fabric."

Currently international consensus exists on:

– the belief of preserving towns and cities as a combined expression of tangible and intangible heritage;
– the need for a holistic methodology for towns and cities preservation, including physical, social and economic factors;
– the requirement of including different governmental levels and expertise in the process necessary to programme towns and cities preservation.

The case study of Kathmandu shows the relevance of a place-specific approach to conservation. According to the Western culture, the Nepalese approach wouldn't be acceptable; however, due to the historical context, reconstruction follows a cultural pattern perfectly acceptable in the Nepalese tradition.

The Nepalese conservation procedure deeply depends on the particular culture, the traditional materials and the urban context and should aim at combining the social and cultural values with the conservation needs, providing guidance for the decision-making process (Tiwari 2012).

Regarding the opportunity of using new materials and techniques as proposed in article IV of the 1930 Charter of Athens, the experiences of modern architecture proved that reinforced concrete, especially when it not properly realized, is not as durable as it was considered when it was invented: “The experts heard various communications concerning the use of modern materials for the consolidation of ancient monuments. They approved the judicious use of all the resources at the disposal of modern technique and more especially of reinforced concrete.”

Moreover, several restauration conducted after the disruption of the Second World War have underlined the damages that can occur in a structure where concreate is not compatible with the original material.

These were the reason why the following 1964 Venice Chart introduced in article 9 a more cautious approach on the convenience of using new materials:

> Where traditional techniques prove inadequate, the consolidation of a monument can be achieved by the use of any modern technique for conservation and construction, the efficacy of which has been shown by scientific data and proved by experience.

It is clear that, in the appropriate situations and condition, the use of traditional material instead is strongly supported and recommended.

The appropriate methodology of reconstruction, especially for the areas likely to be subject to natural hazards, can be improved thanks to models of “best practice” for what concerns risk prevention and reduction, emergency measures and operational management.

ICOMOS Italia, following the earthquakes in Italy on the 20th and 29th May 2012, has identified a list of actions, aiming to recover historical urban areas, promote traditional techniques and materials, include different levels of decision makers and promote correct planning policies.

The proposed actions (ICOMOS 2012) include:

- To enlist the heritage on the basis of the priority in case of a catastrophic event;
- To arrange the rational reconstruction of urban areas in advance at the planning level, taking into account redevelopment and conservation needs;
- To maintain periodically the buildings, in order to prevent further damage;
- To ensure the compatibility and reversibility of both temporary and permanent interventions on heritage which should preserve the existing structures and guarantee the usability;
- To promote the participation of private founds to economically support the conservation of cultural heritage;
- To extend the knowledge related to seismic behave of traditional structures, both monumental and residential.

As the recommended strategy is general, it could be possibly identified as a “best practice” and be applied also in Nepal.

Moreover, relating specifically to this case study, it could be definitely appropriate to create a governmental group involving also local stakeholders, in order to establish policies concerning reconstruction, conservation and restauration. The group could be supported by technical and scientific committee, which can interact with international specialists so as to benefit from the rest of the several successful experiences accomplished in the other parts of the world.

References

Adams C (2013) Japan's Ise Shrine and its thirteen-hundred-year old reconstruction tradition. J Archit Educ 52:49–60. doi:10.1111/j.1531-314X.1998.tb00255.x

András R (2002) Reconstruction: from the Venice Charter to the Charter of Cracow. In: Strategies for the World's Cultural Heritage. Preservation in a globalised world: principles, practices, perspectives, ICOMOS 13th General Assembly and International Symposium, Madrid, Spain, 1–5 Dec 2002

Bullock N (2002) Building the post-war world: modern architecture and reconstruction in Britain. Routledge, London

Chapagain N (2008) Heritage conservation in Nepal: policies, stakeholders and challenges. In: Paper presented at the Third Annual Himalayan Policy Research Conference, Madison, WI (USA) 16 Oct 2008

CIAM (1993) Athens Charter, VI, Technique of conservation, p. 32

Council of the European Union (2014) Conclusions on cultural heritage as a strategic resource for a sustainable Europe. In: Paper presented at the Education, Youth, Culture and Sport Council meeting, Brussels, 20 May 2014

Denyer S (2011) Retrospective statements of outstanding universal values for world heritage properties: authenticity & integrity. In: ICOMOS, Workshop for the 2nd Cycle of World Heritage Periodic Reporting for Western Europe Prague 27 May 2011

Dixit AM, Parajuli YK, Guragain R (2004) Indigenous skills and practices of earthquake construction in Nepal. In: Paper presented at the 13th World Conference on Earthquake Engineering Vancouver, B.C., Canada, 1–6 Aug 2004

Dushkina N (2005) Reconstruction and its interpretation in Russia. In: Paper presented at the Monuments and Sites in their Setting: Conserving Cultural Heritage in Changing Townscapes and Landscapes, 15th ICOMOS General Assembly and the International Scientific Symposium, China, 17–21 Oct 2005

Francesca Talò (2012) Conservazione e ricostruzione dei tessuti storici dal secondo dopoguerra agli anni settanta. Teoria e prassi del restauro nell'opera del soprintendente Alfredo Barbacci. PhD Dissertation, Università di Bologna

Glendinning M (2013) The conservation movement: a history of architectural preservation antiquity to modernity. Routledge, London

Govinda Sherestha R (2006) A final report on conservation of 55 windows palace. http://www.hdm.lth.se/fileadmin/hdm/alumni/papers/cmhb2005/cmhb2005-27.pdf. Accessed 12 Aug 2016

Gutschow N (2016) Architectural heritage conservation in South and East Asia and in Europe: contemporary practices. In: Weiler K, Gutschow N (eds) Discourses, opinions, experiences in Europe, South and East Asia. pp 1–71

Hall D (2002) Brand development, tourism and national identity: the re-imaging of former Yugoslavia. J Brand Manage 9(4–5):323–334

Hourbart C, Dawans S (2011) Identical reconstruction and heritage authenticity. In: Paper presented at the conference S.A.V.E. Heritage: Saveguard of Architectural, Visual, Environmental Heritage, Italy, June 9–11 2011

ICOMOS (1990) International council on monuments and sites: summary report. 9th General Assembly and International symposium: ICOMOS, a quarter of century, achievements and futur[e] prospects, Lausanne, October 6-11, 1990

ICOMOS Italiana (2012)—Working Group on the Seismic Event in Emilia Romagna, Proposal

Jokilehto J (2006) Considerations on authenticity and integrity in world heritage context, City & Time 2(1):1. http://www.ct.ceci-br.org. Accessed 18 Apr 2016

Jokilehto, J (2013) Reconstruction in the world heritage context. European Association for Architectural Education, Rome 28–31 October 2013. https://engagingconservationyork.files.wordpress.com/2014/02/reconstruction-in-wh-context-rev.pdf. Accessed 10 May 2016

Larkham PJ, Pendlebury J, Erten E (eds) (2014) Alternative visions of post-war reconstruction: creating the modern townscape. Routledge, Abingdon

Marino L, Pietramellara C (2007) Tecniche edili tradizionali. Contributi per la conoscenza e la conservazione del patrimonio archeologico. Alinea

Nezhad SF, Eshrati P, Eshrati D (2015) A definition of authenticity concept in conservation of cultural landscapes. Int J Architect Res, ArchNet-IJAR 9(1):93–107

Petzet, M (2004) Principles of preservation: an introduction to the international charters for conservation and restoration 40 years after the Venice charter. In: ICOMOS International Charters for Conservation and Restoration. Monuments & Sites. ICOMOS, München

Piazza M, Riggio M (2007) Typological and structural authenticity in reconstruction: the timber roofs of church of the Pieve in Cavalese, Italy. Int J Architect Heritage 1:60–81

Rossato L (2008) Conservazione architettonica nei paesi in via di sviluppo. La Valle di Kathmandu ed il suo paesaggio urbano storico: un nuovo concetto di patrimonio da tutelare, Il paesaggio nella storia nella cultura nell'arte e nella progettazione urbanistica, assunti teorici ed esperienze, Territorio della ricerca su insediamenti ed ambiente. Edizioni Scientifiche Italiane, Naples

Shakya K, Pant DR, Maharjan M, Bhagat S, Wijeyewickrema AC, Maskey PN (2013) Lessons learned from performance of building during the September 18, 2011 earthquake in Nepal. Asian J Civ Eng (BHRC) 14(5):719–733

Shakya M, Varum H, Vicente R, Costa A (2014) Seismic vulnerability and loss assessment of the Nepalese Pagoda temples. Bull Earthq Eng 13(7):2197–2223. doi:10.1007/s10518-014-9699-5

Smets M (1987) The reconstruction of historical cores in Belgian cities after their destruction in the first world War. In: ICOMOS, Old cultures in new worlds. 8th ICOMOS General Assembly and International Symposium. Programme report, US/ICOMOS, Washington

Stanley-Price N (2006) Excavated foundations and total reconstruction. Paper presented at the International conference on reconstruction of the Hwangnyongsa Temple, National Research Institute of Cultural Heritage, Republic of Corea, Apr 28–29 2006

Stanley-Price N (2009) The reconstruction of ruins: principles and practice. In: Richmond A, Bracker A (eds) Conservation: principles, dilemmas and uncomfortable truths. Elsevier

Tiwari SR (2012) Making space for the present and the local, creativity in heritage conservation. In: Paper presented at the Inaugural Conference of the Association of Critical Heritage Studies, Gothenburg, Sweden, 5–8 June 2012

Tiwari SR (2016) Material authenticity and conservation traditions in Nepal. In: Weiler K, Gutschow N (eds) Discourses, opinions, experiences in Europe, South and East Asia. Springer, Berlin

UNEP (2005) Making tourism more sustainable, a guide for policy makers. United Nations Environment Programme Division of Technology, Industry and Economics

UNESCO (1976) Recommendation concerning the Safeguarding and Contemporary Role of Historic Areas. Annex I

UNESCO (1993) Dubrovnik 1991–1992. The Institute for the Protection of the Cultural Monuments and Natural Environment of Dubrovnik, UNESCO Paris

UNESCO (2003) Decision adopted by the 27th Session of the World Heritage Committee in 203, WHC-03/27.COM/24, 10 December 2003

UNESCO (2007) Advisory Body Evaluation, Kathmandu Valley (Nepal), WHC-07/31.COM/7A. Add, No 121 rev, 24–29 Apr 2007

UNESCO (2010) Managing Historic Cities. In: World Heritage Papers 27, World Heritage Centre

UNESCO (2015) Revisiting Kathmandu, safeguarding living urban heritage. International Symposium Kathmandu Valley, 25– 29 Nov 2013

Varagnoli C (2015) Ricostruzione, conservazione, restauro. Ricerche e cantieri dopo il terremoto abruzzese del 2009, In: conference at the Università degli studi Mediterranea di Reggio Calabria, 12 Nov 2015

Vieira N M (2004) A discipline in the making: classic texts on restoration revisited. City & Time 1 (1):5, available on line http://www.ct.ceci-br.org. Accessed 28 June 2016

Viollet-le-Duc Eugène-Emmanuel (1990) The foundations of architecture. George Braziller, New York

Wise NA, Mulec I (2015) Headlining Dubrovnik's tourism image: transitioning representations/narratives of war and heritage preservation 1991–2010. Tourism Recreation Research (37). http://www.tandfonline.com/doi/abs/10.1080/02508281.2012.11081688?journalCode=rtrr20. Accessed 23 July 2016

Can We Prevent Structural Failure Under Earthquakes?

Uwe E. Dorka

Abstract Discussing the needs of the prevalent structural concept (the reinforced concrete frame with masonry infill: RCF) during the design and building process in order to provide adequate safety under earthquake loading, the robustness of this concept is called into question. It is concluded that, as long as we continue to build in this way, un-manageable earthquake disasters will strike our large urban centres. During the past two decades, new structural concepts have emerged that are not only more robust then RCF but also more economical to build. Among these are reinforced masonry, confined masonry and so-called seismic control concepts like Base Isolation, Hyde System and Tendon System. These concepts, their applications and advantages are briefly presented, also in the context of historical structures. For these, the Tendon System is particularly suitable, but basic understanding of the seismic performance of historic structures is missing. This is particularly true for Nepalese pagodas. It must be investigated using full-scale shaking table tests before any intervention or reconstruction should be allowed. Finally, strategies are suggested how to promote these concepts in order to substitute RCF eventually. If successful, widespread structural failures under earthquakes will become history.

Keywords Earthquake robustness · Earthquake codes · Reinforced masonry · Confined masonry · Seismic control · Historic structures

1 Building Practice Versus Earthquake Safety

Earthquakes don't kill – structures do!

On and again, this famous quote has proven its validity with every major earthquake in this world. And it will continue to do so unless it is finally recognize what is really wrong with our building practice in earthquake prone regions.

U.E. Dorka (✉)
Department for Civil and Environmental Engineering, Universität Kassel,
Kassel, Germany
e-mail: uwe.dorka@uni-kassel.de

J.H. Kruhl et al. (eds.), *Living Under the Threat of Earthquakes*,
Springer Natural Hazards, https://doi.org/10.1007/978-3-319-68044-6_8

The disaster management community only calls for the enforcement of building codes. If these rules are met, an earthquake safe environment is secured. But modern earthquake codes are not “codes of practice” (as they should be), since actual building practice usually violates these rules. Only two (albeit very important) examples are given here to illustrate this.

The first example is the reinforcement in typical concrete structures. Today, about 80% of all structures in the world are reinforced concrete frames (RCF) with masonry infill. This structural concept is architecturally versatile and cheap to build. It is a development from non-seismic countries, especially France and Germany: The first reinforced concrete structures were small bridges for parks in France by Joseph Monier in the late 18-hundreds. In Germany, Gustav Adolf Wayss and Conrad Freytag learnt about Monier’s technology and introduced it into mainstream building practice. It is a very robust structural concept for regular load cases (like dead, wind or snow loads), but requires very intricate detailing of the reinforcement for earthquakes. Figure 1 compares the required reinforcement and it’s detailing of a code compliant frame corner (Fig. 1a) with typical building practice found in most regions of this world (Fig. 1b). Typically, the required reinforcement is very dense and has details that are very difficult to execute, like closing the hooks at the end of stirrups, ensuring that the stirrups are in the right place (with a required spacing of around 50 mm, a 10 mm deviation already makes a big difference) or even placing the bend bars in the corner with enough space in-between to pour and compact the concrete correctly. All these details are necessary for a frame corner to perform properly during an earthquake. If they are not correct (like in Fig. 1b), it is very likely that such a corner will fail and with it, the whole structure. And there are hundreds of such details in any regular RCF building. Basic probability considerations tell us that there is a good chance that several of them are wrong, even if qualified workmanship is considered. This makes RCF a structural concept with very little robustness under earthquakes and an impractical requirement on workmanship and quality control in most regions.

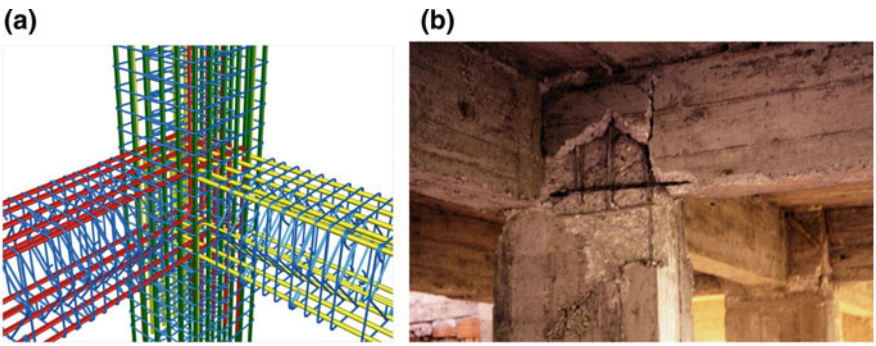


Fig. 1 Impractical code required reinforcement for earthquake safe RCF (**a**) versus reality (**b**, from EERI slide collection)

The 2nd example is the so-called "soft storey" (Fig. 2). It is a basic requirement in modern architecture in order to provide parking in the ground floor or open spaces for shops, especially in inner city buildings. Soft storeys are very dangerous because an earthquake will concentrate all horizontal deformations there and if they exceed the very definite storey drift limit, stability is lost and collapse is inevitable and sudden. Building codes therefore don't allow them but building function often requires them. The structural engineer is left with no code provisions to design it safely, but ends up with the responsibility for the lives lost during the earthquake.

There are many more such "impractical" issues found in our current building codes when it comes to earthquake resistant design. So what is needed to remedy the situation?

To begin with: more ***robust structural concepts*** are needed that do **NOT**

- Require intricate and impractical detailing
- Request superior workmanship, which is not available in most countries
- Require unrealistic and expensive quality control
- Or cost more than RCF (then nobody will use them)

Such structural concepts do exist! The following introduces a few of them.

Fig. 2 Soft storeys are an important architectural requirement. They are one of the most dangerous features but there are no design rules for them in codes: Instead, they are forbidden (from EERI slide collection)

2 Walls with Integrity for Earthquake Protection

The first such concept is called “confined masonry” (CM, Fig. 3a). It is mainly a Latin American development, which is now spreading across the globe. It looks like RCF but it isn’t. Whereas the frame in RCF is built before and the walls are then “filled in” (which is particularly awkward for the top layer of bricks just below the beam!), the concrete members in CM are built afterwards, locking into the walls. Thus, they are not acting like frames, but “confine” the masonry walls in order for them to bear the earthquake action (and not the frames, which are now to weak for this!).

This confinement provides structural integrity during the earthquake even if one of the walls starts to crack: it will redistribute the action to the other walls of which there are usually plenty and thus provide robustness.

Detailing and reinforcement is simple (Fig. 3b), with very little quality control required. Simple manuals (Meli and Brezev 2011) explain what to do even to workmen who have little or no prior training. And it is faster and less expensive to build than RCF!

The next (and even better) concept is reinforced masonry (RM). Figure 4 shows a project in Chittagong, Bangladesh, which has a high seismic hazard. It requires hollow-core blocks and preferably horizontal layers of reinforcement in the joints (opposite to what was done there). Concrete quality and reinforcing details are even less a concern than in CM. But like in CM, the walls take the earthquake action and provide robustness simply by their number, enough of which is provided by typical residential architecture.

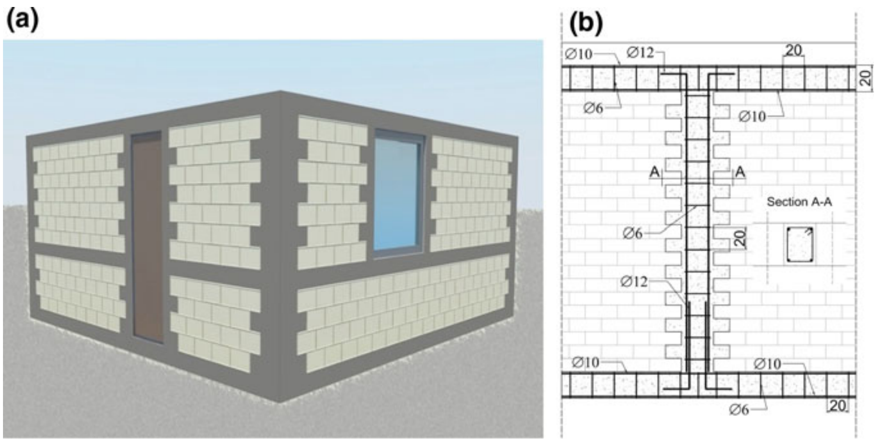


Fig. 3 Confined Masonry (CM) (**a**) is more robust, requires less detailing (**b**) and quality control and is more economical than RCF

Fig. 4 In Chittagong, Reinforced Masonry (RM) proved to be even better and more economical than CM (pictures by the author)

3 Seismic Control

This concept is about controlling the forces in a structure during an earthquake. Earthquakes are very ambiguous: No one knows how much shaking the next one will produce. But if the forces are under control in a structure, the particularities of the shaking will not matter much, unlike in conventional RCF.

The key to achieving this is rigid body motion control. That is, to construct a building as an assemblage of rigid bodies and control the forces between them with suitable devices (Dorka 2004). Four basic types have evolved so far: Base Isolation, Hyde System, Tendon System and Pagoda System (Fig. 5). The advantage of these concepts over conventional structures becomes immediately clear, if one looks at the energies that develop in the structure during an earthquake (Fig. 6). In a conventional structure, kinetic and elastic energy alternate (as physics dictates) and some energy is dissipated, sometimes by using additional dampers. But it is the elastic energy that causes internal forces and stresses and the kinetic energy is a measure of motion. Both are not only connected, but provide a considerable portion of the total energy that goes into a conventional structure. This is mainly due to dynamic amplification effects that occur in most structures during an earthquake.

The picture is completely different when looking at a rigid body seismic control structure like the ones given in Fig. 5: Potential and kinetic energy are greatly reduced (because there is no amplification) and most of the energy is mitigated in the control devices. Thus the structure moves less and internal forces are not only small, but suitable devices control their limits.

Among those 4 concepts, Base Isolation has the most applications in the world. Many designers still believe that it raises the cost of construction, but this is history long gone. It was the case when regulators did not trust this new development and the structure had to be designed as if there was no Base Isolation. This made it more expensive, of course. Today, all structural codes allow the designer to take full advantage of the mitigating effects and that leads to structures that are not only more robust, but also economically very competitive to conventional structures.

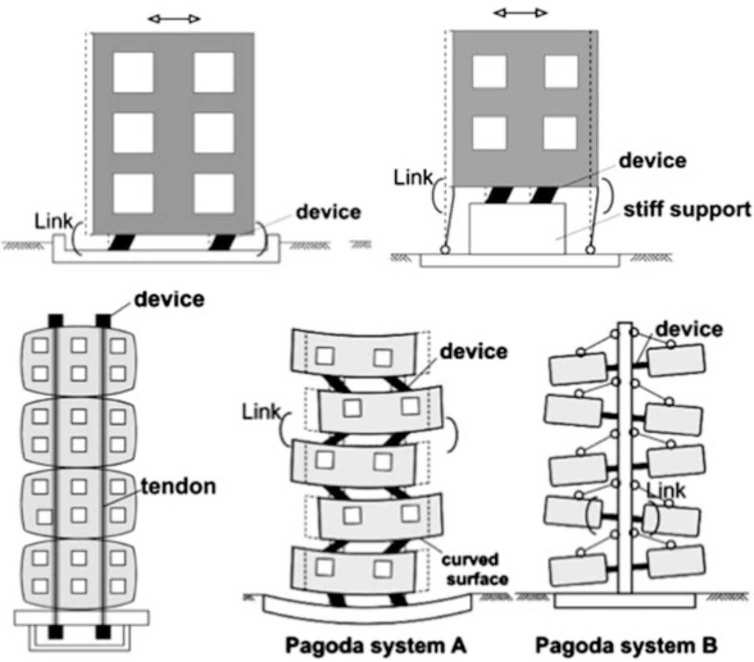


Fig. 5 Controllable rigid body mechanisms for structures. Base Isolation (*top left*), Hyde System (*top right*), Tendon System (*bottom left*) and two possible versions of the Pagoda System (*bottom right*)

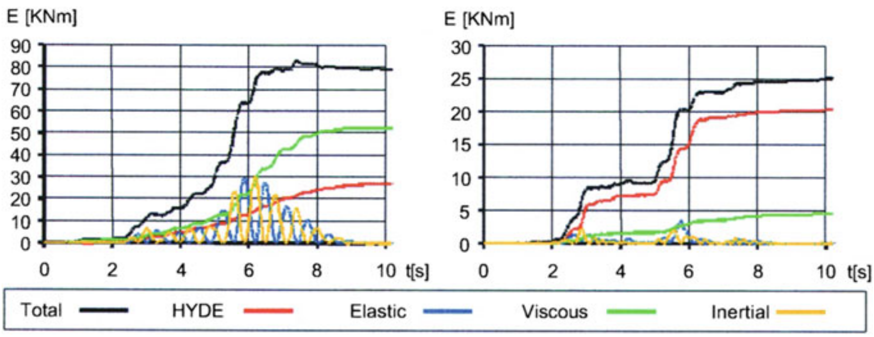


Fig. 6 Energies developing in a structure during an earthquake. Elastic and kinetic energies play an important role in a conventional structure causing forces and deformations. They are greatly reduced in rigid-body seismic control structures. Hyde stands for "Hysteretic device", which can be used to enhance damping in a conventional structure, but is better placed in a link of a seismic control system where it takes care of most of the energy input and limits the forces in the structure

This has been proven many times over, especially during the CASE Project in L'Aquila (Calvi and Spaziante 2009), which provided new housing for people, who lost their homes in the 2009 earthquake (Fig. 7). Conventional prefabricated 3-storey buildings were constructed on top of isolated plates, where parking is now provided underneath. Conventional prefabricated buildings are very economical, but also very dangerous during earthquakes. By controlling the maximum forces that can enter them through lead-rubber bearings (LRBs) underneath the plate (and keeping them small because of rigid body motion), these buildings are now more robust but equally economical than the usual RCF.

Even simpler is the Hyde System (Dorka and Gleim 2005; Ahmed et al. 2005). Here, a "soft storey" can be used to place simple force-limiting devices (like shear-panels) to control a rigid body motion. Figure 8 shows a layout for a typical residential building where the ground floor walls are only connected to the slab above with shear panels. The motion is concentrated in this floor (the "seismic link") and the plastic shear force capacity of the shear panels limits the forces that can enter the structure above. This structure now behaves like a rigid body with all the advantages mentioned already. Because of the small and controlled forces, simple masonry walls, preferably as reinforced masonry, will suffice, making this concept more economical than RCF or Base Isolation. Because a lot of conventional modern buildings have such "soft storeys" already (inner city buildings with shops in the ground floor or residential buildings with parking there), the Hyde System lends itself to an easy, robust and cost-efficient retrofitting of these buildings. This is very necessary, because without a Hyde System, soft-storey buildings are some of the most dangerous buildings in the world (as has been explained above): Hardly any survives even a moderate earthquake!

Base Isolation and Hyde System can be applied using modern codes. This is not yet the case for the Tendon System. We are currently studying it for applications in historic structures. The object of this study is the Neptune Temple in Paestum, Italy (Fig. 9) in a project financed by DFG (Do360/25-1). By running a tendon through the columns, the column motion can be stabilized.

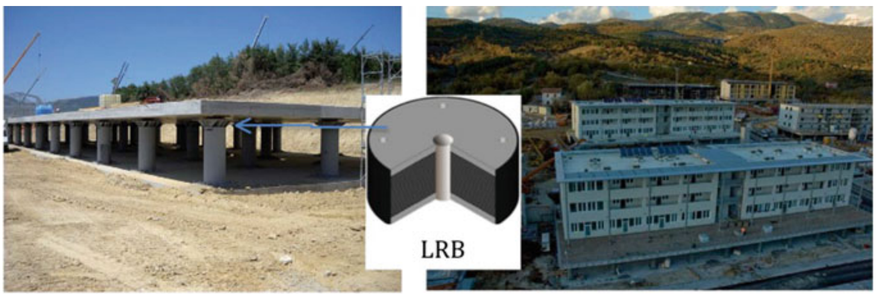


Fig. 7 Competitive Base Isolation for new residential buildings in L'Aquila, Italy. The rubber bearings with a lead core (LRBs) are located between columns and slab. In this "seismic link" horizontal forces are under control (modified from Calvi and Spaziante 2009)

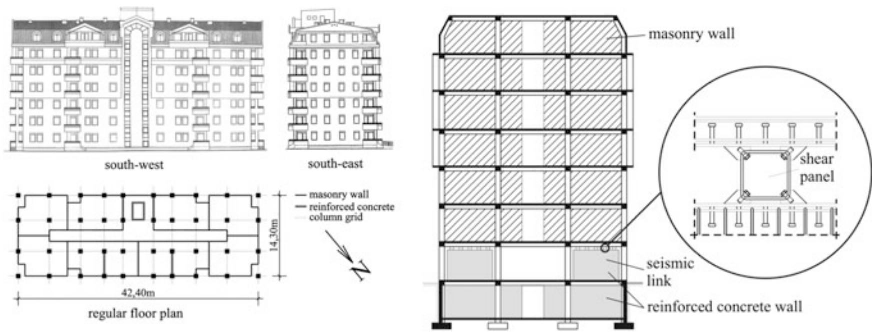


Fig. 8 In a Hyde System, a floor becomes the seismic link where horizontal forces are controlled by simple shear panels. This is even more economical than Base Isolation and lends itself easily to retrofitting soft storey buildings (from Dorka and Gleim 2005)

Fig. 9 Neptune Temple in Paestum, Italy and 1:3 scale column in the structural laboratory of Universität Kassel, Germany. During hybrid simulations, the lab column can take any position (indicated in *green*) within the virtual structure (indicated by *red* and *yellow* elements). The mechanical properties of these elements are updated based on the behaviour of the lab column

This was demonstrated during so-called hybrid simulations (Obón and Dorka 2012) using a 1:3 scale column in the structures lab at University of Kassel, Germany. The hybrid simulation coupled this specimen online to a virtual model of all the peripheral columns and the architrave. 5 hydraulic cylinders connected to the architrave in the lab (2 vertical and 3 horizontal ones) provided this coupling by introducing the displacements to the specimen and feeding the resulting forces into the virtual structure. This process is performed about 100 times a second providing a smooth and realistic coupling between specimen and virtual structure under any kind of earthquake input. The mechanical behaviour of the virtual columns are updated based on the observations on the specimen. This results in a realistic mechanical model for such structures, including the effect of a tendon.

Tendon Systems can be used with advantage in historic structures because they do not change the historic structural concept (which also must be preserved as our heritage, not only the architectural appearance of a building!). They only produce forces that stabilize the motion during an earthquake. And they can be removed easily leaving only a small hole in the centre. Thus, they are very low interference, a basic requirement for any intervention in historic buildings. It should be possible to stabilize pagodas, temples and palaces in Nepal with this concept. The Dharahara Tower, if it is ever going to be rebuilt, should not be without a Tendon-System!

Before applying this concept to historic structures in Nepal, further studies similar to the investigations on the Neptune Temple must be done:

> Realistic mechanical models are needed for these structures, which must be validated by hybrid simulation or shaking table tests before any intervention should be allowed to take place!

This is of general importance: It applies to all structural interventions in historic buildings. There are already too many cases in the world, where historic structures have been damaged beyond repair by modern interventions because this principle was not observed!

At a first glance, the Pagoda-System looks well suited to protect Nepalese pagodas. After all, this concept is found naturally in the Japanese pagodas, which seem to be impervious against the effects of earthquakes since they were introduced in Japan about 1200 years ago. It is not found in modern structures and nobody is studying it in this context. But it is a true seismic control concept relying on a well-balanced rigid body motion (Nakahara et al. 2000) that controls the forces in the structure (the so-called "snake-dance", Fig. 10).

There is a profound structural difference between Nepalese and Japanese pagodas: The Japanese pagodas are only timber structures whereas the Nepalese ones combine a timber frame with masonry walls. Even if the timber frame could perform the snake dance, the walls (especially if they are stiffened with modern mortar, as has been done in some cases) may prevent this. This would amount to forcing a conventional structural "straight-jacket" on this otherwise beautiful seismic control concept. More studies are needed here to understand the seismic behaviour of Nepalese pagodas, especially full-scale shaking table tests. Such tests are possible e.g. at the E-Defense facility near Kobe, Japan (E-Defense 2017) or in the multi-functional shake tables lab at Tongji University in Shanghai, China (NEES 2012).

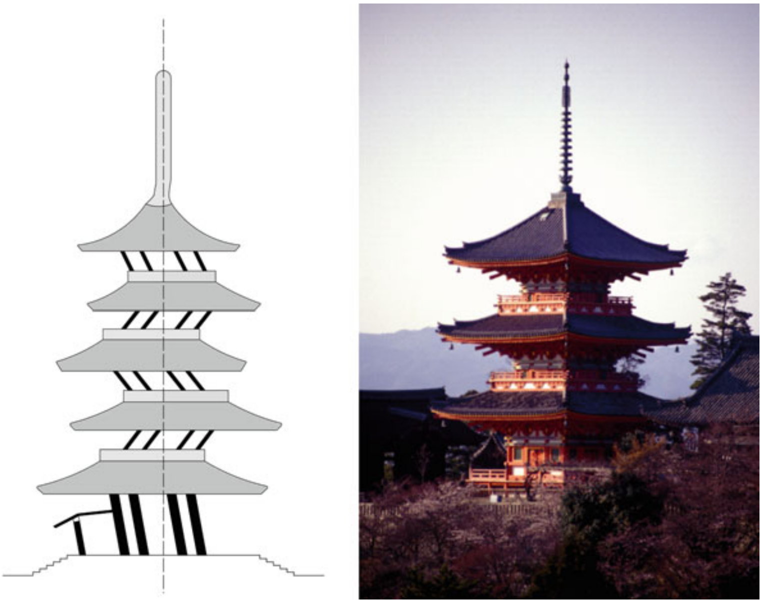


Fig. 10 Snake dance of the Japanese Pagoda during an earthquake. This rigid body motion balances the mass effects and thus limits the forces in the structure. The Pagoda System is the oldest (and highly proven!) seismic control system in the world (picture by the author)

4 Some Resulting Observations, Not Only for Nepal

Conventional RCF structures cannot be produced with the quality required for earthquake safety of large numbers of buildings due to a multitude of critical details: Too much can and will go wrong and codes alone cannot prevent this

RCF must be replaced as the main structural concept, especially in developing countries!

There are excellent alternatives, which are not only more robust but also less expensive:

- **"Wall systems with integrity"**, like *reinforced masonry* or *confined masonry* are easier to build and cheaper. They require only moderate workmanship and little quality control.
- The **"Seismic Control concepts"** *Base Isolation, Hyde System, Tendon System* and eventually *Pagoda System* utilize rigid body control, which reduces forces and displacements and provides full control over maximum forces in a structure. This makes these structural concepts **superior in performance, robustness and costs** over any conventional structure.

Seismic Control concepts are also very suitable for **historic structures**, especially the Tendon System. But **realistic mechanical models are needed for these**

structures, which must be validated by hybrid simulation or shaking table tests before any intervention should be allowed to take place! There are already too many cases in the world, where historic structures have been damaged beyond repair because this principle was not observed. It would be a pity, if this happens again in Nepal!

How can those concepts be introduced on a large scale, which are ready for application (e.g. confined masonry, reinforced masonry, Base Isolation and Hyde System)?

Organizations like World Bank, UNDP, etc. should provide:

- ***Highly visible demonstration projects*** in different regions of this world, especially now in Nepal
- ***Easy-to-follow design and instruction manuals*** for engineers, contractors and workers
- ***An information campaign*** (TV, newspapers, booklets for owners and developers etc.) on robustness and cost superiority of these concepts

The answer to the initial question: "Can we prevent structural failure under earthquakes?" is obviously straightforward:

> YES, if we change the way we built: In particular, we need to change our structural concepts!

References

Ahmed MZ, Ahsan R, Dorka UE (2005) A possibility of using Hyde Systems for seismic safety of soft-storey buildings in Bangladesh. In: Tahmeed M, Al-Hussaini (eds) BES-1: 1st Bangladesh earthquake symposium, December 2005, Dhaka, Bangladesh Earthquake Society, pp 195–202

Calvi GM, Spaziante V (2009) Reconstruction between temporary and definitive: the CASE project. J l'industria italiana del Cemento iiC 854:124–150

Dorka UE (2004) Erdbebensicherung durch Structural Control. Stahlbau 73:661–667

Dorka UE, Gleim S (2005) Hyde Systems for earthquake protection of residential buildings. In: Wasti ST, Ozcebe G (eds) Advances in earthquake engineering for urban risk reduction. Nato science series: IV: Earth and environmental sciences 66, Springer, Dordrecht

E-Defense (2017) http://www.bosai.go.jp/hyogo/ehyogo/index.html. Accessed 20 Mar 2017

Meli R, Brezev S (co-chairs) (2011) EERI & IAEE Confined Masonry Network: Seismic design guide for low-rise confined masonry buildings. Available via EERI https://www.eeri.org/products-page/world-housing-encyclopedia-2/seismic-design-guide-for-low-rise-confined-masonry-buildings/. Accessed 20 Mar 2017

Nakahara K, Hisatoku T, Nagase T, Takahashi Y (2000) Earthquake response of ancient five-story pagoda structure of Horyu-ji Temple in Japan. In: 12WCEE: 12th World Conference on Earthquake Engineering, Feb 2000, Auckland

NEES (2012) Introduction to the multi-functional shake tables lab at Tongji University. https://nees.org/site/resources/pdfs/MPSTL-Introduction-updated.pdf. Accessed 20 Mar 2017

Obón SF, Dorka UE (2012) Effects of large numerical models in continuous hybrid simulation. In: 15th WCEE: 15th World Conference on Earthquake Engineering, September 2012, Lisbon

A Critical Appraisal on Turkey's Neoliberal Quest of Urban Renewal in Historic Urban Landscapes

Zeynep Gunay

Abstract The paper aims at presenting a critical appraisal on Turkey's quest for urban renewal under the threat of man-made disasters, through a special consideration on historic urban landscapes, and particularly its world heritage sites. It deals with how policies designed to mitigate earthquake risk and provide quality of life in the transformation of historic urban landscapes turn into tools of extensive clearance of spatial, social and cultural fabric with the experiences from Istanbul. The paper hopes that the lessons learned from Istanbul's experience provide a medium to discuss the severe challenges and their resolving instruments associated with natural revanchist disasters as well as man-made disasters, especially in developing countries and in the sites with outstanding common heritage values such as Kathmandu.

Keywords Urban renewal · Historic urban landscapes · Man-made disasters · Neoliberal urbanism

1 The Quest for Urban Renewal: Glory, Dirt and Earthquake

While cities become the epicenter of political and ideological strategies of neoliberal policies as the primary source for growth and wealth, the transformation of inner city deprived neighborhoods has become a major issue in the urban agenda. This enthusiasm has led historic urban landscapes to become the opportunity spaces of market-oriented economic growth and consumption models through symbolic urban interventions via the prominence of concepts such as revitalization, regeneration and above all, *renewal*. Especially in developing countries such as Turkey and Nepal, the attempts to remove the obstacles fronting change that are introduced

Z. Gunay (✉)
Istanbul Technical University, Istanbul, Turkey
e-mail: gunayz@itu.edu.tr

J.H. Kruhl et al. (eds.), *Living Under the Threat of Earthquakes*,
Springer Natural Hazards, https://doi.org/10.1007/978-3-319-68044-6_9

to increase the competitive advantage for the creation of global cities may have even more deteriorating effects on heritage and the heritage community.

Even though the term urban renewal has become a catchphrase in Turkey over the last decades in line with the rise of neoliberal urban policy and planning agenda, *destruction* as a result of state-led urban transformation is not a new phenomenon (for an overview of the evolution of urban renewal policies and programs, see Gunay et al. 2015). Evoking negative references, it is always associated with destruction, complete replacement, relocation, community dissolution and segregation. The rationales have changed in time and in due course of political conjuncture within a broad range from beautification to disaster vulnerability. However, this could not prevent historic urban landscapes in larger cities, particularly Istanbul, to undergo massive urban restructuring since the 1940s. The heritage, the memories, the tangible and intangible values of the communities have become targets to the destructive politics under mainstream politics, either under the influence of the modernity project of the 1950s or the global vision of 1980s, or under the name of neoliberal urbanism in the 2000s.

1950s brought the institutionalization of urban renewal as an attempt of economic revival and development of cities. This was the start of a period, when renewal has gained connotations with *unfitness*, *cancerous growth* together with *beautification* and *prestige* (Gunay 2016). Under the motto of *beautifying Istanbul* and *glorifying Istanbul's Ottoman past*, new transportation arteries were opened, historic neighborhoods surrounding major monuments were demolished. Coming to the 1960s, the modernity strategy was conducted via the transformation of cityscape by the replacement of traditional urban pattern with apartment blocks and by the clearance of squatter areas, the latter of which were once encouraged during the 1940s' ambitious urbanization and industrialization because of their *self-made* housing character in coping with the shortage of public funds to accommodate the new inhabitants migrated from rural areas. Nonetheless, most of the physical transformation and urban restructuring associated with globalization and neoliberal agenda has taken place since the 1980s through the liberalization movement, and the enacted global urban vision of city administrations, especially in Istanbul. This has resulted in major financial and structural changes in the urban governance, and has consequently led to the emergence of an entrepreneurial local government and market-driven interventions in urban restructuring (for an overview of the neoliberal urban restructuring after the 1980s, see Keyder 2000, Bartu-Candan and Kolluoglu 2008). The changes have included, on one hand, the construction of office complexes/towers, finance districts, mega projects, gated communities, privatized public services; on the other hand, the introduction of mega urban renewal projects for the opening of large boulevards, the demolition of industrial complexes, and the continuing eviction of squatter areas.

During the most recent decade, though, we have been re-witnessing the mounting of such restructuring projects with a target on the waterfronts, squatter areas, urban public spaces, and historic urban landscapes. The 2000s is a period that foresees a growing tendency towards neoliberal planning in the urban agenda through the deployment of renewal as the base of planning policy under the leadership of Justice and Development Party (AKP) since 2002 followed by major legal and institutional reforms. This is also a period when the quest for alternative solutions for urban problems is transformed into the total clearance of problem areas within cities. With increasing emphasis on large-scale, area-based interventions rather than individual parcel-based practices, squatter areas have been demolished, state-owned lands have been privatized, and historic urban landscapes have been put into the market as renewal zones. Once more, the historic city has been a subject of destruction and reconstruction to get rid of the obstacles fronting a *global* and *modern* city with familiar mottos; *unfit*, *unhealthy*, *cancerous cell*, *shame bag* or *dirt*. One of the differences between the former periods and the 2000s is the fact that urban renewal is started to be conducted by the powerful stakeholders, namely the state and real-estate developers comparative to the un-powerful actors of the former periods such as contractors or squatter dwellers (Tekeli 2009). Another difference is the change of emphasis in creating a rationale for neoliberal restructuring, *disasters*—as a continuum of what Klein (2007) calls "disaster capitalism". The 1999 Marmara Earthquakes have played a major role in increasing awareness on the importance of an urbanization perception by institutionalizing renewal process, and especially by focusing on what already exists (A 7.5 magnitude earthquake hit Izmit in 17 August 1999, followed by a 7.2 magnitude earthquake of Duzce in 12 November 1999. According to the Crisis Management Centre of Prime Ministry, 18,243 individuals died, 376,379 housing units totally destroyed leaving 600,000 homeless. It heavily affected Istanbul as well as the industry center of Turkey, the Marmara.). However, it has also given irresistible political *legitimacy* to large-scale area-based urban renewal interventions (Gunay 2015).

2 Renewal Agenda in Historic Urban Landscapes: Law 5366

Area-based urban renewal programs are part of the legal and institutional reforms brought in the 2000s as part of the growing tendency towards neoliberal planning in the urban agenda. Between 2002 and 2012 major attempts were made to prepare the legal format for the employment of neoliberal urban policies including the alteration of Mass Housing Law (Law no. 5162) in 2004 to transfer of Mass Housing Authority (TOKI)—responsible institution for the provision social and affordable housing—from the Ministry of Public Works and Settlement to the Office of the Prime Minister; to authorize TOKI to realize, prepare and alter all kinds and scales of development plans in areas determined as the mass housing settlement regions; and the transfer of 64.5 million square meter of state property into its portfolio to avoid bureaucratic obstacles. These were followed by three fundamental laws defining the legal and institutional base of renewal schemes in Turkey: Law on the Protection and the Revitalization of Deteriorated Historical and Cultural Immovable

Assets (No.5366, 05.07.2005), Law on the Transformation of Areas under Disaster Risk (No.6306, 31.05.2012) and Municipality Law (No. 5393, article 73, 13.07.2005).

Law 5393 authorizes municipalities with the right of designating renewal sites and determining renewal projects in deprived, earthquake-prone or historic areas. While the squatter areas turn into major targets, reconstruction is the major method in renewing existing building stock. Having issued by the slogan of *making squatters history*, Law 6306 brings forward a definition for risk areas to be transformed as "buildings within or outside risk areas that have completed their economic life, or which are scientifically and technically proven to be at risk of demolition or high damage." Being materialized through the authority of Ministry of Environment and Urbanism and Mass Housing Authority (TOKI), the Law is far from solving neither the quality problem in housing provision nor in urbanization, but rather raises serious debates on environmental, cultural and social consequences including the transformation of conservation sites, agriculture and forest areas into reserved housing zones for construction, the demolishment of even steady housing stock and the displacement of inhabitants (Gunay 2015). Through newly attained responsibilities, the Ministry and TOKI are authorized to expropriate all the immovable properties; to transfer property and zoning rights to other defined areas; to divide and allocate property shares and to establish rights. This paper focuses on Law 5366 because of its direct relevance to historic urban landscapes (for further information on the legal context of planning and renewal in Turkey, see Unsal and Turk 2014).

Law 5366 propounds renewal sites in order to consolidate the urban structure for earthquake risk mitigation, low quality of life standards, and to regenerate deprived urban nodes of historic city centers by bypassing regular urban plans and planning processes (Gunay et al. 2015). The scope of the law is limited to the areas that are already declared as protection sites. It was an attempt to disable the Law on the Protection of Cultural and Natural Assets (No. 2863/23.07.1983) in order to redefine the institutional responsibility areas and intervention models in historic urban landscapes in the favor of private sector and corporate power of the state ideology (Gunay et al. 2015). The main features of the Law are as follows:

- The law introduces a highly centralized governance structure. The municipality, as controversially *de facto* central administration, has the sole power to declare any site as renewal site and to define the implementation and financial framework.
- The implementation model may vary; however the main model is public-oriented implementation. Key implementation instrument is *urgent expropriation* to overcome postpone and to increase the ability of intervention, although it can only be utilized in course of national security/defence according to the Expropriation Law (No. 2942). Expropriation is an important instrument when dealing with small parcels and fragmented ownership structure, but negotiation and agreement should be essential. The law calls for municipal

authority for expropriation in the lack of agreement as well as for sale of property to third parties.

- The Law introduces new actors of empowerment and control. It propounds the establishment of 'Boards of Renewal', the members of whom are assigned by the government, authorized to approve the renewal projects. This regularization bypasses 'Boards of Protection' under the Ministry of Culture and Tourism, which were responsible in the control of conservation status of historic neighborhoods since the enactment of the Law 2863. TOKI is contradictorily the most powerful institution in the implementation of the law, by shifting from constructor towards planner, after the alteration of Mass Housing Law (No. 5162) in 2004 for the authorization to realize, prepare and alter all kinds and scales of development plans. The law also foresees the corporations of municipalities such as Istanbul Residence Development Plan Industry and Trade Inc. (KIPTAS) to act as the main property owner in the realization of renewal projects. Control Bureaus for the Conservation of Cultural Assets (KUDEB) are promoted in providing technical assistance.
- Financial model is based on the *sale* of affordable housing to affected property owners through monthly instalments of long-term credits. TOKI can allocate the revenues generated through the *revenue sharing model* from high-income housing projects in state-owned land. Transfer of development rights or increase in development rights for private sector are major instruments in attracting private sector investment. Private sector that participates in renewal project is also freed from tax together with TOKI. The monopoly shows itself also in construction through the hegemony of a few large developers withdrawing small and medium size firms.
- Mutual agreement between the authority and property owners constitutes the base of implementation process. The Law calls for municipal authority for expropriation in the lack of agreement with the property owners. Participation is limited to the notification or consultation whereat the necessity is defined by the authority. The owners of historic buildings not to be demolished are obliged to carry out their own conservation projects under the assistance of KUDEB. Otherwise, they are given dwellings in one of the mass housing zones constructed by TOKI at the periphery of the city. Thus, the property owner is enforced either to become the partner of projects or to sell the property willingly or to be part of expropriation. The implementation and financial models ignore tenants.

3 Controversies, Contrasts and Challenges… to Renew or not

While urban renewal has become a catchphrase in Turkey over the past two decades, the historic urban landscapes have turned into valuable resources in line with the rise of neo-liberal urban planning agenda. Istanbul is no exception. The enactment of the Law 5366 in 2005, followed by other above-mentioned laws, has introduced a major challenge for the future planning history of Istanbul. Renewal has been introduced as an evolving urbanization model to respond to the need of mitigating the risks as well as to improve the living conditions in deprived urban areas. While the private sector has valorized this process as a continuum of immense market pressure, historic urban landscapes have become controversial playgrounds for these new urbanization models as an *excuse* of living under the threat of earthquake.

The controversies, contrasts and challenges include the following:

Law 5366 introduces a controversial process in the hands of hegemonic power relations of AKP into the need to re-create global and competitive cities (for an overview of state interventions in Turkey, see Eraydin and Tasan-Kok 2014; Turkun 2011; Oktem 2006; Cavusoglu and Strutz 2014). Legal and official obsolescence in providing strategic, responsive, transparent and inclusive planning instruments, methodologies and organization forms has made the problematic even worse such as in other developing countries. Over-centralized structure of urban renewal interventions as a continuum of asymmetric power relations prevents participatory multi-actor decision-making processes, ignores the dynamics of local governance and limits transparency of process through the elimination of different interests of empowered actor groups, and independent governmental and non-governmental control mechanisms. The new actors constitute “dangerously powerful institution directly at the service of the executive branch of the government” (Advisory Group on Forced Evictions 2009, p. 16). Even some scholars state that the AKP requires no less than a massive program of demolition and resettlement in order to erase much of the physical and social legacy of the past half-century due to the undemocratic style of urban governance (for instance, see Lovering and Turkmen 2011, p. 75). These unique sites currently act as giant construction zones of economic rant, land speculation and displacement, while raising many concerns about the management approach, actors and processes involved.

Law 5366 and its respective executions introduce project-based approaches fragmenting the planning process via the prominence of concepts such as revitalization, transformation, and renewal. Planning’s intervening and controlling role in entrepreneurial practices undergoes a change via neoliberal policies, thus, private sector-oriented partial projects replace comprehensive planning approaches such as in conservation planning versus renewal projects. The existing planning approach in urban conservation introduces a problematic approach through the increasing use of renewal concept especially in the absence of a specific legislation concerning World heritage sites. Public authority and public resources are being used not to provide affordable and high-quality urban environments to the lower-income groups, but to open up profitable investment areas either for the state or for certain private developers—in Harvey’s (2000, pp. 133–181) words, “public takes the risks, private takes the profits”.

The focus of Law 5366 creates a shift towards land development and renewal as a continuous destruction and construction process, from an integrated approach of conservation based primarily on safeguarding the integrity and authenticity of existing historical buildings. The definition of renewal sites based on physical and locational determinants ignores the historical and social layers of urban landscapes. In Istanbul case, the world heritage value is also under attention—Istanbul was enlisted in UNESCO World Heritage List in 1985 with its four archaeological and historic zones including the Archeological Park of Sultanahmet, Suleymaniye, Zeyrek and Landwalls. The Peninsula has also been under national protection since 1995 as an urban, historical and archaeological site. There are concerns on the overlap of newly declared renewal sites either with historic areas of Istanbul that are on the World Heritage List and that of the exclusion of specialists in the newly forming renewal boards to evaluate and approve the projects to take place in those renewal sites. Although the World Heritage Management Plan was completed in 2011, it could not empower central and local authorities in changing the emphasis on urban development priorities. As a showcase of Law 5366, only in the Istanbul Historic Peninsula, the UNESCO World Heritage Site, nearly 37 urban nodes within historic neighborhoods were declared as renewal sites between 2006 and 2010 (for an overview of declared urban renewal areas in historic urban landscapes, see, Dincer et al. 2010; regarding the renewal practices in the Historic Peninsula, see Gunay et al. 2015). Ayvansaray, Suleymaniye and Sulukule are among the neighborhoods that suffered the most destructive impacts of this legal format, immediately after their declaration as renewal sites. In the Peninsula, this meant a *world heritage (renewal) site*. The threats are well documented in various international conservation expert reports (see for instance the decisions of UNESCO/WHC 2008, 2009, 2010, 2012). According to these, there is concern at urban renewal projects with a focus on land development, which is critical for the World Heritage sites. Despite these sceptic views, Law 5366 has become a unique example for the massive physical destruction—*bulldozer renewal*—of historic urban landscapes that are inscribed in the UNESCO World Heritage List, as well as the destruction of all the meanings, memories and social relations attached to this historic urban landscape and its oeuvre.

Urban renewal has increasingly been justified as the only possible solution for the so-called *naturalized* urban problems (Bartu-Candan and Kolluoglu 2008, pp. 18–19), such as the mitigation of earthquake risk, the elimination of invasion, high crime, terrorism, drug addiction, illegal economic activity; social exclusion and displacement have started to be seen as an inevitable effect. Isik and Pinarcioglu (2001) call this process a transition from a *softly segregated city* to a *tense and exclusionary urbanism*. A significant number of studies have pointed out the implications of state-led and increasingly authoritarian urban renewal policies and particularly their relation to heritage and heritage communities since the early 2000s (see for instance Bartu-Candan and Kolluoglu 2008, Kuyucu and Unsal 2010, Lovering and Turkmen 2011, Gunay 2015, Cavusoglu and Strutz 2014). The implications of the law show that it has neither brought an integrated approach to the socio-economic problems of the neighborhood, nor it has achieved a sustainable area-based strategy to resolve the problems that challenge the everyday life of citizens. Instead, renewal projects justify the change of ownership of properties after the destruction decisions and urgent expropriations. The current urban renewal policy is structured upon the idea of compensation by the property owners. However, it disregards the reality that the choice of constructing a living in such neighborhoods is bounded closely to the economic vulnerability of communities. In that sense, urban renewal creates new poverty zones of displaced and dispossessed communities with increased expenditures, dependency to bank interest mechanisms and erasure of social life and networks of solidarity. While the developers, speculators and the elite are the main beneficiaries, the projects embody potentially destructive threats to the meanings associated with these neighborhoods and their strong social networks, which may help them preserve their heritage, and could lead to social development as a way of existence strategy. The fate of tenants is uncertain.

4 Nepal: Lookin' Through the Window

In a chapter presenting a critical appraisal on Turkey's quest for urban renewal, a look through the window of Nepal indicates an alternative dialectic not only upon conventional or Turkish urban discourse upon the menace of naturalized or man-made disasters, but also that of authorized heritage understanding. On the contrary to Turkey's urge to renew all of which exists from the past, the lessons learnt from Nepal and particularly Kathmandu's endurance to recover the past introduce major inputs against all the odds in understanding the need for a paradigm shift in renewal.

Nepal suffered from vast loss of lives and devastation of human settlements on 25 April and 12 May 2015, when respectively magnitude 7.8 and 7.3 earthquakes struck this outstanding land (NRA 2016, p. 1). It was neither the first nor the last of unfortunate incidents; though, the territory has undergone chronic destruction throughout the history by the so-called *forces of nature* (for a brief overview, see, Weise 2015). The same forces have also helped in the formation of close links between the community, the environment and the heritage—allowing for a system of cyclical renewal based on a *self-renewal*, *self-recovery* process in action, while introducing a more resilient and transformative heritage concept. Thus, the deployment of renewal as the base of planning policy is not a new phenomenon (see for instance, UNESCO 2015; Sandolhz 2017, pp. 137–185). Regarding Kathmandu and its valley, renewal is in the traditional mind-set and everyday life of this particular society, due to the outstanding historic urban landscape under threat of earthquake-prone setting, followed by rapid and uncontrolled urbanization, excessive building densities, new constructions of poor quality, inadequate infrastructure, global exploitation of heritage, socio-spatial fragmentation and poverty, and the lack of effective and responsive management mechanisms. As in Turkey, earthquakes also play a major role in increasing awareness on the importance of planned urbanization, institutionalized post-recovery process, as well as the reconciliation of heritage and change.

Recalling *urbicide* in many parts of the world, renewal in Nepalese context is furthermore distinctly associated with the traditional wisdom on *faith/destiny*, *authenticity* and *self-healing*.

The belief on *faith*, *destiny* or *wrath of god(s)* with regard to disasters, which is hard to understand in a contemporary *Western* approach but very familiar in traditional Turkish context, creates either a safety net for vulnerabilities or hope and resilience in coping with the negative influences of the present. Heritage at risk also delivers a *space of hope*. Despite intensive needs across an array of diverse political, economic, and urban states of affair, this insight prevails for the people of Nepal to find ways to re-build their lives, cities and heritage with or without state support.

Considering renewal contextualization based on the authenticity of heritage as a second remark, it is not wrong to state that Nepalese heritage discourse is rooted in *continuity* rather than *authenticity*, as an evidence of existence. The tradition of *pratisamskara*, for instance, as a principle of conservation asserts the fundamental of '*keeping near to the original*' (Tiwari 2015, p. 171), while accepting change and that of renewal against the conventional heritage preservation discourse. This tradition of replacing old with new, controversially, creates an urban palimpsest of history and meanings.

The state-driven efforts concentrate on the preservation or renewal of monuments before every-day-life spaces of community. But approaching heritage as a healing instrument with close links to intangible values normalizes the insufficiencies in responding to community needs. This situation leads the people of Nepal to *own* associated responsibilities to safeguard heritage as well as cities as a whole. The spontaneous *self-recovery* and *self-made* process may construct the base for participatory frameworks, although can be claimed as a management failure in Eurocentric/conventional understanding. The origins of this approach go back to the Guthi System of the Kathmandu Valley, which can also be termed as a community-based conservation model (Tiwari 2015).

5 Concluding Thoughts and Prospects for Future: From Istanbul, with Love

Urban transformation is a multi-faceted phenomenon without a unified form of policy or practice in the world. Regarding historic urban landscapes, it is evident that it is only successful if it can flourish with different spatial, economic and especially social traits together to achieve an improvement in the integrity and sustainability of heritage and the livelihood of the heritage communities. Despite this definition, the recent practices both in the developed and developing world show that, the heritage and its communities has increasingly been neglected in order to create opportunity spaces for market-driven investments. The increasing monopoly of urban renewal (the prioritization of urban renewal has contradictorily been included in the UN's New Urban Agenda as regard to 'sustainable and inclusive urban prosperity and opportunities for all' in 2016), in return, has become an instrument of gentrification, socio-spatial segregation and social exclusion driven by neoliberal urban policies.

State-driven urban renewal policy in the historic landscapes, in particular, is increasingly becoming a state-driven exclusion strategy, while the heritage, the memories, the tangible and intangible values of the communities have become targets to the destructive politics under mainstream politics (Fig. 1).

The solution calls for a change of emphasis in the governmental perception and that of an urban paradigm shift to employ holistic, inclusive and transformative framework in urban politics:

- The cities, especially in the developing world such as Nepal and Turkey, are in urgent need of urban renewal despite the changing rationales in time and in due course of political conjuncture. The vulnerability of urban landscapes is indisputable either in historic or post-disaster settings resulting from uncontrolled or planned urban growth, large amount of squatter areas and slums due to haphazard urbanization, disaster-prone building stock due to lack of administrative control over construction and building construction technology, historic building stock in need of careful conservation, rehabilitation and continuous maintenance. It is therefore of major importance to justify urban renewal not as a project, but rather as a transformative and responsive process without reducing the need into a spatial, architectural and aesthetic solution. The process, then, should be scientifically contextualized and justified with respect to local causalities, rationales, needs and intangible values depending on what is to be achieved, how it is achieved, with and for whom it is to be achieved.
- Urban renewal based on destruction and reconstruction is not the only possible solution for the *naturalized* urban problems such as the mitigation of earthquake risk. There is a need for urban policy frameworks that encourage reinvestment and improvement rather than destruction. Regarding severe damage caused by disasters, post-recovery should consider the authenticity and integrity of historic urban landscapes together with its layering of intangible values, while ignoring the creation of artificial marketable and expendable opportunity spaces and identities. This is further related to the controversial approach of reconstruction; thus, it is of major importance to respect diverse understandings of authenticity, while ensuring the continuity of living cultural heritage in balance with taking change and diversity into account. Historic urban landscapes, not only world heritage sites, should not be taken outside planning system through the effective employment of Management Plans to manage change.
- Social exclusion and displacement are not inevitable effects of urban renewal. Historic urban landscapes should not be divorced from the community that become part of these landscapes. The existing implementation and finance models of urban renewal can be applicable for high-income real-estate targets, but in the case of historic environment and vulnerable disadvantaged settlements, the models should avoid excessive economization, commodification, real-estate and property market-driven developments and commercial interests. Built upon the idea of housing as a human right, alternative finance mechanisms should be allocated by facilitating trust funds, donor involvement, micro-financing and self-help mechanisms.

- Centralized governance structure based on public-led implementation is efficient in conserving heritage and rights of ownership, given the fact that it is responsive to strategic, transparent and inclusive planning instruments, methodologies and organization forms as well as open to multi-actor participation in decision-making, the inclusion of heritage experts and specialists and the facilitation of independent control mechanisms such as professional boards. The facilitation of coordination, negotiation and interest among institutional and local stakeholders is essential to strengthen empowerment in urban governance.
- Urban renewal is a divisive process, when it is not integrated with inclusive approaches. There is an urgent need to emphasize right to the city that comprehensively represents community interests and their collective memories by developing community governance models (such as the guthi of Kathmandu Valley) as a shift from social exclusion to socially inclusive urban transformation interventions in historic urban landscapes. This is related to a wider understanding on urban politics as a medium of socially inclusive public policy that considers social impacts and enforces the idea of historic urban landscape within the community as a public good and a social asset.

Fig. 1 From Istanbul, with love: Picture from Ayvansaray in ruins, a historic neighborhood along the Landwalls of Istanbul Historic Peninsula, which was a UNESCO World Heritage Site since 1985 (*Photo courtesy* Z. Gunay)

The loss has taken the form of the inevitable, when destruction has been subject to unnatural but naturalized disasters just like in Kathmandu Earthquake of 2015 or Marmara Earthquakes of 1999. The loss has also shown its destructive path in the form of unnatural just as the man-made disasters of the so-called neoliberal re-structuring of the cities under the name of renewal. From Kathmandu's urge to re-new the destructed heritage after the earthquake to Istanbul's to renew the living heritage before the earthquake, the paper hopes that the lessons learnt from Turkey's experience provide a medium to discuss the severe challenges and their re-solving instruments associated with natural revanchist disasters as well as man-made disasters, especially in developing countries and in the sites with outstanding common heritage values such as Kathmandu.

References

Advisory Group on Forced Evictions (2009) AGFE Mission: Advisory Group On Forced Evictions To The Executive Director Of UN-HABITAT, 8–11 June 2009

Bartu-Candan A, Kolluoglu B (2008) Emerging spaces of neoliberalism: A gated town and a public housing project in Istanbul. New Perspectives on Turkey 39:5–46

Cavusoglu E, Strutz J (2014) We'll come and demolish your house!: The role of spatial (re) production in the neoliberal hegemonic politics of Turkey. In: Akca I, Bekmen A, Ozden BA (eds) Turkey Reframed: Constituting Neoliberal Hegemony. Pluto Press, London, pp 141–154

Dincer I, Enlil Z, Evren Y, Kozaman-Som Z (2010) Istanbul'un Tarihi ve Dogal Miras Degerleri: Potansiyeller, Riskler ve Koruma Sorunlari [Istanbul's Historic and Natural Values: Potentials, Risks and Conservation Problems]. Bilgi University, Istanbul

Eraydin A, Tasan-Kok T (2014) State response to contemporary urban movements in turkey: A critical overview of state entrepreneurialism and authoritarian interventions. Antipode 46 (1):110–129

Gunay Z (2015) Renewal agenda in Istanbul: Urbanisation vs. urbicide. ICONARP Int J Archit Planning 3(1):95–108

Gunay Z (2016) Temporality and limits to hospitality in the ruins of a world heritage (renewal) site: Suleymaniye in Istanbul Historic Peninsula. In: Proceedings of the 52th ISoCaRP Congress on Frontiers of Planning, Durban, September 2016, pp 180–189

Gunay Z, Koramaz TK, Ozuekren AS (2015) From squatter upgrading to large-scale renewal programmes: Housing renewal in Turkey. In: Turkington R, Watson C (eds) Renewing Europe's Housing. Policy Press, Bristol, pp 215–244

Harvey D (2000) Spaces of hope. Edinburgh University Press

Isik O, Pinarcioglu M (2001) Nobetlese Yoksulluk: Sultanbeyli Ornegi [Poverty in turn, squatter housing and urban poor: The example of sultanbeyli]. Iletisim, Istanbul

Keyder C (ed) (2000) Istanbul: Küresel ile Yerel Arasında [Between the Global and the Local]. Metis, Istanbul

Klein N (2007) The shock doctrine: The rise of disaster capitalism. Alfred A. Knopf, Toronto

Kuyucu T, Unsal O (2010) Urban transformation as state-led property transfer: an analysis of two cases of urban renewal in Istanbul. Urban Stud 47(7):1479–1499

Lovering J, Turkmen H (2011) Bulldozer neo-liberalism in Istanbul: The state-led construction of property markets, and the displacement of the urban poor. Int Plann Stud 16(1):73–96

NRA (2016) Post-disaster Recovery Framework 2016–2020 by the Government of Nepal National Reconstruction Authority

Oktem B (2006) Neoliberal küreselleşmenin kentlerde inşası: AKP'nin küresel kent söylemi ve İstanbul'un kentsel dönüşüm projeleri [Construction of neo-liberal globalisation in cities: The global city discourse of AKP and the urban regeneration projects of Istanbul]. Planlama 2:53–63

Sandolhz S (2017) Urban Centres in Asia and Latin America: Heritage and Identities in Changing Urban Landscapes. Springer International, Cham

Tekeli I (2009) Kent, Kentli Hakları, Kentleşme ve Kentsel Dönüşüm [City, Citizen Rights, Urbanisation and Urban Transformation], Istanbul: Tarih Vakfi

Tiwari SR (2015) Material authenticity and conservation traditions in Nepal. In: Weiler K, Gutschow N (eds) Authenticity in Architectural Heritage Conservation: Discourses, Opinions, Experiences in Europe, South and East Asia. Springer International, Cham, pp 169–186

Turkun A (2011) Urban regeneration and hegemonic power relationships. Int Plann Stud 6(1):61–72

UN (2016) New Urban Agenda: Quito Declaration on Sustainable Cities and Human Settlements for All. United Nations Conference on Housing and Sustainable Urban Development [Habitat III], A/RES/71/256, p 11, Quito, October 2016

UNESCO (2015) Revisiting Kathmandu: Safeguarding Living Heritage. Paris

UNESCO/WHC (2008) State of conservation of World Heritage properties. WHC-2008/32COM 7B.Add.2, p 21–25

UNESCO/WHC (2009) State of Conservation (Historic Areas of Istanbul). Decision WHC-09/33COM 7B.124, Sevilla, p 155–156

UNESCO/WHC (2010) State of Conservation (Historic Areas of Istanbul). Decision WHC-10/34COM 7B.102, Brazilia, p 188

UNESCO/WHC (2012) Joint ICOMOS/UNESCO WHC Reactive Monitoring Report: Historic Areas of Istanbul (Turkey) (C 356), November 2012

Unsal F, Turk SS (2014) Legal and Institutional Context of Urban Planning and Urban Renewal in Turkey: Thinking about Istanbul. In: Erkut G, Shirazi R (eds) Dimensions of Urban Re-development. Technische Universität Berlin, Berlin, pp 15–30

Weise K (2015) Conserving continuity. Himal Southasian 28(2):N/A

Traditional Buildings and Preliminary Report in Construction Methods to Combat Earthquake

Rabindra Puri and Sukriti Suvedi

Abstract The earthquake of April 2015 has affected lives of Nepalese people in a very disturbing way. Although an earthquake cannot be stopped or correctly predicted, proper measures can be taken to prevent the hazards' impact. Construction of earthquake resistant buildings is one of the major steps towards minimizing the risk. Numerous major earthquakes occurred throughout Nepal's history. Consequently, earthquake-safe building is necessary and care needs to be placed in choosing the building material, type and construction methodology. Readily available materials like stones and mud can redeem as the most economic and reliable source of constructing the village houses throughout Nepal. Houses constructed in traditional Nepalese hill style with proper reinforcements have proven earthquake resistant, as seen from the houses built in Namuna Gaun, Sanga, and Bardali Ghar, Phulbari, Kabhre. Similarly, the earthquake-damaged houses need to be managed properly so as to reuse and reutilize most of the material from the old buildings. This will not only reduce the costs of construction material but also play the most significant role in heritage preservation and conservation. The houses in Gachhen area (Bhaktapur) are filled with artistic handicraft windows and doors from Malla era. Proper care has been taken to dismantle the shattered houses and recover materials intact as far as possible. There have also been cases of theft of ancient artefacts from houses. Hence, much care has been taken to store the materials reliably and safely. Addressing the needs of earthquake-affected people, care has to be taken in the economic front as well. The construction needs to be reliable as well as within budget. This fact can be met when the materials such as wood, bricks, stones, roof tiles etc. from the old buildings are reused. In context of reconstruction of earthquake resistant buildings, traditional Nepalese style building would be one of the best options.

R. Puri (✉) · S. Suvedi
Rabindra Puri Foundation, Bhaktapur, Nepal
e-mail: namuna.ghar@gmail.com

S. Suvedi
e-mail: sukriti.suvedi@gmail.com

J.H. Kruhl et al. (eds.), *Living Under the Threat of Earthquakes*,
Springer Natural Hazards, https://doi.org/10.1007/978-3-319-68044-6_10

Keywords Traditional Nepalese style building · Earthquake safe building
Indigenous construction methods · Artifacts preservation · Maintenance

1 Introduction

The two earthquakes of 25th April 2015 and 12th May 2015, with magnitudes of 7.8 and 7.3 Mw, has shaken the lives and economy of Nepalese people very severely. The Gorkha Earthquake was followed by 460 aftershocks with local magnitudes > = 4 until 3rd June 2016 (National Seismological Center 2016). 602,257 houses were fully damaged and 285,099 houses were partially damaged (Government of Nepal 2015).

2 Background

Gachhen, Bhaktapur

The ancient city of Bhaktapur was also devastated by the earthquake (Fig. 1). According to Bhaktapur Municipality, 18,900 houses have been fully and 9054 partially damaged out of 43,536 households (Nepal Earthquake 2015).

Fig. 1 Post earthquake situation in Gachhen, Bhaktapur

Model Village, Kavre

From the reports it is seen that 49,933 private houses have been severely damaged in Kavre (Kabhrepalanchowk) District of Nepal. 318 lives have been taken and 1179 persons have been injured. 548 schools were affected; 48 government buildings, 55 health facilities, and 904 classrooms have been fully damaged (Nepal Earthquake 2015).

The main aim of Rabindra Puri Foundation for Conservation is to build the houses for at least 30 household in the district. The houses will be special on the basis that it would be built on traditional construction methods, i.e., only wood, mud and stones will be used for construction.

The houses will be as per the recommendation by "Design Catalogue for Reconstruction of earthquake resistant houses, Volume I". Furthermore, the houses have been analyzed by Finite Element Method. At the points where the stress is exceeded, tensile wooden members have to be added.

3 Preservation of Heritage and Artifacts

Preservation of artifacts is one of the ways, through which we can transfer the rich cultural heritage and traditions to the next generation. The area of Gachhen, Bhaktapur, consists of one of those types. The craftmanship and designs of windows and doors of the houses of the area can be traced back to eighteenth century AD.

A severe need was felt for saving the wood retrieved from the buildings of the area after the earthquake. Wooden struts, windows and door frames and shutters would be severely damaged if left with the debris during the monsoon season (July through September). Rabindra Puri Foundation for Conservation acted upon the idea of preserving what is left after the earthquake. The locals and owners of the houses were gathered and made aware of the persisting danger and a solution for the problem was suggested.

It was a rigorous task to extract the artefacts from the debris of the houses (Figs. 2, 3 and 4). Keeping it in proper condition is also a challenge. But the foundation has been able to take out the useful windows, doors and pillars from the houses and store it in a well ventilated shed, away from direct sunlight and rain water, and preserve it from dampness (Figs. 5 and 6).

The final achievement of the foundation would be to construct the area as it was before the earthquake, with all the artifacts intact. The houses will have a traditional look from outside but will have all the modern facility available inside. Although it would be constructed as a frame structure with cement, sand, bricks and steel being the major components of the construction, still there would be no compromise in the frontal views of the buildings. These buildings would be made within traditional outlook in mind.

Fig. 2 Volunteers, students and workers taking extra care to remove the window frames

Fig. 3 Volunteers, students and workers taking extra care to remove the window frames

Fig. 4 Removal of the components of window with precision

Fig. 5 Storing of the wooden components of the building

Fig. 6 Storage of wooden components of buildings with number coding for each building

4 Traditional Construction Methods in Villages

The indigenous construction methods of Nepal consists of using wood, stone and mud to build homes. These are the three materials that are available throughout Nepal, including the remote parts of the country. Traditionally, the houses are constructed of two floors in the villages, of which the load is evenly distributed to the walls and timber pillars and struts.

Rabindra Puri Foundation for Conservation aims to construct at least 30 houses in the traditional design using locally available materials. These houses would act as a model for the community people to use indigenous skills and techniques (Figs. 7 and 8).

It has to be noted that the estimated costs of the building construction is NRs. 10,00,000. This sum of money would be high for the house owner to bear personally, so RP Foundation will be helping 50% of the amount. The other 50% of the amount will be covered by the house owners in terms of collection of construction resources, local involvement, and provision of land for construction.

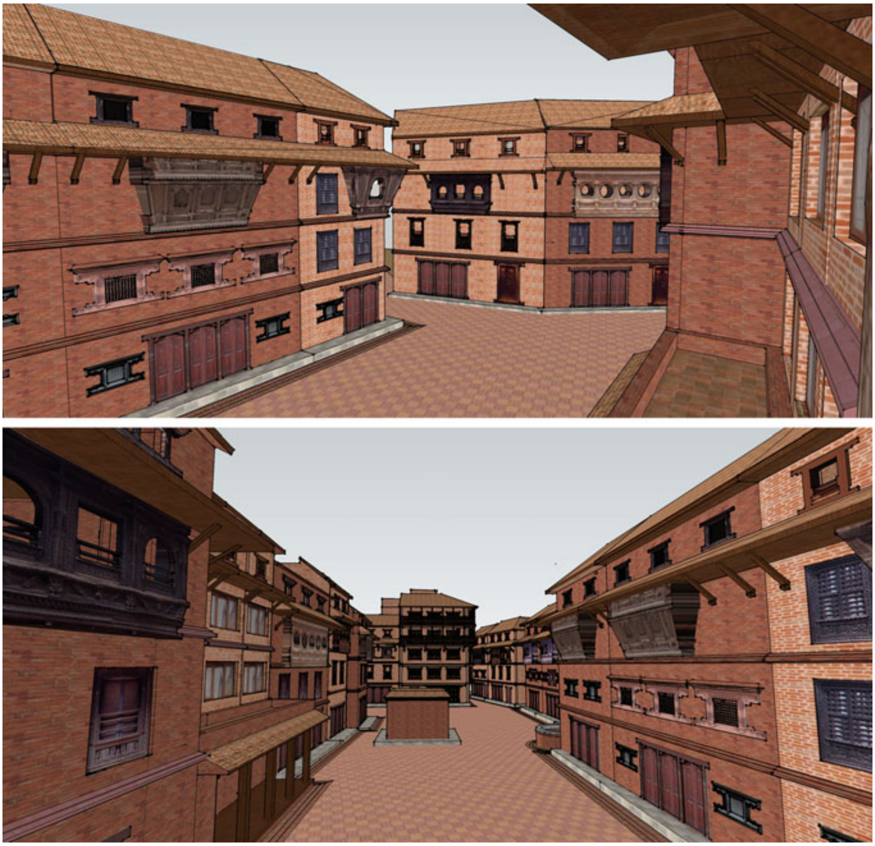


Fig. 7 Computer aided design of the Gachhen courtyard after reconstruction

5 Summary

The construction method has vital importance. The loss and damages due to earthquake of April and May 2015 were mostly due to ignorance in construction methods and improper practices. The best practice in construction with brick and stone mud mortar can be seen in the five-storied Nytapole Temple situated in Bhaktapur Taumadhi Square (Fig. 9). This infrastructure was erected during the seventeenth century, and have survived at least 3 major earthquakes in the region. Yet except for some minor damages, it stays strong and stable.

Another major fault with respect to damaged houses is the lack of maintenance. The private houses, due to negligence or insufficient knowledge, could not maintain the wooden posts, the walls, window and door frames. These have been seen as the major fault.

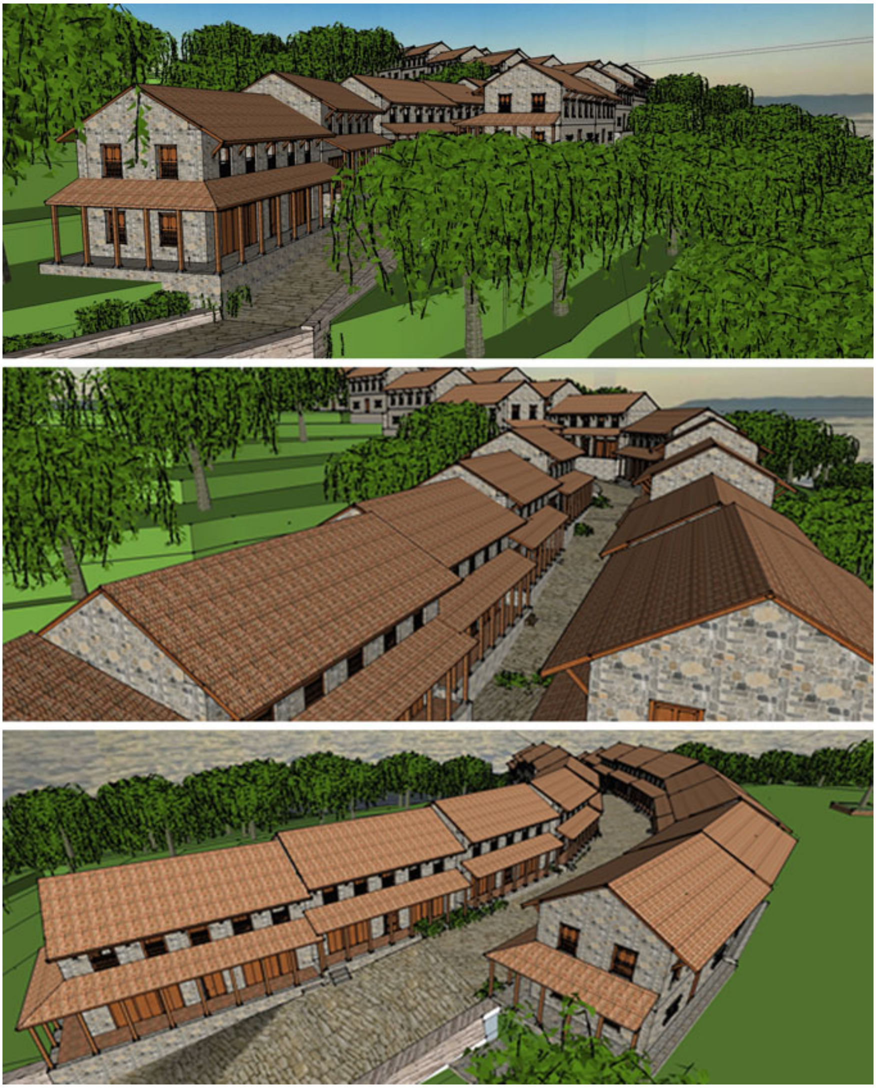


Fig. 8 Computer aided design of the Namuna Village, Kavre

If the construction of houses are only done with concrete and brick mortars then there would be a huge problem for the upcoming generation as they would never know the techniques used in the ancient times in Nepal. Construction of a concrete jungle will always impose a threat to the heritage preservation of the Nation and further more to cities and civilization like that of Bhaktapur.

Indigenous construction methods should be followed specifically and no measure should be left unattained. For example, addition of *Tham* (Posts made out of

Fig. 9 Nyatapole Temple, Bhaktapur (Wikipedia)

Wood) should be added to every 10 feet (3.048 m) of walls to support the structure. Corners should be well bound and intact. Gable walls should be build as light as possible and tie beams or wooden frames should be provided. All these add up to make the houses stable and more durable in the events of earthquakes.

References

Government of Nepal (2015) Design catalogue for reconstruction of earthquake resistant houses, Nepal. Government of Nepal, Ministry of Urban Development, Department of urban development and building construction

National Seismological Center (2016) Recent earthquakes. National seismological center. http://www.seismonepal.gov.np/index.php?listId=161. Accessed 1 June 2016

Nepal Earthquake (2015) Nepal earthquake district profile. http://drrportal.gov.np/ndrrip/main.html?id=1. Accessed 10 July 2016

Wikipedia (2016) Nyatapola temple. https://en.wikipedia.org/wiki/Nyatapola. Accessed 28 June 2016

Part III
Disaster Management and Economics

Medical Aspects of the Gorkha Earthquake 2015: Disaster Preparedness and Response

Monika Brodmann Maeder and Matiram Pun

Abstract This chapter includes exemplary accounts from two medical doctors pertaining to the situation in the capital and in remote valleys. Within both accounts, the authors describe their personal experience, beginning with the first few hours post the initial quake. These experiences are firsthand accounts, ranging from uncoordinated medical aid in a governmental hospital in Kathmandu and a mountain hospital in Lukla to the ad hoc rescue chain in the Khumbu valley for those victims coming predominantly from Everest Base Camp. Unfortunately, the threat of future earthquakes and other natural hazard events in Nepal cannot be diminished. Therefore, in order to better manage any future mass casualty event, it is clear that there is a pressing need for further development of medical and rescue training services for both existing practitioners in the capital and those individuals based in rural Nepal. Moreover, the development of an international, coordinative body with rapid response time and specialist skill base must be discussed and deployed effectively in the case of any future national emergency.

Keywords Earthquake · Disaster preparedness · Disaster response
Emergency medicine · Himalaya

M. Brodmann Maeder (✉) · M. Pun
EURAC Research, Institute of Mountain Emergency Medicine,
Bolzano, Italy
e-mail: monika.brodmann@eurac.edu

M. Brodmann Maeder
Department of Emergency Medicine, University Hospital Inselspital,
Bern, Switzerland

M. Pun
Mountain Medicine Society of Nepal (MMSN), Kathmandu, Nepal

J.H. Kruhl et al. (eds.), *Living Under the Threat of Earthquakes*,
Springer Natural Hazards, https://doi.org/10.1007/978-3-319-68044-6_11

1 Introduction

The 7.8 magnitude earthquake, which struck Nepal on April 25 2015, plus all subsequent aftershocks, had huge consequences for the Nepalese healthcare system and the overall health and wellbeing of the Nepalese people. According to official documents from the Nepalese government and the World Health Organisation (WHO 2015a), more than 8700 people were killed, and nearly three times as many injured. Overall, 5.6 of the 27.8 million residents were affected. In the rural regions around the epicentre in Sindhupalchok and Langtang, the earthquake triggered lethal rock falls and landslides. Everest Base Camp (EBC) was partly destroyed by an avalanche originating from Pumori, and in Kathmandu injuries and fatalities were mainly caused by building collapse. 446 public health facilities were completely destroyed and 765 partially damaged. Many hospitals were overwhelmed by the huge number of patients, and due to the fear of strong aftershocks treatment areas were established outside of the buildings under tarpaulins. In this article we will give an overview of disaster preparedness and management in Nepal and outline situational specific examples both during and after the first earthquake. We further describe and examine health care management on April 25 and the days subsequent. The examples are based on the experience of the two authors, both medical doctors, and are a personal insight into the hours and days after the mass casualty earthquake event that struck Nepal in spring 2015.

2 Disaster Preparedness in Nepal

2.1 Government Policy

In an official document of the World Health Organisation WHO (WHO 2012), Nepal has been classified as one of the hotspots of multiple hazards; such as epidemics, landslides, forest fires, avalanches and earthquakes. The Global Earthquake Safety Initiative (GESI) declared Kathmandu as having, “the highest earthquake risk per capita among 21 megacities in the world, largely due to building collapse and insufficient preparedness and medical care” (www.reliefweb.int) The main factors contributing to Nepal’s vulnerability are associated with poor access to effective health care, especially in remote areas and mountainous region where many of the multiple hazards occur. In their National Strategy for Disaster Risk Management (2009), the Ministry of Home Affairs issued clear strategies for disaster risk management. The Ministry of Health and Population was also incorporated in the development of these strategies. However, despite a clear shift from reactive (relief and response), to proactive (preparedness) risk reduction, in review the experts of the WHO still questioned whether, “the health sector will be able to respond effectively and efficiently in order to reduce avoidable mortality and morbidity during emergency and disaster”. Equally, on review several benchmarks were outlined for continuous strategy development, "regularly updated disaster preparedness and emergency management plan for the health sector, effective SOP (Standard Operation Procedure) management, plus establishment of emergency directory or national coordination focal point in place". The resultant report heavily recommended that prioritization should be given to facilitating training and simulation exercises at all health care levels.

2.2 Hospitals

University Hospitals, such as Tribhuvan University Teaching Hospital (TUTH), have their own disaster management cells with mainly three core objectives. Firstly, they must deliver an effective service in the hospital, even in exceptional circumstances, whilst remaining connected to all disciplines and administration. Secondly, they should be ready to respond to mass casualties or disasters in the country, and finally they should train appropriate staff members and medical trainees in disaster preparedness and management. The disaster management committee often involves all disciplines, but more prominently: emergency medicine, surgery, orthopedics, anesthesia and nursing. Regular drills, plus collaboration with other nationals/international organizations have been introduced in order to encourage sharing of professional experiences and keeping up with latest guidelines as they are introduced.

The disaster management cells of hospitals are primarily designed to inform their own staff on how to handle the casualties. They virtually have no programs for the public. There is provision from the government to endorse public access buildings from the municipality (such as hospitals) when they are constructed, but safety standards are often ignored. On top of that, there are no regular checks, if the previous constructions were built based on the approved parameters.

2.3 Disaster Management in Medical Education

Medical training in Nepal follows more or less the old British system, similar to other countries in the region such as India, Pakistan and Bangladesh. The combined Bachelor in Medicine and Bachelor in Surgery (MBBS) is a five and half year program with a compulsory one-year internship. The training focuses on internal medicine, surgery, gynecology & obstetrics and pediatrics, with the majority of postings and a majority of classes in these areas. Disciplines including Ear, Nose and Throat (ENT), ophthalmology, orthopedics, psychiatry, anesthesiology and emergency medicine are considered minor postings. Minor postings start in fourth year only, and final exams are done in the same year. Hence, students have only a short exposure and few taught interactions in these areas. However, within minor postings, emergency medicine has a special place; students spend one full month exclusively in the emergency department (ED). They are actively incorporated as members of the ED team and have the opportunity to learn from faculties, residents, house officers and nurses. Subsequently, in the internship, it is compulsory for each intern to do another month in the Emergency Department under specific supervision; the goal is to enable them to work independently as emergency house officers. A specialty in emergency medicine or similar well-defined postgraduate training in emergency medicine is still under development in Nepal.

The training in medical schools and academic departments are a combination of Emergency Medicine, General Practice and Family Practice. This program generates good general practitioners, but not really full-fledged, trained emergency physicians. Recently, steps have been taken to introduce doctorate levels for medicine and surgery as well as for emergency medicine. The programs are more academically focused. Currently there are no further training opportunities or diploma courses for candidates to practice their skills in trauma, emergency and disaster medicine scenarios. The nursing training for emergency care and disaster response is similar to the physicians' situation: Most of the emergency care nursing staff receive general training and gain more experience in that particular field by working in an emergency department. Currently, neither the bachelor nor the master level of nursing qualification specializes in the area of emergency or disaster management.

2.4 Rescue Teams

In 2014 Nepal was struck by two major multiple hazardous events, both taking place in remote areas of the Himalayas. The first event was the avalanche in the Khumbu icefall in April 2014 during the start of the climbing season of Mount Everest: 16 Nepalese icefall doctors and climbing Sherpas were killed by an avalanche in the so-called 'popcorn field', 9 were injured and 3 have not yet been found (oral tradition August 2015). All patients who were evacuated received proper primary management due to the fact that in Everest Base Camp several medical personnel (doctors from the health post of the Himalayan Rescue Association and help from other climbers) were present. Moreover, enough supplies for the number of patients were available and air transportation to tertiary level medical centers in Kathmandu could be organized the same day for the nine injured people. The feedback from the rescuers involved with this operation was that despite good patient management, proper guidelines for mass casualties were still missing.

The second mass casualty happened in October 2014, when a snowstorm in the Annapurna region (Thorung-La) affected more than 500 people: 50 individuals died, and the remaining around 550 survivors had to be evacuated (oral tradition August 2015). In this case medical assistance was not available, and one of the responsible coordinators of the rescue and evacuation effort stated, 'that in this situation clear governmental policy and an operational rescue system would have been of utmost importance, besides the availability of equipment and human resources' (e.g., enough well-trained helicopter pilots).

Previously, Nepal Police and Nepal Army had been instrumental in all kinds of disasters in Nepal prior to the earthquake (e.g., the Annapurna mass casualty), and could profit from their prior experience. The deployment of such uniformed forces has been appreciated but their training for such situations is not transparent. Similarly, there has been little collaboration and co-ordination with other organizations.

Kathmandu possesses the 'BarunYantra Karyalaya', the fire brigade of Nepal. This service dates back to the Rana Prime Minister Juddha Shamsher and is housed within a building entitled 'Juddha BarunYantra Fire Station'. Since then, with ongoing development and the help of international non-profit organizations, it has gone through a slow transformation process. For example; the Autonomous Province of South Tyrol supported them with equipment and training assistance. However, despite been better equipped, disaster preparedness has hardly been taken into consideration, especially in regard of natural hazards such as earthquake.

Prehospital emergency medicine was initiated a few years ago by international projects for mountain and helicopter rescue teams. Experts in mountain rescue and mountain medicine had trained mountain guides, physicians and helicopter pilots for the mountain rescue in Nepal and had helped to develop mountain rescue in Nepal. These initiatives were private and supported by national and international organisations like the International Commission for Alpine Rescue (ICAR), EURAC in Italy, ENSA (Ecole Nationale de Ski d'Alpinisme) in France or Air Zermatt in Switzerland. From the above-mentioned two mass casualties in 2014, mountain rescuers and helicopter crews had gained some disaster preparedness. But the competence building was limited to less than 20 mountain guides, rescuers and physicians with a special interest in mountain medicine and helicopter pilots with special training for rescues in high altitude (Brodmann Maeder et al. 2014; Thapa et al. 2014).

3 Medical Situation in the First Hours and Days

The two authors were present in Kathmandu during the first and strongest earthquake on April 25 and give their personal insights in the events during, and in the first hours and days afterwards.

3.1 Situation 1: Thamel Tourist Area and Nepal International Clinic (M Brodmann Maeder)

When the shaking started, I was sitting in a garden restaurant just outside Thamel, the tourist quarter of Kathmandu. I had met very close Nepalese friends in a bar a few minutes ago and we had decided to move from the crowded place in the second floor of a building into the quiet garden, because we wanted to talk about our projects. For a few seconds we did not know what happened, until somebody called "earthquake". We tried to hold each other in order not to fall down. Most of the people in the garden wanted to run away, but as the garden seemed to be far from high buildings, I persuaded my two friends to stay. We sat down in the middle of the garden, and were ready to sneak under the tables if walls or other objects should fall into the garden (Fig. 1). A transparent bottle with a blue cleaning agent inside and pendant lamps alerted us when the next shock started. More and more people came into the garden, and only now we realized the noise from falling objects and screams outside of our safe place. Amazingly, my mobile phone still worked, and I was able to call my family and my work place in order to let them know that I was alive. Moreover, I could contact my Nepalese "Didi" Lhakphuti in order to inform her where I was and to tell her to come to us because the garden was free from falling objects and seemed to be very safe.

About half an hour later, she came in, and we decided collectively to leave the relative safety of the garden. As the Nepal International Clinic (NIC) was not far from this place we started to walk there. I wanted to offer my help for injured people who might come there in order to get treatment. In the streets we saw collapsed buildings and walls, power poles and cables lying in the streets and cars hit by falling objects. People were standing around, not knowing what they should do next. When we arrived in NIC, we were welcomed by one of the nurses. He showed us the medical supply, and we realized that the locker with the drugs had

Fig. 1 Situation in garden restaurant after first shock, Kathmandu April 25, 2015

Fig. 2 Medical treatment in Nepal International Clinic NIC, Kathmandu April 25, 2015

collapsed, and all the phials were broken. In the meantime, the first patient arrived with an open fracture of the forearm. Due to a dislocation he suffered from paresthesia in the hand. Therefore, he needed urgent reduction, but we were unable to give him sufficient analgesia during this intervention. He tolerated the procedure without complaining. The fracture was fixed with an improvised splint (Fig. 2).

As we experienced regular aftershocks, we performed the treatments outside in the garden of the clinic. The next patient suffered from severe soft tissue injury of his lower leg. We cleaned the wound and wanted to make a temporary surgical adaption of the skin, but he decided to go to another hospital to receive treatment. The director of the NIC was not able to come to the clinic because he was blocked in elsewhere in the city. Our patients exclusively were foreigners who knew the NIC, because this clinic or indeed outpatient-department is dedicated to foreigners. When we realized that there were no more patients coming to NIC, Lhakphuti and I decided to walk back to her home. We put up tents and passed the night outside, waking up with every aftershock we felt.

3.2 Situation 2: Governmental Hospital Kathmandu (M Pun)

It was Saturday April 25th 2015, a warm sunny, calm day in the Kathmandu valley. The offices and schools were off. While I was walking along the ring road in

Maharajgunj area of Kathmandu at around 11:55 am I felt that there was sudden and weird shaking around me. There were strange and strong sounds all around. It took a little while for me to figure out what was happening. The buildings were shaking, motorbikes were tumbling and people were screaming, trying desperately to run to safe places. The birds were all up in the sky and flying zigzags. I tried to move on the side of the ring road, but it was almost impossible to move. I fell down a couple of times and got a minor injury on my palm due to falling. Then I stayed on the ground and slowly crawled to a tree-trunk. It was dusty all around and there was sense of immense shock and fear. We felt continued swinging and shaking from smaller aftershocks, but we tried to assure ourselves that the big one had passed. People soon started to send and get updates about their nearest and dearest. But the majority of cell phone networks were not working properly. Most of us were not able to update our family and friends about the situation. Even after half an hour later, I was still trembling and felt I had no energy to move. I seemed both mentally and physically drained.

After a while, it seemed the shaking had settled a bit and people were gaining confidence to move around to help injured persons. I saw people carrying others to the hospitals, some walking, whilst others were looking for vehicles. I made my way to the Tribhuvan University Teaching Hospital (TUTH) at Maharajgunj where I work. It was not far from where I was and I reached there within 15 min. The hospital was already flooded with the patients. Since TUTH is the first university teaching hospital in Nepal, and has one of the best reputations in the country, the wards are usually full. The management of the hospital had kept this in mind to handle this situation. Hence, they assisted patients as they entered, literally right from the entry-point. Everyone got involved in whatever they could do. Medical staff, residents, medical and nursing students made themselves available. Administration got involved in the organizing of patients. The public immediately showed up to volunteer wherever necessary for patient transportation, transfer and taking care of dead bodies.

The hospital was quickly overwhelmed with the number of patients. Open spaces (lobbies, gardens, parking areas and wherever space was available) were converted into consultation units, where we started managing patients. Aftershocks went on, but after a while we got used to them and lost any fear as we worked outside in the open. Injured patients started to come on trucks, taxis or busses. Many of them were directly rescued from the rubble, while some were referred from other hospitals. Dead bodies kept on piling up; it was just like a war zone! The shelter nearby (in front of emergency ward), was used for temporarily piling the dead bodies, but it was quickly filled. So in the end the whole of the basic science building was used to store dead bodies.

In the hospital and adjacent premises, as we got overwhelmed with casualties, prompt and handy help came from medical students. From first year medical students, to the final years, they were fully engaged at the hospital. They helped in triage, transfer and managing the mass casualties. They were involved throughout the crisis period and worked extremely hard to manage the situation. Moreover, prompt help came from the general public, from non-profit organizations and most notably from young members of a rather nascent political party. As the days passed and the situation in the hospital was under control, the medical students got themselves mobilized in the search and rescue efforts and other work in remote villages of Nepal.

Patients and casualties kept coming to TUTH from different smaller centers of Kathmandu and other parts of the country. Although the influx of the cases got more stable in terms of numbers and frequency of arrival, surgeons (orthopedic and general), anesthetists and emergency physicians were overwhelmed by the number of patients. They worked round the clock for those who needed immediate interventions. However, the number of fatal casualties continued to grow, the handling and identifying of the dead bodies becoming an equally persistent and difficult challenge.

Slowly, pictures from the earthquake started to come in from national and international news. The mega-earthquake had shocked us all, and we were deeply mourning. The cell-phone networks were only partially working on that day late evening. Tired and shocked, all of us had little idea what to do. Since there were regular aftershocks, we were scared of entering buildings. People stayed outside (Fig. 3) and were entering their houses quickly in order to get essential things like food and clothes. Many were buying biscuits, noodles and water for dinner. The continuous aftershocks were scary. I quickly entered the room for food and got out with necessary things to sleep outside. A friend of mine and me slept on the roadside in front of our rented room.

Next day (Sunday April 26), was another day, but still with fear and doubt clearly expressed in the faces of the people. The frequent aftershocks went on. I walked to the hospital. The scenes were depressing. But there were many encouraging signs from the public, non-profit organizations, students and other institutions who came to support and help. The youth from different organizations, schools or young people on their own made themselves available to help in hospitals like TU Teaching Hospital. Sympathy poured in from the International community, and Nepalese expatriates also began to assisting whatever way they could help.

The Japanese International Cooperation Agency (JICA) Nepal cooperation had built TU Teaching Hospital and basic science buildings, considering safety standards for earthquake resistance. Hence, there was only minimal damage, if any, caused by the earthquake. Therefore, the hospital and the area surrounding were considered the safest place to be. At around 1 PM, in front of academic building where the dead bodies were being piled up, we felt another big earthquake of 6.7 magnitudes. The moment it shook was terrifying and it seemed as if the earth was opening up. We all quickly sat or lay on the ground in open space. There were not as many casualties at this time simply because the public were all out in the safe open green spaces due to frequent aftershocks. For the next few days, I kept on finding new safe spaces to sleep (e.g., a hospital corridor, the open space of police academy, space in front of the Institute of Medicine's Dean's office). It was very difficult to find a place outside, as everyone was sleeping out in the open. In the hospital, the energy and resources (including human resources), were redirected

Fig. 3 Improvised shelters in Kathmandu, April 25, 2015

towards those departments that needed it most, for example the emergency and orthopedic departments.

As days went on, aftershocks continued to shake us, however the magnitudes were of a smaller scale (less than 5). The public were getting used to these constant smaller shocks, but remained scared of the possibility of another major shock. We started to establish safety precautions where we could. In the meantime, people started gaining confidence and tried to get back to their normal lives (e.g., entering their house and sleeping inside). Then there was another big earthquake with a magnitude of 7.3 at around 1 PM on May 12, 2015. Many buildings that had been

Fig. 4 Dr. Pun's tent, Kathmandu April 25, 2015

seriously affected previously collapsed this time. However, there were not as many casualties as previously, since people were in the majority outside and prepared. On this day, my wife and me were about to have lunch, she immediately ran under the table and I was holding the pillar. We survived! During the day, all of us around were busy setting up a camp in open space for the next few days. We set up a tent in one of nearby paddy fields with some old workshop and conference posters. For more than a week, we continued to sleep out in the field in our make-shift tent (Fig. 4), whilst constantly adapting to our new post-quake reality.

3.3 Situation 3: Lukla PLNN Hospital and Airport (M Brodmann Maeder)

Already in the first hours after the earthquake, it became evident that not only had the earthquake caused injuries through collapsing buildings of falling objects. In Kathmandu we heard the first news about Everest Base Camp, where an avalanche was said to have destroyed a part of the tent village at 5364 m above sea level.

The situation outside of Kathmandu in other regions was completely unknown, as recon-flights were not available at that time.

That same evening, I was able to contact Captain Siddharta Gurung, chief pilot of Simrik Air and the most experienced helicopter rescue pilot in Nepal. I offered my help if Simrik Air planned to fly to more remote areas the next day. We agreed to meet the next morning at 6 am at the domestic airport.

When we arrived there, more information about the remote valleys slowly came in, and we learnt that a friend of ours had been trapped in a big landslide Langtang Valley. One of his friends had died, whilst another was severely injured. The two survivors could only be evacuated the day after the earthquake, and the helicopter mission was risky due to bad weather. Fortunately, the severely injured lady survived. Simultaneously, news came in regarding victims from Everest Base Camp, who were currently on the way to Lukla. With the help of the pilots from Simrik Air I was able to fly to Lukla in a Russian MI-17 helicopter. Amongst the small group flying up to the village in the Khumbu valley on 2850 m above sea level, I met an American paramedic who spontaneously agreed to help with the treatment of the injured Nepalese and international climbers coming from Everest Base Camp. In the rear of the helicopter a coffin with an earthquake victim from the Khumbu valley was transported to his home. When we arrived in Lukla I headed towards Pasang Lhamu Nicole Niquille Hospital (PLNN), where I soon realized that the building was heavily destroyed and treatment was no longer possible inside the hospital. The staff from PLNN Hospital was working outside under improvised shelters, waiting for victims of the earthquake, which fortunately had hit Lukla much less than Kathmandu (Fig. 5).

Fig. 5 Staff from Pasang Lhamu Nicole Niquille (PLNN) Hospital, Lukla April 26, 2015

With the help of local authorities, we established a triage post in Lukla airport. On arrival, more than ten people (amongst them nurses, doctors, paramedics and a policeman from different European countries and the US), addressed me in order to offer their help. Based on the counts of local authorities in Luka, 65 victims, around half of them foreign climbers and the other half Nepalese expedition staff, arrived by helicopter. We quickly realized that they had already been treated by very experienced healthcare professionals at Everest Base Camp and afterwards in Pheriche. In Lukla, we were the third part of an ad hoc rescue chain for those people who had been in Everest Base Camp, either as international climbers, expedition staff members, climbing Sherpas or icefall doctors. In Lukla, more than 30 injured victims received treatment in PLNN Hospital. There the X-ray room was still working, and so we could diagnose several fractures of the arms, legs and ribs. Overall we saw all sorts of injuries; such as, head injuries, suspected spine and pelvic fractures, thoracic traumas, extremity and soft tissue injuries.

As the weather was changing, we ran the risk that flights to Kathmandu might be cancelled due to bad weather (Fig. 6). Therefore, we worked hard to get an overview of the patients in order to decide on the priority of being flown out (Fig. 7), plus to decide on which patients should be carried to the hospital for further diagnostics and treatment (Fig. 8, top). The main treatment in Lukla consisted of pain therapy and the cleaning of soft tissue injuries (Fig. 8, bottom). This procedure was performed in Lukla hospital, which meant that the patient had to be carried on an improvised stretcher up to Lukla Hospital. We were very grateful to have many

Fig. 6 Patients from Everest Base Camp (EBC) waiting for flight to Kathmandu, Lukla Airport April 26, 2015

Fig. 7 International group of healthcare professionals, Lukla Airport, April 26, 2015

local volunteers who were coordinated by a representative of the local authority. The less severely injured patients received sweet drinks and some food, all of which had been organized by the local people from Lukla. Two patients were severely injured and needed either blood transfusions or immediate surgery. Therefore they had to be transported to Kathmandu as a priority, as Lukla Hospital does not have a blood bank or advanced surgical capacity.

Only two people stayed in Lukla and received treatment in an adjacent intact house. A follow-up on all the patients was difficult because of a lack of coordination in Kathmandu airport. Patients were transported to different hospitals in the capital, where treatment was hard to obtain because of overwhelming numbers of patients. Moreover, the expedition organizations had trouble to find their collaborators and clients in the different hospitals. Later we heard that the two severely injured patients who were transported to Kathmandu with highest priority, did not survive because of a subsequent lack of appropriate medical treatment.

3.4 General Medical Situations in Nepal After April 25

We are referring to an update published by WHO in August 2015 (WHO 2015b). The medical situation almost 100 days after the first big earthquake on April 25 stated that 99% of the destroyed and damaged health facilities had resumed services, despite difficulties due to landslides and road blockages. Many of them

Fig. 8 Treatment of an EBC victim EBC by staff from PLNN Hospital (*top*) and Transport of an EBC victim to PLNN Hospital by local people, army and police (*bottom*), Lukla April 26, 2015

needed reconstruction in alignment with architectural standards, which should make them more resistant for future earthquakes. The WHO publication counts 446 fully and 765 partially damaged public health facilities. In total 8898 people had reportedly lost their lives, and 22,309 patients had been injured. 7324 surgical interventions had been performed, and overall the earthquake affected 5.6 million Nepalese people. Amazingly, apart from a minor outbreak of typhus (Basnyat 2016), there was no large outbreak of communicable diseases, despite the fact that monsoon season started shortly after the mass casualty. Health priorities shifted from disaster management, to the provision of on-going care for injured people with rehabilitative needs and securing access to health care for the Nepalese population with pregnant women, mothers and children of any age as priority focus groups.

3.5 Remote Areas

Information about remote areas and the most affected regions like Sindhupalchok or Dolakha arrived very slowly due to blocked roads and difficult access to these areas. Moreover, weather conditions made recon-flights risky. But the first pictures, which were brought from helicopter missions, were alarming. Devastating landslides had caused whole villages to disappear with all their inhabitants, and villages could no longer be recognized because all the houses had collapsed. Thanks to the initiative of the Nepalese people themselves, who walked in groups into these areas, these underprivileged people in very remote regions were provided with food, blankets and shelter. Official numbers state that for example in Sindhupalchok, more than 1% (3438 of 289,780 inhabitants) died and over 1500 were injured. The local healthcare system was not able to cope with this situation because the only hospital was completely destroyed, 1 of 3 Primary Health Care Centers was unable to function due to damage and the two others were partially damaged. Of the 78 health posts only 6 were functional. Health care professionals had also been killed or injured, and this might partially explain the much higher amount of casualties compared with injured people.

4 Disaster Relief

Financial and medical support poured in immediately both nationally and internationally. Nepalese and international non-profit organizations became active. Under the auspices of the United Nations, and mainly the World Health Organization, a cooperation with the Nepalese government was established in order to coordinate the emerging international help. According to their bulletin from August 2015 they had 227 health cluster partners and performed more than 3000 health cluster activities (Thapa et al. 2014). Tents were erected where hospital staff could work during the reconstruction of the damaged or destroyed buildings. Mainly international organizations quickly forged partners with their locally trusted organizations to reach out to the most affected areas. But at the same time, the Nepalese community came up to directly help people in the most remote areas like Langtang Valley, Sindhuplachok and the Gorkha region. Not only did they bring food, clean water, tarpaulins and shelter, they also started to raise monetary funds for their country. In the first few days, there was hesitation to help from the Prime Minister's Fund, but that quickly picked up. After the first mass casualty situation was under control, international healthcare professionals started decentralized rehabilitation units for patients with orthopedic or spine lesions.

Medical camps were restarted after a while in order to give inhabitants of very remote areas in Nepal access to basic health care. PLNN Hospital in Lukla, although still busy with reconstruction work in the completely destroyed hospital, conducted a so-called LUHMA camp in November 2015 in Bung. A team of Nepalese and European healthcare professionals (nurses, General Practitioners, ophthalmologists, a dentist and a physiotherapist), were transported to a very remote region of the Khumbu valley by helicopter and provided treatment for more than 1000 patients in four days.

In the future, special attention should be given to mental disorders in the aftermath of the earthquake—not to forget the many helpers and health care professionals who were confronted with death, grief, loss of their beloved-ones or threats of losing their own lives. According to a publication from the Ministry of Health and Population from May 26, 2015 (MoPH 2015), Nepal disbursed more than 623,000 USD into the health sector in order to respond to the disaster. WHO talks about 41.8 Million USD, which was requested for the health sector, of which45.8% had been funded by August 2015.

5 Conclusions and Remarks

Despite the existence of well-written policy documents which clearly addressed the risks associated with natural hazards (mainly earthquakes), complete with steps depicting how to best to prepare and eventually manage such scenarios, many of the documents were pure paper and did not lead to concrete measures or proactive training. Disaster preparedness was limited to people who had been involved in earlier mass casualty events, but there was no structured approach to mass casualties on such a large scale. Mainly, the health sector has not yet been able to establish a well-defined curriculum in emergency medicine, let alone disaster medicine. Initiatives in order to develop a rescue system have to date only been developed by private international and non-profit organizations.

When the earthquake struck Nepal on April 25, it was Saturday around noon. Many people were outside, schools and offices were closed, and this might explain the relatively low rate of casualties—although almost 9000 deaths is still a shocking number, and every dead person is a tragedy for a family. Most striking is the lower proportion of injured people compared to the fatalities in the regions around the epicenter like Sindhupalchok district. This might be explained by the mechanism of damage; devastating landslides buried complete villages, and people had no chance to escape. On the other hand, it might also be an expression of an insufficient rescue and healthcare system in remote areas.

Nepal, a developing country, was able to handle this first phase unexpectedly well. Immediate and rapid response to the earthquake came from the Nepalese people together with government, Army, Armed Force Police and local non-profit organizations. It was amazing to watch the solidarity, which could mobilize impressive forces. The Ministry of Health, in collaboration with support from different UN organizations, coordinated a huge number of national and international organizations. The international community reacted by sending humanitarian aid, tons of equipment and human resources. Moreover, a lot of money was raised all over the world as an expression of sympathy and solidarity with Nepal and its inhabitants. Hence, some of the fund raising from both national and international organizations was unregulated and not transparent. WHO supported the health sector and supported the country by coordinating the medical relief with equipment, medical supplies and health professionals. But dealing with more than 200 organizations is a big challenge.

6 Disaster Preparedness for Nepal in the Future

We all hope that the country can steadily recover from the tragic events which started with the first earthquake on April 25, 2015. The restoration process will still take several years, and will only be complete when all Nepalese inhabitants can live in relative good health and environmentally protected circumstances. When we take the WHO's definition of health as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity (WHO 1946, 2006), we realize that the country is just at the beginning of the restoration process. Unfortunately, the world community who initially gave a lot of support and sympathy has eventually lost attention for Nepal, and still an impressive amount of funds raised by the international community has not yet reached Nepal, let alone the Nepalese people who urgently require money for the reconstruction of buildings according to earthquake precaution standards. From a medical point of view, all efforts must be taken to guarantee the severely affected Nepalese people that their basic needs are covered. Where possible they should be encouraged to return to those buildings considered safe constructions as soon as possible and reassured that they have access to basic health care and eventually rehabilitation facilities in those cases where handicapping injuries were sustained during the earthquake.

Moreover, lessons should be learnt from the mass casualty scenarios that presented as a result of this destructive natural event. Disaster preparedness training and community initiatives must be implemented on a national, district and local level. Public awareness must be improved, plus mainly in the health sector, competencies built in order to enable improved, effective specialization in such mass casualty events. Emergency medicine both for out-of-hospital rescue and in-hospital must be developed, integrating disaster medicine as an important focus. On a global level, international organizations must learn to collaborate in a coordinated way, accepting that a regulatory body from an international organization (e.g. UN or WHO) may intervene in order to coordinate and structure the international help; aid which is essential for disasters like the earthquake in Nepal.

Although the experience of a severe earthquake, notwithstanding fear for one's own life, seeing others injured or dying, losing all personal belongings in collapsed buildings and not knowing what the future will bring is hard, it was impressive to see how quick and motivated the Nepalese people were in helping each other. Nepal can be proud of the initiatives taken by the Nepalese themselves. Solidarity within the country was huge and important in the first few hours and days after the earthquake. But without the very quick international help, a developing country such as Nepal could never have overcome the situation. Nepal will fight for restoring a normal life for many years, and in this time international solidarity and support must go on.

Acknowledgements Monika Brodmann Maeder wants to thank all the healthcare professionals in Lukla who volunteered during the evacuation of victims to Kathmandu in Lukla airport on April 26, 2015. Our special thanks go to Rachel Turner, researcher at EURAC Institute of Mountain Emergency Medicine, Bolzano, for reviewing the manuscript.

References

Basnyat B (2016) Typhoid versus typhus fever in post-earthquake Nepal. Lancet Glob Health 4: e516–e517

Brodmann Maeder M, Basnyat B, Harris NS (2014) From Matterhorn to Mt Everest: empowering rescuers and improving medical care in nepal. Wilderness Environ Med 24:177–181

MoPH (2015) Ministry of Health and Population, Health Emergency Operation Centre, Kathmandu, Nepal, World Health Organization, Nepal. (May 26, 2015)

Thapa GB, Neupane M, Strapazzon G, Basnyat B, Elsensohn F, Brodmann Maeder M, Brugger H (2014) Nepalese Mountain rescue development project. High Altitude Med Biol 15:91–92

World Health OrganizationWHO (1946) Preamble to the Constitution of the World Health Organization as adopted by the International Health Conference, New York

World Health Organization WHO (2006) http://www.who.int/governance/eb/who_constitution_en.pdf

World Health Organization WHO (2012) Assessment of Capacities using SEA Region Benchmarks for Emergency Preparedness and Response

World Health Organization WHO (2015a): Health Cluster Bulletin No. 6. 19 June 2015

World Health Organization WHO (2015b) Health cluster bulletin No. 8. 6 Aug 2015

www.reliefweb.int/report/nepal/nepal-earthquake-rapid-review-response-and-few-lessons-learnt

Meaningfulness of OR Models and Solution Strategies for Emergency Planning

Tanka Nath Dhamala, Iswar Mani Adhikari, Hari Nandan Nath and Urmila Pyakurel

Abstract In the context of growing number of natural or man-made disasters, operations research methodologies are imperative for optimal and equitable use of resources available for saving life and relief supports. On the PPRR risk management model, preparedness or planning is most important in unavoidable disasters, as most of the damages are due to lack of proper policy and effective planning strategies for optimal use of available resources. To cope with problem of saving affected and normalizing the situation after disaster is also challenging. On the basis of the recent researches, the importance of mathematical modeling in emergency planning is highlighted. In this work, basic models for facility locations, evacuation planning, and relief distribution (humanitarian logistics) are discussed with examples. Recent trends in extending models to make them closer and closer to real-life situations are recorded with their solution strategies, applications, and case studies in brief.

Keywords Network flows · Transportation network
Emergency planning · Algorithms · Complexity
2010 mathematics subject classification:
primary: 90B10, 90C27, 68Q25; Secondary: 90B06, 90B20

T.N. Dhamala (✉) · U. Pyakurel
Central Department of Mathematics, Tribhuvan University, Kathmandu, Nepal
e-mail: amb.dhamala@daadindia.org

U. Pyakurel
e-mail: urmilapyakurel@gmail.com

I.M. Adhikari
Prithvi Narayan Campus, Tribhuvan University, Pokhara, Nepal
e-mail: adhikariim35@gmail.com

H.N. Nath
Bhaktapur Multiple Campus, Tribhuvan University, Bhaktapur, Nepal
e-mail: hari672@gmail.com

J.H. Kruhl et al. (eds.), *Living Under the Threat of Earthquakes*,
Springer Natural Hazards, https://doi.org/10.1007/978-3-319-68044-6_12

1 Introduction

Operations research (OR), sometimes known as operational research, management science or industrial engineering, is a branch of mathematics which deals with the use of mathematical procedures for complex decision processes. In the modern decision-making processes and planning, OR methods have been proved vital in the best use of available resources. The Operations Research Society of America rightly describes OR as scientifically deciding how to best design and operate man-machine systems, usually under conditions requiring the allocation of scarce resources (Ravindran 2009).

In spite of various discoveries and urbanization, natural or man-made disasters e.g. earthquakes, tsunamis, landslides, volcanic eruptions, hurricanes, typhoons, floods, terrorist attacks, chemical explosions, etc. are posing threat to human life. For optimal use and equitable distribution of available resources to cope with such situations, application of operations research methodologies is unavoidable.

To cope with disastrous situations, the widely applied model is PPRR risk management model, in which there are four steps/phases (Cronstedt et al. 2002; EMA 2004).

1. *Prevention/Mitigation*: building codes, building-use regulations, public education, public information, insurance, legislation, tax incentives/disincentives, zoning/land-use management
2. *Preparedness/Planning*: emergency response plans, mutual aid agreements, training programs, warning systems, public education, public information, evacuation plans, emergency communications, resource inventories, refuge shelters, test exercises
3. *Response*: plan implementation, inform higher authorities, search and rescue, emergency declarations, institute public health measures, public information, activate coordination centers, provide medical support, warning messages, evacuation, mobilize resources, provide immediate relief, registration and tracking, damage assessments
4. *Recovery*: restore essential services, distribute recovery stores, restore public assets, counseling programs, public information, economic impact studies, temporary housing, long-term medical support, review development plans, financial support/assistance, manage public appeals, initiate reconstruction tasks

Most of the critical decisions to be made in emergency phases are related to preparedness (planning) step/phase in the PPRR framework. The decisions related to the choice of the locations of facilities so that the demand of the disaster region is covered, identification of ideal routes in a transportation network, and assignment of vehicles in case of evacuation of people to safe areas as quickly as possible, distribution of relief supplies, etc. optimally, require mathematical tools and swift computations. Fortunately, OR methods, especially optimization modeling, has become a powerful tool to carry out such emergency decisions, since its first adoption in maritime disaster situations in the 1970s (Caunhye et al. 2012).

2 Motivation

The most fundamental necessity of human beings is saving life. But life of a human being is in danger because of various reasons. Natural or human-created disasters put lives of the whole population of certain region in danger. Most of the disasters cannot be predicted and are unavoidable, and the damages caused by them are severe, if the strategies are not well-planned and well-implemented.

Because of the geological reasons, Nepal is always under the threat of earthquakes, landslides, floods, avalanches, epidemics, and many more. The earthquake of 1255 has been reported to destroy many houses and temples of Kathmandu valley with the loss of one-fourth to one-third population. Similarly, the earthquakes of 1408, 1681, 1810, and 1833 A.D. were also devastating. The earthquakes of 1934, 1998 created great damages on most of the physical structures with loss of lives and properties. The 7.8 magnitude earthquake of 2015, followed by two powerful aftershocks killed at least 8891 people, injured 22,302 people and also damaged 602,567 private homes fully and 284,479 partially. Besides this, 2687 government offices are fully damaged and 3776 partially causing considerable damage to most of the historical buildings and the cultural heritages (Dhamala and Pyakurel 2016; Nepal Seismological Centre, n.d.). Earthquakes are prevalent all over the world. The most devastating with magnitude 8.6 or more are: Assam Tibet Earthquake (1950), Northern Sumatra Indonesia (2005), Rat Islands Alaska (1965), Off the Coast of Ecuador (1906), Bio Bio Chilie (2010), Kam Chatta Russia (1952), Sendai Japan (2011), Sumatra Indonesia (2004), Great Alaska Earthquake (1964), Valdivia, Chile (1960). Moreover, earthquakes happening under the sea or the ocean are the major causes of tsunamis (Uppal 2015).

The tsunami in the Indian Ocean and Japan, the two major hurricanes Katrina, Rita, and Sandy in the U.S.A. (Litman 2006), the horrible terrorist attacks of September 11 in New York City and Washington D.C. in the U.S.A., Bhopal (India) gas tragedy (1984), the Banqiao dam collapse in China (1975), etc. also created great damages.

The frequency and scale of natural or man-made disasters have increased and such disasters may occur all around the world at any time. Such disasters have incisive impact on human life as well as the economy and environment. So emergency management planning has been in focus nowadays as it is highly applicable and with novel humanitarian values to the society.

After any kind of disaster, the problem of saving affected and normalizing the situation is challenging. Most damages are because of the lack of proper policy and planning strategies. An effective emergency management plan with optimal use of available resources has always been a challenge for researchers, planners, policy makers, resources allocators, and concerned government authorities.

3 OR in Emergency Planning

OR studies in emergency planning are focused on finding clearly defined activities to be done in optimized way to save life. Any disaster operation has two phases: pre-disaster operations and post-disaster operations. The pre-disaster activities on which most of the OR studies focus are short-notice evacuation, facility location, stock pre-positioning, etc. and post-disaster operations on which they focus are: relief distribution, casualty transportation, etc.as shown in Fig. 1 (Caunhye et al. 2012).

In the forthcoming sections, we discuss OR in emergency planning under three headings—facility locations, evacuation, and relief distribution or humanitarian logistics.

3.1 Facility Locations

In general, facility location decisions studied in OR are related to locate the sites where a factory, warehouse, business complex, office, etc. can be built to obtain the maximum efficiency and effectiveness with minimum operating cost. Location decisions are equally important in humanitarian relief in disaster situations. However, there are differences between commercial facility decisions and facility locations in emergency, in terms of their strategy goals, customer and demand characteristics, and environmental factors (Balcik and Beamon 2008). In emergency planning the facility locations include locating public emergency services like ambulance station, fire stations, etc. with the primary objective to minimize the response time (Haghani 1996).

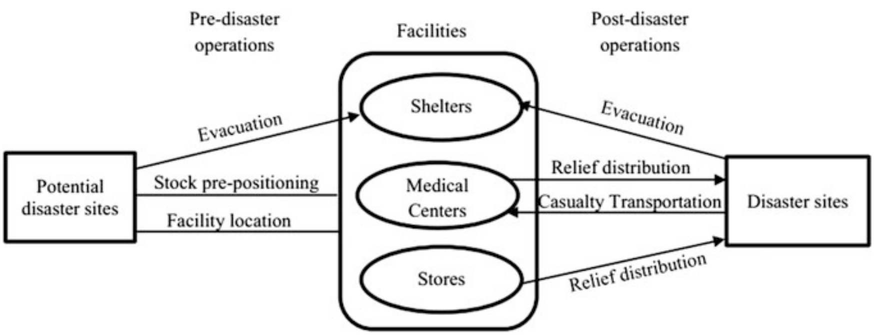


Fig. 1 Framework for disaster operations

3.2 Evacuation

Emergency evacuation is the immediate and urgent movement of people away from threat, from the danger zone to the safety zone. According to DHS (2004), an evacuation of a region is “organized, phased, and supervised withdrawal, dispersal, or removal of civilians from dangerous, or potentially dangerous areas, and their reception, and care in safe areas” (p.65). In OR, an emergency evacuation problem, in general, focuses on finding the optimal use of vehicles and the routes in the process of shifting residents from danger zones to safety areas as effectively as possible with utmost reliability (Dhamala 2015). In fact, the evacuation planning includes not only the removal and transfer of affected people, but also their care, protection, logistic support, and much more.

3.3 Relief Distribution or Humanitarian Logistics

After any disaster, distributing necessary medical supplies and other life supporting goods is imperative. Effective relief distribution focuses on optimal equitable assignment of relief materials.

According to Ahmadi et al. (2015), in any disaster planning, humanitarian logistics planning is the core of every relief operation. To decrease human losses, a sufficient amount of supplies must be distributed after a catastrophe within some time limit. In disaster situations like earthquake, some parts of the transportation network may be damaged or may not be accessible which results in difficulties to dispatch and deliver relief goods. So, proper mathematical modeling is required to carry out relief distribution effectively.

4 Model Diversities

The power of OR methodologies rely heavily on mathematical models. In emergency planning, most widely used models are facility location models, evacuation models, and humanitarian logistic models.

4.1 Facility Locations Models

For given demand points and potential facility sites, the emergency facility location problems focus on two aspects: which sites should be selected as depots for facilities, and how many facilities should be placed at each depot. The facility location models used in emergency planning are based on the following location models:

1. ***P*-median models:** A P-median problem is formulated to determine location of P facilities so as to minimize the average (total) distance between demands and the facilities. The problem is mathematically expressed as follows (Hamacher 2016):

Let $a_1, \ldots, a_N$ be existing locations. Suppose that $X_1, \ldots, X_p$ are the new facilities. Let $d(X, Y)$ denote the distance between two points X and Y. The objective of P-median problem is to minimize

$$\sum_{i=1}^{N} \sum_{j=1}^{P} w_{ij} d\left(a_i, X_j\right) + \sum_{l=1}^{P} \sum_{k=l+1}^{P} \hat{w}_{lk} d(X_l, X_k) \tag{1}$$

The number $w_{ij} \geq 0$ denotes the weight between the demand location a_i and the new facility location X_j. The greater the value of w_{ij}, the closer a_i and X_j will be. There is a similar interpretation about $\hat{w}_{lk}$ between the new facility locations X_l and X_k.

2. ***P*-center models:** A P-center model minimizes the maximum distance between any demand point and its nearest facility. It considers that a demand point is served by its nearest facility and therefore full coverage to all demand points is always achieved (Jia et al. 2007; Li et al. 2011). According to Hamacher (2016), its objective is to minimize:

$$\max \left\{g^{ex}(New), g^{new}(New)\right\} \tag{2}$$

$$\text{where} \quad g^{ex}(New) = \max_{i=1}^{N} \max_{j=1}^{P} w_{ij} d\left(a_i, X_j\right) \tag{3}$$

$$\text{and} \quad g^{new}(New) = \max_{l=1}^{P} \max_{k=l+1}^{P} \hat{w}_{lk} d(X_l, X_k) \tag{4}$$

3. **Covering models:** The main objective of covering model is to provide "coverage" to demand points. The demand point is considered as covered only if a facility is available to service the demand point within a distance limit (Jia et al. 2007; Li et al. 2011).

The location set covering model (LSCP) is formulated as follows (Toregas et al. 1971). Suppose that V is the set of demand points, W is a set of potential facility cites, W_i is the set of facility sites covering demand point i. Let x_j be a binary variable which decides whether the facility is located at site j, i.e., $x_j = 1$ if a facility is located at the site j, otherwise $x_j = 0$. Then the objective is:

$$\min \sum_{j \in W} x_j \tag{5}$$

$$\text{subject to} \sum_{j \in W_i} x_{ij} \geq 1, \quad i \in V \tag{6}$$

$$x_j \in \{0, 1\}, \quad j \in W \tag{7}$$

The objective (5) minimizes the total number of required facilities. Constraint (6) ensures that the demand points are covered by at least one facility. For intensive review on covering models and optimization techniques for emergency response facility location and planning, the procedure mentioned in literature by (Li et al. 2011) is incorporated.

Example 1 To plan a location for a helicopter to serve some locations on their demand in case of a emergency situation, let us consider five places of Western Nepal—Huti, Muchu, Simikot, Rowa, and Jayaprithvi. To choose a single location of a helicopter among all the points on the map, we should consider the point in such a way that its distance from the farthest place is minimum. The problem can be modeled as a P-Center problem, taking $P = 1$. The latitude and longitude of the places (as shown in Fig. 2) are used to locate the positions of the points and Euclidean distance is used as the distance between the points. Feeding the information to software LoLoLA, the helicopter location is found near latitude, longitude (29.71, 81.41).

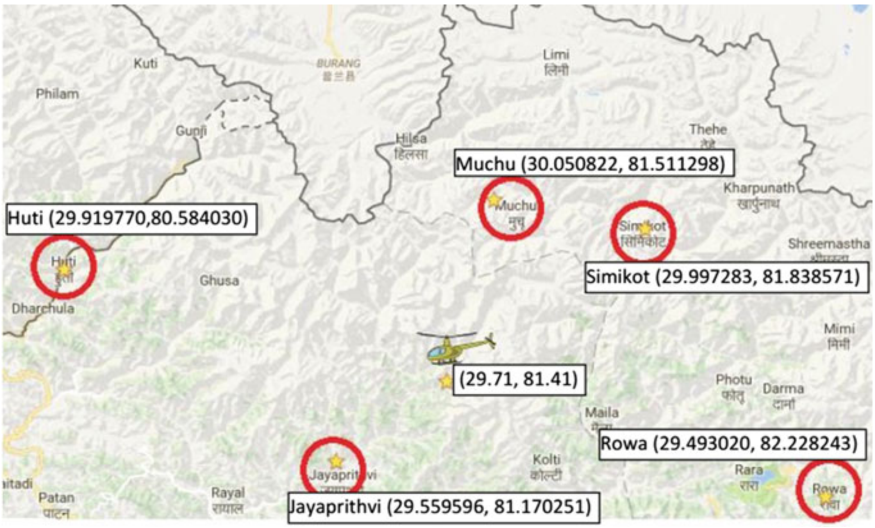


Fig. 2 1-center location example

The above-mentioned models are basic models. As per the requirements, the models can be modified. Some models with such modifications are mentioned below.

Haghani (1996) has presented two mixed-integer linear programming models for a capacitated maximum covering location problem. The first maximizes covered demand and the second maximizes the weighted covered demand as well as minimizes the average distance from the uncovered demands to the located facilities. A variant of this model is developed by Balcik and Beamon (2008) to determine the number of locations of distribution centers in a relief network and the amount of relief supplies to be stocked at each distribution center to meet the needs of affected population. Their model integrates facility locations and inventory decisions, considers multiple item-types and captures budgetary constraints, and capacity restrictions.

Based on location models, Jia et al. (2007) propose a large-scale emergency medical service problem (LEMS) and analyze covering, *P*-median, and *P*-center variants of it. In large-scale disasters such as biological attacks, hurricanes, or earthquakes, *P*-center problem cannot be used without modification, as most of the facilities located too close will be either damaged or become function-less (Huang et al. 2010). They propose a variant of *P*-center problem with an additional assumption that the facility at a node fails to respond to demands from the node. They use dynamic programming approach for the location on a path network.

Recently, a three-objective decision optimization model for emergency rescue facilities in the context of large scale urban environmental accidents has been constructed by Zhao and Chen (2015). The first objective is to maximize the amount of demand covered by a specified number of facilities, the second objective is to minimize the sum of total weighted distances between any demand units and its closest facility, and the third objective is to minimize the maximum distance from any demand point to its closest facility.

4.2 Evacuation Models

Basically, evacuation models can be classified into two broad categories, *microscopic* and *macroscopic*. The microscopic models emphasize individual parameters like walking speed, reaction time, physical ability, and the interaction of each evacuee with the other evacuees during the movement. On the other hand, the macroscopic models treat occupants as a homogeneous group (Hamacher and Tjandra 2001; Dhamala 2015).

Most of the macroscopic evacuation models (especially auto-based) are based on dynamic network flow models (discrete and continuous) (Dhamala 2015; Pyakurel and Dhamala 2015). We describe the discrete dynamic network flow model in brief.

As mentioned earlier, the region to be evacuated is modeled by a network in which the intersection of the streets (roads) are considered as nodes, and the streets (roads) are considered as edges of the network. The locations where evacuees are situated initially are *source nodes* and the safe locations where the evacuees are to be transported are *sink nodes*. The maximum number of people (or vehicles or such commodities) at a node that can be present at a time is the *capacity* of the node and the maximum number of people (or vehicles or other such commodities) that can travel through an edge at a time is the capacity of the edge. For the sake of mathematical manipulation, an imaginary node s, called *super source* node, is added with capacity equal to sum of the capacities of the source nodes and connected to the source nodes by imaginary arcs with infinite arc capacities. Likewise, A *super sink* node t with capacity equal to the sum of the capacities of the sink nodes is connected with the sink nodes by imaginary arcs with infinite arc capacities.

Let V be the set of nodes and E be the set of arcs in a network $N = (V, E)$. Let $A(v)$ denote the set of arcs starting from the node v and $B(v)$, the set of arcs ending at v. It is assumed that $A(s) = B(t) = \emptyset$. The egress time (i.e. the time evacuees need to move towards the safety area) of T units is discretized as $\mathbf{T} = \{0, 1, 2, \ldots, T\}$. Suppose that $x(e, \theta)$ represents the number of evacuees which start moving along the arc e at any time θ and reach its end after time $\tau(e)$. If $b(e, \theta)$ is the capacity of the arc e at any time $\theta \in \mathbf{T}$, then in the following mathematical formulation, the constraint (8) guarantees the evacuees entering an intermediate node leave it within the egress time. Constraint (9) allows holding the evacuees at intermediate nodes, and the constraint (10) does not allow the flow of evacuees in any arc exceed its capacity (Ford and Fulkerson 1958).

$$\sum_{\sigma=\tau(e)}^{T} \sum_{e \in B(v)} x(e, \sigma - \tau(e)) - \sum_{\sigma=0}^{T} \sum_{e \in A(v)} x(e, \sigma) = 0, \forall v \notin \{s, t\} \tag{8}$$

$$\sum_{\sigma=\tau(e)}^{\theta} \sum_{e \in B(v)} x(e, \sigma - \tau(e)) - \sum_{\sigma=0}^{\theta} \sum_{e \in A(v)} x(e, \sigma) \geq 0, \forall v \notin \{s, t\}, \forall \theta \in \mathbf{T} \tag{9}$$

$$0 \leq x(e, \theta) \leq b(e, \theta), \forall e \in E, \forall \theta \in \mathbf{T} \tag{10}$$

The objective function is set as per the requirement of the evacuation. For example, if the requirement is to maximize the number of evacuees within a given time, we maximize the total number of evacuees entering the super sink (i.e. leaving the super source) within the given time horizon T:

$$\sum_{\sigma=0}^{T} \sum_{e \in A(s)} x(e, \sigma) = \sum_{\sigma=\tau(e)}^{T} \sum_{e \in B(t)} x(e, \sigma - \tau(e)) \tag{11}$$

Depending on the objectives, the following are different dynamic network flow problems:

1. *Maximum flow and minimum cost problems* to estimate the maximum possible number of people that can be transfered through the evacuation network in a given time horizon.
2. *Lexicographic flow problems* deal with maximizing the flows leaving the terminals in the given order in a multi-source multi-sink network. This also lexicographically minimizes the flows entering the sinks in the given order.
3. *Quickest flow problems* deal with the minimization of the time-horizon to transfer a given amount of flow value from initial position to the destination along the paths.
4. *Earliest arrival flow problems* deal with transferring the evacuees from the source to the destination such that the total number of evacuees reaching the destination is maximal for all points in time simultaneously.
5. *Time-dependent problems* deal with time-varying inputs in the network, i.e., the arc travel times, arc and node capacities, and supply at the source vary with time (Miller-Hookes and Patterson 2004).
6. *Contraflows* deal with finding a network configuration with ideal directions to each lane for a desired objective. Contraflow technique is also applicable to reduce congestion and traffic jams during the day-to-day rush hours. See also Pyakurel (2016).

Contraflow has gained a considerable attention in evacuation literature because finding ideal direction of lanes of a road network, the flow can be increased and evacuation time can be reduced as compared to the evacuation in the existing road configuration. Depending the objective, the contraflow variants are: maximum dynamic contraflow problem, lexicographic contraflow problem, the earliest arrival contraflow problem, etc. (Pyakurel and Dhamala 2014, 2016, 2017; Pyakurel 2016).

Example 2 Let us consider a two terminal dynamic evacuation network as in Fig. 3a. Each node represents a city or a region and each arc represents the road segment between them. Nodes s and d are modeled as a disastrous area and a safe destination, respectively. Each arc has capacity and travel time. For example, an arc between nodes s and x has capacity 3 and transit time 1, i.e. if time unit is 3 min, maximum 3 units of flow can simultaneously travel in 3 min from s to x. Let $T = 5$ be the evacuation time, i.e., the time of the longest path. The maximum flow value within time $T = 5$ is 10 through different paths. Here path $s - x - y - d$ reaches to

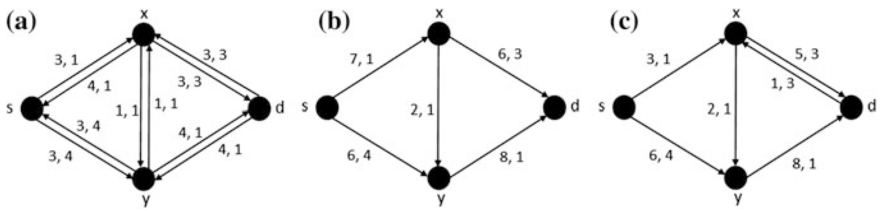


Fig. 3 **a** Evacuation scenario **b** Controflow solution **c** Optimal network

d at time 3 with 1 flow and it repeats at times 4 and 5. Path $s-x-d$ carries 2 units of flow at times 4 and repeats at time 5. Similarly, path $s-y-d$ reaches to d at time 5 with 3 units of flow. In other words, if we have to transship 10 flow units from s to d, it takes 5 units of time i.e., the quickest flow with the same repeated paths as describe above. After the contraflow reconfigurations of the evacuation network as in Fig. 3b, the amount of flow through the arc (s,x) is 7 within 3 min and the maximum contraflow is 22 units of flow with the same paths $s-x-y-d$, $s-x-d$ and $s-y-d$. Moreover, we can transship the 22 units of flow within 5 units of time, i.e., the quickest contraflow. Thus, contraflow configuration increases the flow value and decreases the evacuation time significantly in comparison to the case without contraflow. Finally, we can save arc (d,x) as shown in Fig. 3c that may be used for logistic supports during disasters.

Using natural transformation, the discrete dynamic flow models can be converted to continuous dynamic flow models and vice versa. In a recent work, Pyakurel and Dhamala (2016) have studied the continuous version of the discrete dynamic flow model and formulated a mathematical model for a continuous dynamic contraflow problem to send maximum number of flow as a flow rate from the source to the sink in every moment of time unit. Using the similar notations used in discrete formulation, taking $\mathbf{T} = [0,T]$ the continuous formulation, with the objective of the maximum dynamic flow, is to maximize the flow F satisfying constraints (12)–(15).

$$F = \int_0^T \sum_{e\in A(s)} x(e,\sigma)d\sigma = \int_0^T \sum_{e\in B(t)} x(e,\sigma-\tau(e))d\sigma \tag{12}$$

$$\int_0^T \sum_{e\in B(v)} x(e,\sigma-\tau(e))d\sigma - \int_0^T \sum_{e\in A(v)} x(e,\sigma)d\sigma = 0, \forall v \notin \{s,t\} \tag{13}$$

$$\int_0^\theta \sum_{e\in B(v)} x(e,\sigma-\tau(e))d\sigma - \int_0^\theta \sum_{e\in A(v)} x(e,\sigma)d\sigma \geq 0, \forall v \notin \{s,t\}, \forall\theta \in T \tag{14}$$

$$0 \leq x(e,\theta) \leq b(e,\theta), \forall e \in E, \forall\theta \in T \tag{15}$$

A variant of dynamic network flow model is pattern-based discrete dynamic network flow model that restructures the traffic routing to minimize the overall time of evacuation assuming that every person can leave the evacuation zone on its own by a vehicle (Bretschneider and Kimms 2012). For the optimization model every feasible combination of numbers of lanes is constructed in advance and is united in patterns for every intersection and for every street between two intersections afterwards. The dynamic network flow mixed integer program is designed so that exactly one pattern for every intersection and for every street-connection is chosen (Bretschneider 2012).

The above mentioned models, also known as auto-based evacuation models, are developed on the assumption that the evacuees can evacuate using their own vehicles and do not reenter the evacuation zone. Transit based evacuation models are developed for the evacuees needing transit-vehicles, e.g. buses, ambulances, etc. which may require multiple trips to the evacuation zone, and multi-commodity models incorporate both types of aforementioned evacuation models (Bretschneider 2012).

Keeping in mind the inaccessibility of a significant population to private vehicles (because of economic reasons or health issues etc.), based on vehicle routing problem (VRP) as mentioned in Sect. 4.3, bus evacuation problem (BEP) model of evacuation is proposed by Bish (2011). Departing, to much extent from VRP, the objective of BEP is to minimize the time of evacuation in case of a short notice using given number of homogeneous buses, when the number of people to be evacuated is known in advance. BEP is formulated as a mixed integer linear program in which the decision variables determine the assignment of routes to buses and assignment of buses to the evacuees so that the evacuation time of the last evacuee to reach the safe destination is minimized given a set of homogeneous buses and known number of evacuees at the sources. Considering that the number of evacuees is not known at the beginning of the evacuation, Goerigk and Grün (2014), have formulated a robust bus evacuation problem (RBEP).

Example 3 Let us consider, an evacuation scenario in which evacuees gathered at two collection locations A and B are to be evacuated to a safe location S by two identical buses located at depot D (Fig. 4). The time of travel of a bus from D to A, D to B, A to S, and B to S are 10, 20, 35, and 30 (in minutes) respectively. The number of evacuees at A is equal to 2 bus-loads and that at B is equal to 1 bus-load. Denoting the buses by BUS1 and BUS2, we have different possibilities, e.g.

(i) BUS1: D-A-S (45 min), BUS2: D-B-S (50 min),
BUS1: S-A-S (70 min)
Travel time for BUS1 = 115 min
Travel time for BUS2 = 50 min
Evacuation time = 115 min

(ii) BUS1: D-A-S (45 min), BUS2: D-A-S (45 min),
BUS1: S-B-S (60 min)
Travel time for BUS1 = 105 min
Travel time for BUS2 = 45 min
Evacuation time = 105 min

BEP is formulated, so as to choose the minimum of the evacuation times of all possibilities.

To make the evacuation more realistic, there is growing concern of the research community towards planning evacuation using public transit-vehicles, private vehicles, ambulances, etc. simultaneously. For example, Bretschneider (2012) discusses a multimodal urban evacuation problem to structure traffic flow so that evacuees are evacuated as quickly as possible and evacuees needing medical assistance are transported to hospitals via ambulances. Microscopic models of

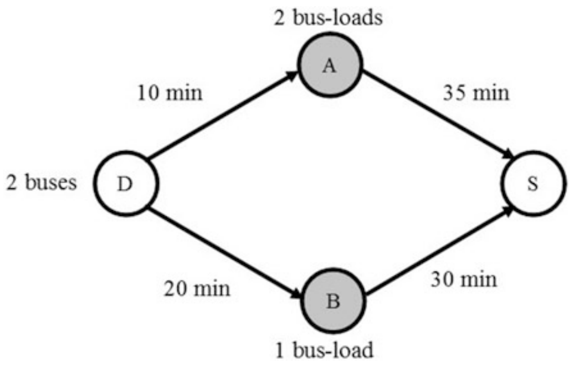


Fig. 4 Elementary BEP instance

evacuation use computer simulations to solve evacuation problem optimally. In a review, Pel et al. (2012) elaborate on mathematical model formulations underlying traffic simulation models incorporating behavioral aspects of evacuees during evacuation.

4.3 Relief Distribution or Humanitarian Logistic Models

Logistic problems are often modeled as variants of the vehicle routing problem (VRP). In this connection, we give the basic model of the VRP. The objective of VRP is to find optimal set of routes for a fleet of vehicles to traverse in order to deliver to a given set of customers with minimum cost.

Let $V = \{0, 1, \ldots, n\}$ where 0 denotes the depot, the location of m vehicles of equal capacity Q. $i(\neq 0) \in V$ represents customer with some demand $q_i \leq Q$. The cost of a bus traveling from a depot or a customer i to j (or from j to i) is c_{ij}. The problem is to find a set of m vehicle routes to minimize the total cost so that (i) the vehicle starts and ends at the depot, (ii) each customer is visited by exactly one vehicle, (iii) the total demand of any route does not exceed Q. For this, we consider, $G = (V, E)$ an undirected graph, where $E = \{(i,j) : i,j \in V, i < j\}$ is the set of edges. Representing the number of times an edge (i,j) appears in the optimal solution by x_{ij}, the problem is the following integer linear program (Laporte 2007).

$$\min \sum_{(i,j) \in E} c_{ij} x_{ij} \tag{16}$$

subject to:

$$\sum_{j \in V \setminus \{0\}} x_{0j} = 2m \tag{17}$$

$$\sum_{i<k} x_{ik} + \sum_{j>k} x_{kj} = 2(k \in V \backslash \{0\}) \tag{18}$$

$$\sum_{\substack{i \in S, j \notin S \\ \text{or} i \notin S, j \in S}} x_{ij} \geq 2b(S), \quad (S \subset V \backslash \{0\}) \tag{19}$$

$$x_{ij} = 0 \text{ or } 1, \quad (i, j \in V \backslash \{0\}) \tag{20}$$

$$x_{0j} = 0, 1 \text{or } 2, \quad (j \in V \backslash \{0\}) \tag{21}$$

The objective function (16) minimizes the total routing cost. Constraints (17) ensure that each vehicle returns back to the depot. Constraints (18) ensure that two edges are incident to each customer vertex. In constraints (19), $b(S)$ is a lower bound on the number of vehicles required to serve all customers of the subset S.

There are several variations of VRP depending on different contexts. Most of the relief distribution models are formulated using these variations. Some such examples are given below.

Based on vehicle routing problem with soft time windows (VRPSTW), in split delivery vehicle routing problem (SDVRP), Lin et al. (2011) propose a multi-objective integer programming model considering multi-items, multi-vehicles, multi-periods, soft time windows, and a split delivery strategy. Their first objective minimizes the total unsatisfied demand especially for high priority items. The second objective minimizes the total travel time for all tours and all vehicles. The final objective minimizes the difference in the satisfaction rate (the ratio between the requested demand and the actual delivered amounts) between nodes.

A variant of VRP in relief distribution is last-mile distribution problem or last-mile delivery problem (LMDP) model. According to Huang et al. (2012), LMDP is formulated with an extension of the set partitioning formulation of vehicle routing problem (VRP) to render the efficient service. Since humanitarian relief in disastrous situations is beyond the minimization of cost, Huang et al. (2012) incorporate, hard-to-measure characteristics, efficacy (i.e., the extent to which the goals of quick and sufficient distribution are met), and equity (i.e., the extent to which all recipients receive comparable service) to formulate a stylized version of LMDP. They explore how efficiency, efficacy, and equity influence the structure of vehicle routes and the distribution of resources.

To establish at which drop-points supplies should arrive and be managed for further distribution, and the international depots from which these supplies should originate the relief distribution in a wide disastrous area, Rennemo et al. (2014) develop a three-stage mixed-integer stochastic programming model comprising facility location and last mile distribution decisions. The planning problem includes creation of a distribution plan for the available vehicle types and commodities, from point of supply to point of consumption via local distribution centers, in order to meet the immediate needs of the affected population. Fairness of distribution is considered by the model by assigning differe nt utilities to different groups of recipients, so that the most needed ones can receive a greater attention. In this model, the types of vehicles available and the characteristics of each type are deterministic. The number of vehicles per type at disposal at each local distribution center, the demand of each commodity at each point of distribution and the availability of each link of the infrastructure are uncertain. In the first stage of the model, selection of local distributions centers and the amount of goods to be sent to them from each main distribution center are decided. After stage 1, vehicle capacity and total demand are supposed to be certain, following which initial routes can be generated at stage 2 based on an anticipation of the state of the network that is the unknown parameter at this stage. In accordance with this plan, vehicles are packed and dispatched, and stage 3 corresponds to recourse actions to be taken once the state of the network is known with certainty.

Similar to the model by Rennemo et al. (2014), a multi-depot location-routing problem model (MDLRP model) is proposed by Ahmadi et al. (2015) to minimize the total distribution time, penalty cost of unsatisfied demand, and fixed cost of opening local distribution centers considering a partial network failure in the aftermath of an earth-quake, and the cost of unsatisfied demand. A significant feature of this model is the feeding real-time GIS data into the planning process. The operational MDLRP is formulated as a mixed integer non-linear programming in which some constraints are non-linear and a linearization approach is used to solve it as suggested in Mahadevi et al. (2010). Broadly analogous to a job shop scheduling problem, Osman et al. (2009) propose a hot zone transportation routine problem (HZTRP) optimization model, where hot zone refers to the geographic region of the catastrophic event. With the objective to minimize the total tardiness (lateness), the model deals with the distribution of logistics in a disastrous area with the aspects of moving people and materials out of and into the disastrous area. Haghani and Oh (1996) have formulated multi-commodity, multi-modal network flow problem with time windows on a time-space network for disaster relief operations.

5 Solution Status

Most of the emergency planning problems formulated mathematically are in the form of mixed integer linear programming problem (MILP) with some binary decision variables (decision variables taking the value either 0 or 1). As the size of the problem increases, the difficulty of getting exact solution (complexity) of an integer program grows more quickly than the linear program with real variables (Fourer et al. 2003). The real world problems related to emergency planning tend to be large and exhibit an exponential complexity with the problem size (NP-hard) (Lima and Grossmann 2011). So, to find the solutions of the formulated problems, the researchers develop algorithms to arrive at the solutions quickly. Below, we give a brief account of common solution strategies.

To solve the capacitated maximum covering location problem, Haghani (1996) presented two algorithms. The first algorithm is a greedy adding heuristic which locates one facility at each iteration. After locating each facility, the set of candidate locations and the allocation of their demands are updated, continuing until no more facility can be located. The second solution procedure is based on Lagrangian relaxation. To solve facility location and stock-prepositioning model, Balcik and Beamon (2008) have used Geometric Algebraic Modeling System (GAMS) using CPLEX solver. As mentioned in Jia et al. (2007), ReVelle and Swain (1970) expressed P-median location problem as a linear integer program and solved by using branch-and-bound algorithm. Zhao and Chen (2015) have used a mesh-based spatial representation and encoding strategy, coupling with the non-dominated sorting genetic algorithm to solve the three-objective model. Lin et al. (2011) have used two heuristics: 1st based on genetic algorithm, 2nd: decomposing the original problem into sub-problems (decomposition and assignment heuristic, DAH algorithm).

To solve most of the discrete dynamic network flow based evacuation problems, the algorithms designed for static network are used in a time-expanded network (Hamacher and Tjandra 2001). Groß and Skutella (2012) have presented an algorithm for generalized maximum dynamic flow. Proving its correctness, Pyakurel et al. (2014) have presented generalized maximum contraflow on lossy network. Moreover, Pyakurel and Dhamala (2016) have presented efficient algorithms to solve various aspects of contraflow in continuous time settings.

To solve the bus evacuation problem (BEP), Bish (2011) has devised two heuristic algorithms and Goerigk et al. (2013) have presented branch-and-bound algorithms to solve a modified version of BEP considering the number of evacuees at each source to be integer multiples of a bus capacity.

6 Applications

Mathematical models seldom represent all the characteristics of real-life situations because when formulating mathematical models, one has to idealize the real-life problem by making some simplifying hypotheses (Lancaster 1976). So, one has to be careful using the solutions of the mathematical models to real world problem. Nonetheless, the models are meant to practical life applications. for example, P-median problem has wide applications in medical services. One of the major applications is the relocation of ambulances during the emergencies in different scenarios in order to minimize the average response time to the service calls. The other location models also have their applications in emergencies like a dirty bomb, anthrax, and small-pox terrorist attacks. For details see Jia et al. (2007).

Various examples can be given to justify the applications of OR models on emergency planning. The evacuation of Yokosuka City by Yamada (1996), and the evacuation of Knox County, Tennessee (Han et al. 2006) were carried out using a maximum cost flow (MCF) network model. The maximum flow models for hurricane evacuation have been considered in Lim et al. (2009) and Lim et al. (2012). The latter uses the Greater Houston area, including the City of Galveston, to evaluate by their approach.

Goerigk et al. (2014) consider two instances of (i) finding a bomb within city center of Kaiserslautern, Germany and (ii) an earthquake with a subsequent flood in the area of Nice, France to test the applicability of their modeling of a comprehensive evacuation planning using genetic solution algorithm.

An application of bus evacuation problem is presented by Pyakurel et al. (2015) in a case study of the evacuation planning of transit dependent people of Kathmandu valley to evacuate population of around 25,672 within the area of 1.45 km^2 using branch-and-bound algorithm and tabu search algorithm. The best results obtained for an instance are: evacuation time of 29 min with 6 or 5 sources and 5 sinks for evacuation of 50% population using 140 buses having 90 evacuees per bus capacity and 15 km/hr speed.

To test the integrated contraflow strategy for the multimodal evacuation, Hua et al. (2014) consider Ningbo city located on the east coast of the Pacific Ocean where there are on an average of 3.1 typhoons per year. They present a plan to evacuate 350,000 people with 69,000 auto vehicles each vehicle with an average capacity of 2.9 and buses with each 35 seats.

To apply a mathematical model for planning helicopter logistics in disaster relief, Ozdamar (2011) used a scenario that is based on the post-earthquake damage data provided by the disaster coordination center of Istanbul.

7 Conclusions

In this work, the importance of operations research methodologies in emergency planning is highlighted subscribing to recent research works done in the field of OR. Mathematical models, their solution approaches with some applications, mainly on facility locations, evacuation, and humanitarian logistics relying on transportation network in emergency situations are discussed. Although the models are formulated to solve real-life problems, because of complexity of the problems, one has to compromise with reality in spite of the developments in fast computing devices. To tackle emergency situations, there is always a need of mathematical model close to reality and solution algorithm fast enough to get solutions. Moreover, there is a need of operations research strategies to address the other issues of PPRR framework.

Acknowledgements The first and the fourth authors would like to thank Alexander von Humboldt Foundation for the research support. The second and the third authors would like to acknowledge the support of German Academic Exchange Service (Deutscher Akademischer Austauschdienst, DAAD) for their research stay in the Philippines.

References

Ahmadi M, Seifi A, Tootooni B (2015) A humanitarian logistics model for disaster relief operation considering network failure and standard relief time: a case study on San Francisco districts. Transp Res Part E: Logistics Transp Rev 75:145–163

Balcik B, Beamon B (2008) Facility location in humanitarian relief. Int J Logistics: Res Appl 11 (2):101–121

Bish DR (2011) Planning for a bus-based evacuation. OR Spectr 33(3):629–654

Bretschneider S (2012) Mathematical models for evacuation planning in urban areas, vol 659. Springer Science and Business Media

Bretschneider S, Kimms A (2012) Pattern-based evacuation planning for urban areas. Eur J Oper Res 216(1):57–69

Caunhye AM, Nie X, Pokharel S (2012) Optimization models in emergency logistics: a literature review. Socio-economic plan sci 46(1):4–13

Cronstedt M et al (2002) Prevention, preparedness, response, recovery—an outdated concept? Australian J Emergency Manage 17(2):10

Dhamala TN (2015) A survey on models and algorithms for discrete evacuation planning network problems. J Ind Manage Optim 11(1):265–289

Dhamala TN, Pyakurel U (2016) Significance of transportation network models in emergency planning of urban cities. Cities, People, Places 2(1):58–76

DHS (2004) National response plan. U.S. Department of Homeland Security

EMA (2004) Emergency management in Australia: concepts and principles. Emergency Management Australia, Dickson ACT

Ford LR Jr, Fulkerson DR (1958) Constructing maximal dynamic flows from static flows. Oper Res 6:419–433

Fourer R, Gay D, Kernighan B (2003) AMPL: a modeling language for mathematical programming. Thomson, Brooks/Cole

Goerigk M, Deghdak K, Heßler P (2014) A comprehensive evacuation planning model and genetic solution algorithm. Transp Res Part E 71:82–97

Goerigk M, Grün B (2014) A robust bus evacuation model with delayed scenario information. OR Spectr 36(4):923–948

Goerigk M, Grün B, Heßler P (2013) Branch and bound algorithms for the bus evacuation problem. Comput Oper Res 40(12):3010–3020

Groß M, Skutella M (2012) Generalized maximum flows over time. Approximation online algorithms lect notes comput sci 7164:247–260

Haghani A (1996) Capacitated maximum covering location models: Formulations and solution procedures. J adv transp 30(3):101–136

Haghani A, Oh S-C (1996) Formulation and solution of a multi-commodity, multi-modal network flow model for disaster relief operations. Transp Res Part A: Policy Pract 30(3):231–250

Hamacher HW (2016) Mathematical methods for planar location problems. Presented in the seminar workshop on graph theory and optimization with applications in industry and society, MSU-IIT, Philippines

Hamacher HW, Tjandra SA (2001) Mathematical modelling of evacuation problems: a state of art. Fraunhofer-Institut für Techno-und Wirtschaftsmathematik, Fraunhofer (ITWM)

Han LD, Yuan F, Chin S-M, Hwang H (2006) Global optimization of emergency evacuation assignments. Interfaces 36(6):502–513

Hua J, Ren G, Cheng Y, Ran B (2014) An integrated contraflow strategy for multimodal evacuation. Math Probl Eng 2014. doi:10.1155/2014/159473

Huang M, Smilowitz K, Balcik B (2012) Models for relief routing: equity, efficiency and efficacy. Transp res part E: logistics trans rev 48(1):2–18

Huang R, Kim S, Menezes, MBC (2010) Facility location for large scale emergencies. Ann Oper Res 181:271–286
Jia H, Ordóñez F, Dessouky M (2007) A modeling framework for facility location of medical services for large-scale emergencies. IIE Trans 39(1):41–55
Lancaster P (1976) Mathematics: models of the real world. Prentice-Hall INC, New Jersey
Laporte G (2007) What you should know about the vehicle routing problem. Nav Res Logistics (NRL) 54(8):811–819
Li X, Zhao Z, Zhu X, Wyatt T (2011) Covering models and optimization techniques for emergency response facility location and planning: a review. Math Methods Oper Res 74 (3):281–310
Lim GJ, Baharnemati MR, Zangeneh S, Parsaei HR (2009) A network flow based optimization approach for hurricane evacuation planning. Proc, ICOVACS
Lim GJ, Zangeneh S, Baharnemati MR, Assavapokee T (2012) A capacitated network flow optimization approach for short notice evacuation planning. Eur J Oper Res 223(1):234–245
Lima RM, Grossmann IEG (2011) Computational advances in solving mixed integer linear programming problems
Lin Y-H, Batta R, Rogerson PA, Blatt A, Flanigan M (2011) A logistics model for emergency supply of critical items in the aftermath of a disaster. Socio-Econ Plann Sci 45:132–145
Litman T (2006) Lessons from Katrina and Rita. J Transp Eng 132:11–18
Mahadevi I, Aalaei A, Paydar MM, Solimanpur M (2010) Designing a mathematical model for dynamic cellular manufacturing systems considering production planning and worker assignment. Comput Math Appl 60:1014–1025
Miller-Hookes E, Patterson SS (2004) On solving quickest time problems in time-dependent, dynamic networks. J of Math Model Algorithms 3:39–71
Nepal Seismological Centre (n.d.) Historical earthquakes. http://www.seismonepal.gov.np/index.php?linkld=56. Accessed 27 July 2016
Osman MS, Ram B, Bhadury J, Stanfield P, Davis L, Samanlioglu, F (2009 July) Optimization model for distributed routing for disaster area logistics. In: Service operations, logistics and informatics 2009, SOLI'09, IEEE/INFORMS international conference, p 278–283
Ozdamar L (2011) Planning helicopter logistics in disaster relief. OR Spectrum 33(3):655–672
Pel AJ, Bliemer MCJ, Hoogendoorn SP (2012) A review on travel behavior modelling in dynamic traffic simulation models for evacuation. Transportation 39:97–123
Pyakurel U (2016) Evacuation planning problem with contraflow approach. PhD Thesis IOST, Tribhuvan University, Kathmandu, Nepal
Pyakurel U, Dhamala TN (2014) Earliest arrival contraflow model for evacuation planning. Neural, Parallel, and Scientific Computations [CNLS-2013] 22(3):441–450
Pyakurel U, Dhamala TN (2015) Models and algorithms on contraflow evacuation planning network problems. Int J Oper Res 12(2):36–46
Pyakurel U, Dhamala TN (2016) Continuous time dynamic contraflow models and algorithms. Advances in Operations Research 2016, (Article ID) 368587, 1–7
Pyakurel U, Dhamala TN (2017) Evacuation planning by earliest arrival contraflow. J Ind Manage Optim 13(1):487–501
Pyakurel U, Goerigk M, Dhamala TN, Hamacher HW (2015) Transit dependent evacuation planning for Kathmandu valley: a case study. Int J Oper Res Nepal 5:49–73
Pyakurel U, Hamacher HW, Dhamala TN (2014) Generalized maximum dynamic contraflow on lossy network. Int J Oper Res Nepal 3(1):27–44
Ravindran AR (2009) Operations research applications. CRC Press, Taylor and Francis Group, New York
Rennemo SJ, Rø KR, Hvattum LM, Tirado G (2014) A three-stage stochastic facility routing model for disaster response planning. Transp res part E: logistics transp rev 62:116–135
ReVelle C, Swain RW (1970) Central facilities location. Geogr Anal 2:30–42

Toregas C, Swain R, Ievelle C, Bergman L (1971) The location of emergency service facilities. Oper Res 19(6):1363–1373

Uppal A (2015) Top 10 worst most dangerous earthquakes of all time. http://listovative.com/worst-most-dangerous-earthquakes/, accessed 17 July 2016

Yamada T (1996) A network flow approach to a city emergency evacuation planning. Int J Syst Sci 27(10):931–936

Zhao M, Chen Q (2015) Risk-based optimization of emergency rescue facilities locations for large scale environmental accidents to improve urban public safety. Nat Hazards 75:163–189

Economic Loss from Earthquake in Nepal and Strategies for Recovery and Resilience Building

Ganesh R. Joshi and Narayan B. Joshi

Abstract The earthquakes on April 2015 took over 8790 casualties and 22,300 injuries with the destruction of physical infrastructures, heritages sites, community infrastructures and green infrastructures. This put a tremendous demand on different services and support from the affected people. The relief operations after the disaster were quite encouraging. However, the rehabilitation and reconstruction is delayed due to issues related with political, institutional, legal and governance. In this context, the strategy should aim for inclusive and resilient recovery. It should focus on reducing the disaster related risks and building better back. Moreover, it should consider the reconstruction of damaged assets, improvement in disaster preparedness response mechanism, and enhancement of measures for multi-hazard risk monitoring, vulnerability assessment, risk information dissemination and awareness. Similarly, there is a need to improve legal and institutional arrangements and mainstream disaster risk reduction into the developmental sector. There are several aspects of recovery which can be implemented only by developing a national consensus. Strong political will, sustained resource mobilization and continuous dialogue with the affected people, are among the most important prerequisites of a recovery program. The provision of income generating activities, skills development and community mobilization are catalytic for swift recovery and enhanced resilience. In addition, the existing institutions at all levels should be strengthened.

Keywords Earthquake · Economic · Nepal · Recovery · Resilience

G.R. Joshi (✉)
Commission for Investigation of Abuse of Authority, Kathmandu, Nepal
e-mail: grjoshi20@gmail.com

N.B. Joshi
Sustainable Research and Development Centre, Kathmandu, Nepal

J.H. Kruhl et al. (eds.), *Living Under the Threat of Earthquakes*,
Springer Natural Hazards, https://doi.org/10.1007/978-3-319-68044-6_13

1 Background

Nepal is exposed to multiple recurrent hazards and ranks 4th and 30th in terms of climate change and flood risk, respectively (Dangal 2011) and 20th most disaster prone country in the world (CfE 2015). In addition, Nepal is the 11th most earthquake-prone country in the world (UNDP 2009). Ever since the first recorded earthquake of 1255 AD that killed one-third of the population of the Kathmandu Valley, Nepal has experienced a major earthquake in every few generations. The last great earthquake (of magnitude 8.4) in 1934 AD resulted in more than 10,000 deaths in the Kathmandu Valley. There have been earthquakes causing severe human and physical loss in 1980, 1988 and 2011. Nepal had not faced a natural shock of comparable magnitude for over 80 years period. The earthquake of April 2015 took over 8790 casualties and 22,300 injuries. It is estimated that the lives of 8 million people, almost one-third of the population of Nepal, have been impacted by this earthquake. Out of 75 districts, 31 districts have been affected. Among them, 14 were declared 'crisis-hit' for the purpose of prioritizing rescue and relief operations; another 17 neighboring districts are partially affected. The destruction covered buildings, heritage sites, schools and health posts, rural roads, bridges, water supply systems, agricultural land, trekking routes, hydropower plants and sports facilities. Most of the infrastructures and major heritage sites had to be rebuilt.

Almost all the sectors of the economy affected by disaster and disrupted the livelihoods of millions of people. Agriculture, the mainstay of the economy, was critically affected, with a impact on livelihoods and food security (WFP 2015). About half of the food consumed in rural areas is self-produced (WFP 2015) which decreased significantly in the following year. Markets were impacted widely. Out of 91 markets assessed in 10 districts after 9 months of the disaster, 50% were not functioning, 40% were showing early signs of recovery, and the remaining 10% were functioning but with price increases and unavailability of some commodities (OSOCC 2015).

Prior to the devastating earthquakes Nepal was already among the poorest countries in the world and the second poorest in South Asia with a per capita Gross National Income (GNI) of US$700 in 2014, and ranking 145 out of 187 in the 2014 Human Development Index (UNDP 2014). The people living below poverty line of income were 25.2% of the population (CBS 2011). This disaster further pushed around one million, below the poverty line, thus exacerbating inequalities in Nepali society (NRA 2016). Deterioration of water and sanitation services, disruption of schools and health services, and the possible food insecurity led to a bigger impact on multidimensional poverty (NPC 2015). The earthquake posed a significant disadvantage to the vulnerable groups including women. Fifty-five percent of those who died were female, with data showing that women and girls have been disproportionately affected by the earthquake, depending on their social roles and locations (UNOCHA 2015).

The earthquakes exposed the affected districts of Nepal to socio-economic fragility and vulnerability, put significant stress on government resources, and severely impacted service delivery capacity. This put at risk the recent developmental gains and the hope for graduation from Least Developed Country (LDC) status and posed challenges for further democratic transition. With the above background, this paper aims to document and analyze the losses and damages caused by the earthquake and initiatives undertaken so far for relief, rehabilitation and reconstruction by reviewing secondary information and suggest the measures to be adopted for effective recovery and resilience building related works.

2 Loss and Damage Assessment

2.1 Economic Loss

The government made post-disaster needs assessment (PDNA) report reveals an estimated total value of disaster effects (both damages and losses) caused by the earthquakes is equivalent to US$7 billion (NPC 2015). Of that amount, 76% of the total effects represent the value of destroyed physical assets, and 24% of the total effects reflect the losses and higher costs of production of goods and services arising from the disaster. The estimated value of total damages and losses is equivalent to about one third of the Gross Domestic Product (GDP) in FY 2013/14. The relative distribution of effects, that is, damages versus losses—is typical of disasters caused by natural events of geological origin, whereby the larger fraction of disaster effects represents the destruction of physical and durable assets. According to MOF (2016) the impact of earthquake resulted in an economic growth of 2.32% in FY 2014/15 and just 0.77% in FY 2015/16, lowest in the decade which is a combined effect of earthquake and stagnation of economic activities in our Southern border points (Fig. 1).

2.2 Physical Loss and Damage

The earthquake caused widespread destruction of housing and human settlements. Over half million houses were completely destroyed and more than 250,000 houses were partially damaged. The large-scale destruction of housing resulted primarily from the seismic vulnerability of unreinforced masonry houses that predominate throughout the country. Almost 58% of all housing construction was of low strength masonry stone or brick masonry with mud mortar, without seismic-resilient features. These buildings suffered widespread damage and collapsed throughout the districts that experienced intense ground shaking. Other common building types such as cement-mortared masonry and reinforced concrete frame buildings were

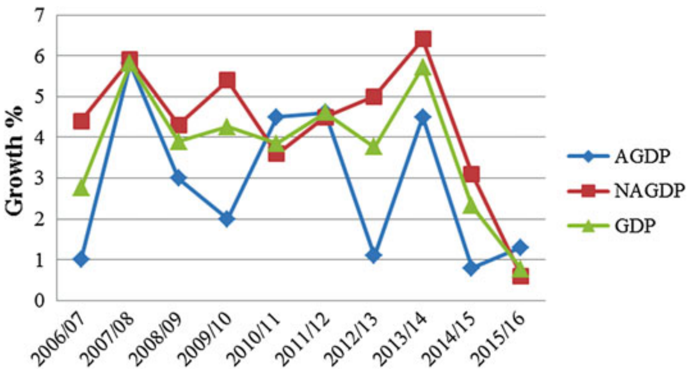


Fig. 1 Percentage growth of the economy for the period from 2006 to 2015

somewhat better off but still suffered significantly due to deficiencies in material, design, detailing and craftsmanship.

Nearly 84% (375 out of 446 health facilities) of the completely damaged health facilities were in the 14 most-affected districts. As a result, the ability of health facilities to respond to health care needs affected and service delivery was disorganized. Consequently, vulnerable population, including disaster victims, were further disadvantaged in accessing health services in remote areas. Approximately 250,000 children from the ages of 6–59 months, 135,000 pregnant and lactating women were affected by earthquake in the 14 districts. Educational services in the affected districts were severely disrupted by the earthquake, which has likely impact on enrolment and attendance, leading to an increase in the number of children out of school.

The earthquake affected about 2900 heritage structures with high cultural and religious values. Major monuments in Kathmandu's seven world heritage monument zones were severely damaged and many collapsed completely.

The earthquakes damaged crop lands, farms and physical infrastructures. Production losses occurred both in crop and livestock subsectors which include the value of lost crops, increased costs of production and estimated production loss in subsequent seasons. The earthquake had a serious impact on agriculture-based livelihoods, increasing the vulnerability of rural communities to hunger and food insecurity.

The infrastructure and functionality of about 290 of 1877 irrigation schemes was reported to be affected to various degrees by the earthquake. Typical damage included small and major cracks on reinforced cement and concrete (RCC) canals, falls or other structures due to ground shaking; displacement of canals due to loss of gradient; degradation or washing away of RCC canal sections due to landslides and rock fall; and damage to retaining walls. The commerce and industry sectors were affected due to physical damages, lack of labor, reduced demand and damaged to trade related infrastructures. Larger establishments suffered less physical damages, while substantial number of household-based micro enterprises suffered major damages. The earthquake heavily impacted the tourism industry of Nepal as popular trekking routes sustained damages from the earthquake and its associated landslides and avalanches. Various aspects of the disaster have posed safety concerns for tourists and hence Nepal attracted about 32% less tourist than the previous year (Prasain 2016). This also resulted the reduction in tourist spending per day from US$35 to 43 (as per industry sources), which will significantly affect revenues. Travel and Tourism contributes 9% to the total Gross Domestic Product and supports 3.5% of total employment in the country (WTTC 2015). The Tourism Employment Survey 2014 shows that every six tourists create one job in Nepal and the tourism industry provides poor communities with better access to revenues generated by the tourism market (Prasain 2016). Therefore, the disaster impacted the livelihoods of around one million people who were dependent on tourism. Other nations that have experienced similar disasters have generally taken several years to recover fully with regard to tourist arrivals. It is estimated that the overall impact of the earthquakes on the Nepali tourism industry will be a reduction of about 20–40% on average over a year period from 1 to 3 years.

In the financial sector, the credit portfolios of microfinance and cooperatives were most severely impacted because people from low income sections in rural areas lost lives and livelihoods. The income flow of most of the borrowers affected and also lack alternative income-earning opportunities.

In the electricity sub-sector, about 115 MW hydropower generation facilities under operation out of the 787 MW total installed capacities in the country (on-grid and off-grid) were severely damaged, while 60 MW were partially damaged. The disaster also caused a heavy damage and loss of community infrastructures. Those were rural transport, water supply and sanitation, irrigation, electricity, community buildings, social infrastructure, and solid waste infrastructure. Damage to community infrastructure can have a negative impact on the livelihoods as well as on time availability of resources from alternative sources. A small percentage of the strategic roads network (SRN) and local road networks were completely damaged or washed out. Blockage of rural roads will create challenges in accessing essential services and marketing agriculture produce to districts and urban markets.

Out of 11,288 water supply systems, 1570 sustained major damages, 3663 partially damaged, and over 200 thousand toilets were damaged. This affected more particularly the women and girls in the rural areas.

The ability of the government to lead the post-earthquake recovery work has been severely affected. Rebuilding and repair of government infrastructure is critical for ensuring service delivery to people. Large landslides, mudflows and other large-scale dislocation of hillsides inflicted damage in forest areas and protected areas. Large areas of natural forests were destroyed, compromising the capacity of natural forest ecosystems to deliver important services and benefits to people.

The earthquakes affected the livelihoods of about 2.29 million households and 5.6 million workers across 31 affected districts, resulting in losses amounting to 94 million workdays and NRs 17 billion of personal income in FY 2015/16. Although personal income loss was equivalent to only 2% of the total disaster effect, it is important to highlight that annual labor earnings in Nepal are extremely low.

Therefore, even a minor income loss has serious implication. It was estimated that 46 million workdays would be lost in the agricultural sector, at least 860,000 workers in commerce and industry, of which approximately 33.9% are women, and at least 84,000 workers in the tourism sector, 52% of them being women, have been affected by the earthquakes.

Following the earthquake, households have faced negative incomes and consumption shocks, resulting in a greater need for social protection and insulation from vulnerabilities. Using welfare analysis, it is estimated that the earthquake would cause average household consumption in most affected districts to decline by 20%. The conditions of households that were already vulnerable prior to the earthquake are likely to be exacerbated. Female farmers are more dependent on agriculture sector and may take longer to recover than their male counterparts, who are more reliant on non-agricultural sector activities.

PDNA report on Nepal Earthquake has concludes that the total value of disaster effects including damage and loss is US$7 billion including US$5.4 billion as private property loss and 1.6 as public loss and US$171 million as losses in personal income. The loss and damages (in financial terms) by sectors is presented in Table 1.

The share of estimated total disaster effects among the main sectors of social and economic activity is given in Fig. 2. It reveals that the most affected are social sectors (58% of the total effects), which includes housing and human settlement. This is followed by productive sectors (25%), infrastructure (10%) and cross-cutting sectors (7%).

A rapid environmental assessment after the earthquake revealed the destruction and damages of greener infrastructure and resources such as forests and protected areas, ecotourism infrastructures (nature trails, trekking routes and camping sites) and renewable rural energy technology solutions such as improved cooking and biogas stoves. Water sources shifted in some areas, with reduced or no flows in places, and new sources starting to flow in others. Freshwater ecosystems were also affected by increased sedimentation and some rivers were temporarily blocked by landslides. The economic cost of loss of ecosystems services from landslides has been estimated at nearly US$328 million (UNEP 2016).

3 Funding Commitment by Development Partners

The International Conference on Nepal's Reconstruction (ICNR) was held in Kathmandu on June 25, 2015 and funding commitment of around US$4.1 billion was received from nations and agencies for recovery and reconstruction in the aftermath of earthquakes. The total funding commitment expressed during the conference was 61% of the country's total recovery and reconstruction needs of US $6.7 billion.

Of the funding commitments made during the conference, the biggest (approximately US$1.4 billion) came from India, which expressed interest to support areas, such as agriculture, housing, roads and transport, electricity, health,

Table 1 The damage and loss by sectors from earthquake in Nepal

Sectors	US$ (million)	Private	Public	Percent
Social	**4086**	**3633**	**453.8**	**100**
Housing and HS	3505	3505	–	85.8
Health	75.44	13.94	61.5	1.8
Education	313.2	23.65	289.5	7.7
Cultural heritage	192.2	89.48	102.7	4.7
Productive	**1781**	**1581**	**197.7**	**100**
Agriculture	283.7	258.1	25.53	15.9
Irrigation	3.83	–	3.83	0.2
Commerce	169.5	169.5	–	9.5
Industry	192.7	192.7	–	10.8
Tourism	812.4	751.1	61.37	45.6
Finance	319.1	209.4	107	17.9
Infrastructure	**667.8**	**172.8**	**495**	**100**
Electricity	212.4	155.7	56.73	31.8
Communication	86.95	17.12	69.83	13.0
Community infrastructure	33.49	–	33.49	5.0
Transport	221.2	–	221.2	33.1
Water and sanitation	113.8	–	113.8	17.0
Cross cutting	**529.3**	**17.55**	**511.8**	**100**
Governance	187.6	–	187.6	35.4
DRR	1.55	–	1.55	0.3
Environment & forest	340.2	17.55	322.7	64.3

Source (NPC 2015)

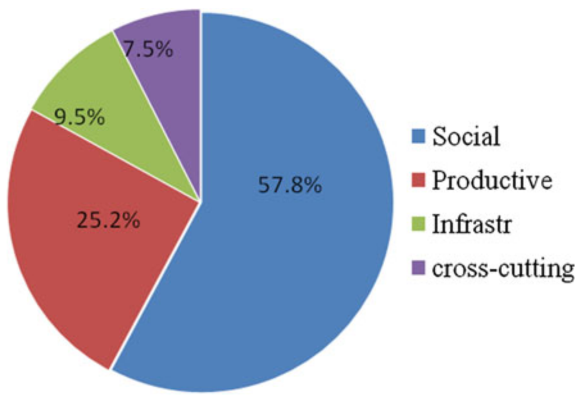


Fig. 2 Share of losses due to earthquake for different sectors

education, cultural heritage and disaster risk reduction. Another neighboring country, China, pledged financial assistance of about US$767 million. All of this assistance would be provided in the 'form of grant'. Japan pledged financial assistance of US$260 million, while the US and the UK expressed commitment to extend US$130 million and US$110 million, respectively. The European Union pledged grant assistance of around US$117 million.

The multilateral lending agencies pledged to provide soft loan for Nepal's reconstruction. Among them, Asian Development Bank pledged to extend US$600 million (including US$15 million on Japan Fund for Poverty Reduction), the World Bank pledged to provide US$600 million (including 100 million for budgetary support) and the International Monetary Fund expressed commitment to extend US $50 million.

Among others, countries like Germany, Switzerland, Norway, South Korea, Finland, Turkey, Sri Lanka, Bangladesh and Pakistan also pledged financial assistance to Nepal. Out of this total commitment, 48% would be in the form of grant.

Following the ICNR event, the government started signing grant and loan mobilization agreements with the development partners. According to the Ministry of Finance sources,[1] about 75% of the total commitment entered into an agreement as of 18th September 2016. Out of this amount, 49% is the loan and 51% is the grant amount (Table 2).

4 Initiatives for Recovery and Resilience Building

The government immediately responded to this disaster by organizing meetings of disaster relief committee and cabinet and secretaries. All relevant institutions of ministries were immediately mobilized for search and rescue (SAR) and life saving actions, establishment of temporary rescue houses in all 16 most affected districts and locations, budget allocated for Prime Minister's Disaster Relief Fund, and the government's cluster mechanisms, comprising 11 sectors, were instantly activated. Over time, 134 international SAR teams from 34 countries responded to Nepal's request for help. For search and rescue operations, more than 90% of the security forces were mobilized. Overall, 22,500 civil servants, 65,000 Nepal Army, 42,000 Nepal Police and 25,000 Armed Police Force, as well as 4000 government and private health workers mobilized to aid rescue and relief efforts. Emergency relief and humanitarian assistance were received with the active support of and contribution by over 60 countries as well as the United Nations and other international agencies. A UN flash appeal for support was launched on 29th April 2015 for a sum of US$422 million to meet critical humanitarian needs for the following three

[1]Personal communication with Ministry of Finance officials.

Table 2 Pledges and agreement for funding support by development partners (US$ million)

S.No.	Devt. partners	Pledges	Agreement	% agreed
1	China	766.927	766.927	100
2	India	1400	1000	71.4
3	Japan	260	247.07	95.0
4	Norway	15.965	0	0
5	USA	130	159.82	122.9
6	ADB	600	215	35.8
7	WB	500	300	60.0
8	EU	117.48	118.37	100.8
9	UK	110	165.5	150.5
10	Austria	1.2	0	0
11	Australia	4.635	0	0
12	Canada	10.5	0	0
13	Bangladesh	0.502	0	0
14	ROK	10	8.4	84.0
15	Pakistan	1	0	0
16	Switzerland	25	0	0
17	Srilanka	2.5	0	0
18	Saudi Arabia	30	0	0
19	Netherlands	26	0	0
20	Sweden	10	0	0
21	Finland	2.238	1.119	50.0
22	Germany	33.567	34	101.3
23	Turkey	2	0	0
24	IMF	50	50	100.0
	Total	**4109.514**	**3066.21**	**74.6**
	Grant	1971.52	1552.08	50.6
	Soft Loan	2138.00	1514.13	49.4

months. The transit shelters were established with official support in designated public spaces.

The international Strategy for Disaster Reduction (ISDR) defines recovery as Planning for Post-Earthquake Recovery and Rehabilitation decision and actions taken after a disaster with a view to restoring or improving the pre disaster living conditions of the stricken community, while encouraging and facilitating necessary adjustments to reduce disaster risks. Early recovery can be started while humanitarian response activities are ongoing.

The people have shown remarkable resilience in the face of the disaster by rebuilding their own homes, lives and their community. Reconstruction can provide an opportunity to build back better and create a stronger and more egalitarian society that is more capable to cope with crises if this is implemented properly.

The GoN organized the ICNR two months after the earthquake in order to garner the financial support from the development partners. The Act on Reconstruction of earthquake affected structures formulated which provides a legal basis for further development works. The National Reconstruction Authority (NRA) was established on 25th December 2015, with the mandate to plan and coordinate implementation of the reconstruction and rehabilitation program. The sub-offices of NRA have been established in 7 affected districts.

The post disaster recovery framework (PDRF) was launched on 12th May 2016 which has been prepared to provide a road map for implementing post-earthquake recovery and reconstruction activities for 2016–2020. The PDNA prepared in 2015, led by the National Planning Commission (NPC), forms the basis for the PDRF. The Recovery Vision of the Government of Nepal is “the establishment of well-planned, resilient settlements and a prosperous society”. The strategies adopted to translate the vision are owner-driven reconstruction, relocation of villages (if needed), integrated habitat approach, urban reconstruction to improve cultural or historical settlements, application of building codes and disaster risk reduction measures, cash transfers, community outreach, social inclusion, capacity building and social and environmental safeguards. The PDRF plans to reconstruct the private houses within 2 years, educational institutions within 3 years and heritages and cultural sites within 5 years.

Over 1700 engineers and social mobilizers mobilized for the collection of digital field level information of households and damage of houses. The government has developed resilient models of houses, provided technical support and helped delivery of construction material to accessible areas. The budget of Fiscal Year 2016/17 has announced to provide an interest free credit of Rs 300,000 for building private houses (for completely damaged ones) under the group guarantee scheme. Similarly, 475 vulnerable areas not suitable for settlements have been identified and recommended for translocation. For reconstruction and building resilience, over a dozen of policies, framework, guidelines, strategies and building codes are in place which are considered key drivers for the success of this initiative.

The agreement with the households that are eligible for receiving grant is in progress and grant amount (first instalment) has been provided to a number of households. Similarly, an amount of Rs 15,000 provided to the affected families for the construction of temporary shelter. GOs, (I)NGOs, Community, Voluntary and private Organizations constructed temporary and permanent shelters. About 2500 engineering manpower (engineers and sub/asst engineers) have been deputed in affected 14 districts (4 in each affected Village Development Committees) for reconstruction of damaged houses.

5 Issues and Challenges

There was delay to pass the reconstruction bill by Parliament due to disagreement over the issue among major political parties which prolonged the post-quake reconstruction work. The appointment of Chief Executive Officer lagged behind due to the political dispute, which took place only on January 2016. The situation has been further exacerbated by the political and economic instability that resulted after the parliament passed the constitution in September 2015, which was opposed by some segment of Nepalese society. The ensuing political protests and economic blockade further derailed the reconstruction and recovery process, with the focus shifting to amending the new constitution.

A total of 629,036 households were eligible for receiving grants because of the damage of their houses. For them, the GoN promised to avail Rs 200,000 as a grant. The GoN initially agreed to avail in four instalments (Rs 50,000 in the first instalment) with the donors as well. However, there was no political consensus as opposition parties demanded to avail it in only two instalments with Rs 150,000 in the first instalment which was also not agreed by the donors. This misunderstanding initially caused delay in agreement and availing grant amount to the affected families. As of December 2016, grant agreement has been done with 86% of the eligible households for receiving grants while the grant amount has been provided to 83% of households with whom agreement was done.

The inaction from the government authorities (including NRA) on issuing guidelines for rebuilding even after several months of earthquake created confusion among the community members whether to initiate rebuilding of damaged houses. They were at risk of losing compensation (promised amount of grant) if it was done without approval by the government authority. Despite this, many people in rural places have started building houses on their own because they were tired of waiting for help from the authorities. More than 31,000 families have built their houses (Shahi 2016). It is also estimated that four million people are still living in temporary shelters, while 113,384 families have moved back into homes that are at risk of collapse during aftershocks (RW 2016).

The factors hampering relief and rehabilitation in Nepal include lack of enough preparedness, logistical and transportation problems, and government's inefficiency. The development of logistical and transportation sectors have been influenced due to economic capacity whereas the government's efficiency is the outcome of fragile politics (Dahal 2016). The ineffective coordination among GOs, NGOs, local governments and other relevant organization also hampered the process of rehabilitation and construction. As the move oriented towards reconstruction from relief and rehabilitation, this ineffective coordination and collaboration among the relevant actors may obstruct in maximizing the opportunities for creating 'build back better'.

The transparency and accountability among the public officials for implementing the post-disaster related works has been an issue. Some officials have also been involved in irregularities, misconduct and corruption in the procurement and distribution of relief materials. Similarly, the responsible personnel for carrying out day to day activities at the grassroots levels remained unaccountable to serve the disaster affected people demanding for increment in extra allowances. The regional recovery dialogue for building back better was organized in order to provide a road map for the recovery process after the Nepal earthquake. Through this dialogue, the lessons for Nepal from Asia Pacific include recovery is a time-consuming process, and needs thoroughness more than speed, sustainability is a fundamental principle for building back better, institutional arrangements need to be collaborative and incrementally evolve, focusing on processing and keeping people at the centre, technical approaches need to be detailed and context-specific, capacity building is a must for long term self-reliance and transparency and accountability are the keys to a successful reconstruction program (UNESCAP et al. 2015). These might be useful for Nepal both for rehabilitation and reconstruction and early recovery. However, there might be lapses in considering these lessons learnt in policy and guidelines preparation.

It has also been observed that the development partners also lagged behind in fulfilling their pledges for financial assistance on time. About three-fourth of the pledged amount has been committed to avail through agreement. However, actual disbursement relative to the agreement might be low. Delay in agreement and partially fulfilling the commitment by the development partners has also created confusion and hampered the planning and reconstruction and recovery of infrastructures.

6 Conclusion and Recommendation

Nepal remains at risk from earthquakes and many other natural hazards. The experience of the 2015 earthquake underlines the importance of strengthening partnerships between the public, private and community sectors to prepare for future emergencies. This involves putting in place stronger business continuity, worker safety, environmental and risk management measures; exploring insurance solutions to manage risk; and streamlining customs arrangements in emergencies. Crucial economic sectors, such as tourism and construction, can also benefit from public-private cooperation for recovery and reconstruction.

Cluster group on early recovery (CWGER 2008) mentions that the successful disaster recovery experiences from around the world have in common the adoption of at least three important approaches such as building back better, converting adversity into opportunity, and prioritizing pro-poor recovery. Similarly, early recovery is a multidimensional process which is guided by development principles that seek to build on humanitarian programs and to catalyze sustainable development opportunities. It aims to generate self-sustaining, nationally owned and resilient post-crisis recovery and encompasses the restoration of basis services, livelihoods, shelter, governance, security and rule of law, environment and social dimensions. The principles, approaches and components of early recovery need to be well considered and integrated in planning and formulating strategy.

Implementing a large scale recovery and reconstruction program, following a major disaster like earthquake, takes a commitment of financial, human and organizational resources. Likewise it takes a concerted effort on the part of many partners to address immediate requirements, put in place implementation arrangements for the medium and longer terms and to ensure that such arrangements are rooted in sound policies, financial strategies and institutional arrangements. The extent and complexity of the natural risks Nepal faces mean that a multi-stakeholder approach to resilience is vital. It is therefore beneficial to learn more about public-private cooperation in Nepal, and risk management activities, construction materials and methods left buildings standing and occupants alive during and after the 2015 earthquake.

Disasters occur every year in different parts of the world including Nepal. The key to minimize any disaster is being prepared for it. The governments should be prepared for bigger scale of disasters so that impact of it can be significantly minimized. For this, the government should be encouraged to implement the Hyogo Framework's three strategic goals: integrate disaster risk reduction into sustainable development policies and planning, develop and strengthen institutions, mechanisms and capacities to build resilience to hazards and systematically incorporate risk reduction approaches into the implementation of emergency preparedness, response and recovery programs (UNOCHA 2008). The disaster in Nepal clearly showed that by not having an emergency response system in place, the response and rescue effort was delayed with multiple confusions, exacerbating the scale of the crisis.

Nepal is at risk from seismic perspective. The experience gained from the 2015 earthquake must be taken as a very important lesson for the entire country in terms of preparedness for disaster. Although there are several issues and challenges to ongoing reconstruction and recovery, it should be considered an opportunity for all the stakeholders to improve the lives of earthquake-affected families, and to develop improved disaster preparedness policies and action plan for the future.

New ways of sharing responsibilities as well as engaging different partners and agencies need to be identified to accelerate documentation, planning and restoration processes. While the investment in DRR assets has been relatively low in past years, in the context of the earthquake and acute risk of cascading disasters it is imperative to establish robust DRR systems. Likewise, a comprehensive Disaster Resilient Livelihoods Strategy has to be developed for continuum from immediate income generation to medium and long-term employment recovery.

Recovery should follow a community-based approach, which encourages communities, utilization of social networks, and built self-reliance efforts using local skills and knowledge. It should largely be an owner driven recovery program. In order to translate disaster recovery into sustainable development, post-disaster recovery strategies must be linked to poverty reduction and livelihood recovery efforts, as well as long-term development goals. Similarly, the recovery should be inclusive and coordinated, with established roles for actors at all levels of government, the private sector, and civil society. Hence, it is necessary to engage diverse institutions, multiple authorities, and stakeholders at all levels, in view of the complex and costly nature of post-disaster reconstruction.

Resilient recovery and reconstruction are recognized as important aspect of sustainable development. To maintain a path toward sustainability, recovery and reconstruction programs require predictable technical and financial resource commitments for planning, implementation, and performance management. In this regard, a predictable funding commitment is necessary for reconstruction works from international communities. The governments and international organizations should also implement community development activities to improve livelihoods and drive the local economy through income generating activities. Investments have also to be made in enhancing the institutional, financial and technical capabilities of affected people. The reconstruction and recovery phase should establish the new way of life for the people. The government leadership is key for effective implementation of reconstruction policies where the international community should support in strengthening the government's capacity. Powerful leadership with political, financial and technical capacity would help to achieve the reconstruction and recovery goals in Nepal. The countries like Indonesia, China, and Chile demonstrated good examples of reconstruction even they faced with great loss.

References

CBS (2011) Nepal living standard survey 2010/11, statistical report. Central Bureau of Statistics, Kathmandu Nepal

CfE (2015) Nepal country overview: Nepal disaster management reference handbook 2015. Center for Excellence. Available at http://www.cfe.dmha.org

CWGER (2008) Guidance note on early recovery IRP. Cluster group on early recovery, UNDP/India

Dahal RK (2016) Earthquake recovery process in Nepal (A comparative analysis with Haiti). International Development, Community and Environment (IDCE) Paper 40

Dangal R (2011) Disaster risk management: policies and practices in Nepal. Asian Disaster Reduction Centre

MOF (2016) Economic survey, 2015/16. Ministry of Finance, Singh Durbar, Kathmandu

NPC (2015) Nepal earthquake 2015, post disaster needs assessment. National Planning Commission, Singh Durbar Kathmandu

NRA (2016) About National Reconstruction Authority. http://www.nra.gov.np/pages/details/about

OSOCC (2015) Situation analysis Nepal earthquake. http://reliefweb.int/sites/reliefweb.int/files/resources/150505_nepal_situation_analysis_osocc_assessmente_cell_1.pdf

Prasain S (2016) Tourism industry bounces back. The Kathmandu Post: year of reckoning. April 24 2016

RW (2016) Update: Nepal quake in numbers, one year later (April 22, 2016). http://reliefweb.int/report/nepal/nepal-quake-numbers-one-year-later

Shahi P (2016) Building back better? The Kathmandu Post: year of reckoning. 24 Apr 2016

UNDP (2009) Global assessment on poverty and disaster risk, Nepal country report. United Nations Development Program, Kathmandu, Nepal

UNDP (2014) Human Development Report 2014. United Nations Development Program

UNEP (2016) http://web.unep.org/one-year-after-nepal-earthquake-supporting-greener-reconstruction-nepal
UNESCAP, SAARC and NPC Nepal (2015) Report of regional earthquake recovery dialogue for building back better
UNOCHA (2008) Disaster preparedness for effective response guidance and indicator package for implementing priority five of the hyogo framework, United Nations secretariat of the International Strategy for Disaster Reduction (UN/ISDR) and the United Nations Office for Coordination of Humanitarian Affairs (UN/OCHA)
UNOCHA (2015) Flash appeal: Nepal earthquake. http://nepal.unfpa.org/sites/asiapacific/files/pub-pdf/flash_appeal_revised_11_june.pdf
WFP (2015) http://reliefweb.int/sites/reliefweb.int/files/resources/wfp273989.pdf
WTTC (2015) Travel and tourism economic impact 2015 Nepal. World Travel and Tourism Council

Social Capital and Good Governance—A Nexus for Disaster Management: Lessons Learned from Bangladesh

Khan Rubayet Rahaman

Abstract This paper summarizes the good practice and lessons learned from the recent cyclone disasters and water surge events from the coastal areas of Bangladesh and reveals how people could facilitate the resilience based on governance and existing chain of social capital. The research identifies that social capital plays important role to boost up resilience based on volunteering and community sense of togetherness along with effective governance system from central to local government. The outcome of the research brings an example which can be adopted for increasing resilience of community while experiencing other natural disasters in particular to earth quake and mud slides. At the same time, the study also brings ideas how remotely sensed data can provide time to time information after disaster period to rebuild the community without investing much money and through the blessings of technology.

Keywords Social capital · Disaster · Governance · Management

1 Background and Objectives

According to Climate Risk Index, Bangladesh is one of the most disaster-prone countries in the World (Harmeling 2009). Bangladesh is highly vulnerable to different types of disaster because of climatic variability, extreme events, high population density, high incidence of poverty and social inequality, poor institutional capacity, inadequate financial resources, and poor infrastructure (Ahmed 2004). Almost every year, the country experiences disasters of one kind or another, such as tropical cyclones, storm surges, coastal inundation, coastal erosion, floods, torna-

K.R. Rahaman (✉)
Department of Geomatics Engineering, University of Calgary,
Calgary, AB T2N1N4, Canada
e-mail: krrahama@ucalgary.ca

J.H. Kruhl et al. (eds.), *Living Under the Threat of Earthquakes*,
Springer Natural Hazards, https://doi.org/10.1007/978-3-319-68044-6_14

does, and droughts, that causes heavy loss of life and property and jeopardizing development activities (Shaw et al. 2013). During the period of 1991–2000, Bangladesh has suffered from 93 large scale natural disasters which killed 0.2 million people and caused loss of properties valued about US$59 billion in the agricultural and infrastructural sector (Climate Change Cell 2009). To manage these unwanted phenomena in one of the poorest nations of the world, governance and administration play important role to ensure safety of citizens, mobilize resources to the disaster-prone areas, coordinate management works, and above all taking the responsibilities within the existing legal framework and policies.

The geographical location, land characteristics, multiplicity of rivers and the monsoon climate render Bangladesh highly vulnerable to natural hazards. The coastal morphology of Bangladesh influences the impact of natural hazards on the area. Especially in the south western part of the country, natural hazards increase the vulnerability of the coastal dwellers and slow down the process of social and economic development. Coastal inundations are an increasing threat to the lives and livelihoods of coastal communities living in low-lying, highly-populated areas. According to a World Bank report in 2005, at least 2.6 million people may have drowned due to coastal inundation, particularly caused by storm surges, inundation/flooding.

The goal of this chapter is understand how several disaster management authorities are working together to tackle disasters in Bangladesh and how the governance system works over the last couple of decades to improve disaster management processes. The contemporary policy and legislative framework in Bangladesh for managing disasters is entitled as disaster management act which is practiced and foresee by the ministry of disaster management. An integrated disaster management plan highlights the tasks and responsibilities of several authorities before, during, and after the disaster to ensure people's safety, security, medical need, and relief aid disbursement in the disaster stricken areas. Major policies and legislative frameworks are being executed and practiced by:

- Standing Orders on Disaster Management (SOD) in 2008;
- National Plan for Disaster Management 2008–2015;
- Ministry of Food and Disaster Management;
- Corporate Plan 2005–2009;
- Poverty Reduction Strategy Paper (PRSP);
- Bangladesh Climate Change Strategy and Action Plan 2009 (draft).

United Nations Development Program (UNDP) has helped Bangladesh since the independence of the country to develop several disaster management strategies so that the loss can be minimized. Some of the important strategies have been in place to develop physical assets, knowledge and human capacity—and the planning, coordination, finance and implementation mechanisms—that underpin its disaster management and risk reduction system. Fundamental of this transformation is highly depending on the existing governance system and if it works properly to follow:

- The Fresh Approach: Lessons from previous decades and bring the ideas into national risk reduction plans;
- Leadership: Take the initiative to engage people who are the champions of disaster risk reduction under a legislative framework;
- Capacity development: training programs, policy revisions, framework development, and stakeholder engagements;
- Multi hazard focus: the governance system that can adhere the focus of different dimensions of disaster managements (such as; drought, flood, cyclone, storm surge, etc.)

This chapter describes the importance of good governance before, during, and after the disasters and how to integrate people as a social capital to minimize loss of disasters. As a result, the specific objectives of this chapter address the following issues:

- To understand the disaster management system currently in place in Bangladesh;
- To know the disaster warning system and dissemination process at field level;
- To explore the issues how people are being engaged in several level of governance system to disseminate information and after the disaster happens for relief aid and medical issues;
- To summarize facts that may help other south Asian countries to learn from Bangladeshi experience of disaster management systems.

2 Forecasting, Warning and Response Systems of Disasters in Bangladesh

Bangladesh suffered from forecast failures several times in the past (Karim and Mimura 2008). Up to 1997 there were plenty of forecast failures that caused huge casualties. For example, there was ample warning prior to the 1991 cyclone that a cyclone might strike, but few people were convinced of the severity of it until they saw the rising water level. Analysts of the cyclone later found that many false alarms were issued prior to that event which lowered the citizen's trust in the warning system (Haque 1997). The development of an accurate and timely forecasting system has been ongoing for several years, but much more needs to be done to prepare for future event and people's participating in building such system is emergent too.

Bangladesh Meteorological Department (BMD) is the authorized organization for cyclone and weather forecasts in Bangladesh that includes storm surges prediction during the cyclones. SWM (Storm Warning Center), under BMD, is responsible for national forecasting on all time scales including the issuance of tropical cyclone forecasts and warning (DMB 2010). The department is responsible for observation, recording, operation, and maintenance of weather stations and

Table 1 Respondents answer regarding the need of integrated warning and forecast system in Bangladesh

Respondents	Need for forecasting and warning system (CIFDP)
Water development board	Yes
Director, Bangladesh meteorological department	Yes
Secretary, disaster management and relief division	Yes

Source Field investigation

weather instruments, and for reporting of daily/weekly weather information to the public. Every day, all weather stations around the country transmit their recorded data electronically to the headquarters of the meteorological department in Dhaka. Major stakeholders who are using the information published in electronic and print media are: BMD, Disaster Management Bureau, Central government organizations, Local government organizations, Non-government organizations, Community workers in the coastal areas (mostly for cyclone and water surges), Fishermen communities in the coastal areas, Religion organizations in the coastal areas, Aid and relief organizations (e.g., Red Crescent and Oxfam), research institutions, Water Development Board (WDB), and relevant organizations (Table 1).

According to the responses from major stakeholders of the recently introduced CIFDP (Coastal Inundation Forecasting Demonstration Project by WMO) in a prescribed questionnaire, all of the respondents seek for a user plan and improved forecasting and dissemination system in coastal areas of Bangladesh. At the same time, technology development and transfer, including training, capacity building would enhance the capabilities of responsible national agencies to produce and provide integrated coastal inundation forecasting and warning services to the people in coastal areas in Bangladesh. The user plan is required to identify major stakeholders and to share responsibilities among them for the warning system to be working properly in advance. At the same time, major stakeholders have felt keen interest to incorporate local people to take social assistance for disaster management and recovery especially through the revised governance system. Volunteer organizations are also included in the national disaster management plan to empower them with specific responsibilities mostly in the information dissemination and recovery process.

2.1 Existing Cyclone and Flood Forecasting and Warning Systems

In recent years, with the technical assistance from USA and Japan, the cyclone forecasting system in Bangladesh has been improved substantially and it has saved hundreds of thousands of lives during the cyclones of 1997 and 2007 with the dissemination of accurate and timely warnings (Karim and Mimura 2008). Prediction of tropical cyclone storm in the Bay of Bengal and issuance of timely warning is the task of the Bangladesh Meteorological Department (BMD). The Storm Warning Center (SWC) of BMD detects and monitors depression or cyclones formation until landfall and forecasting the cyclone's future track and storm surge height. Modern technology has provided the means for early detection and constant tracking of cyclone and storm surge at BMD. The warning issued by BMD includes:

- Position of storm center
- Direction and rate of movement
- Area likely to be affected specifying *Upazillas* (administration unit in Bangladesh) of the district possible
- Approximate time of commencement of gale winds (speed more than 32 km/h or 52 km/h)
- Maximum wind speed expected
- Approximate height of storm surge/tide and areas likely to be affected.

The Flood Forecasting and Warning Center (FFWC) of Bangladesh Water Development Board (BWDB) provides river flood forecast for 24, 48, and 72 h deterministic and 1–10 days experimental probabilistic forecasts. FFWC has updated hydro-dynamic regional models covering the rivers and flood plains of the south–west and south–east hydrological zone of Bangladesh, covered the entire zone total 19 districts.

Cyclone warning system in Bangladesh was started in 1966 by the Bangladesh Red Crescent Society (BRCS). After a devastating cyclone in 1970, the BRCS started the Cyclone Preparedness Program (CPP) in 1972 to minimize the loss of lives and property by strengthening the capacity of coastal people in disaster management. The field level work of the CPP is based on "UNITS", which typically encompasses a village of 2000–3000 people having land area of roughly 2 sq. km. The network of CPP team is expanding with time, but there are still remote locations where CPP team have not yet to be formed (BRCS 2005). Moreover, CPP teams have to be formed for the newly identified hazard zone as well. Dissemination of cyclone warning in appropriate ways is another important aspect of cyclone disaster management in Bangladesh.

Figure 1 shows that CPP teams presently work in all the coastal districts, but not all the risk prone areas.

The characteristics of the disturbances in the Bay of Bengal are staged in several categories by Asian Disaster Reduction Center (ADRC) in 2008 (Table 2).

According to Rogers and Tsirkunov (2010) because of the proper cyclone warning and dissemination to the field level, thousands of lives have been saved during the cyclone *Sidr*. According to them, cyclone *Sidr* was first observed southwest of the Andaman Island in the Bay of Bengal six days before it made landfall on November 15, 2007. Tracking its path and growing strength, the Bangladesh authorities had time to prepare a well-rehearsed response: they issued warning and activated 44,000 volunteers who helped evacuate roughly 3 million people from their homes and accommodated 1.5 million in shelters. Few were

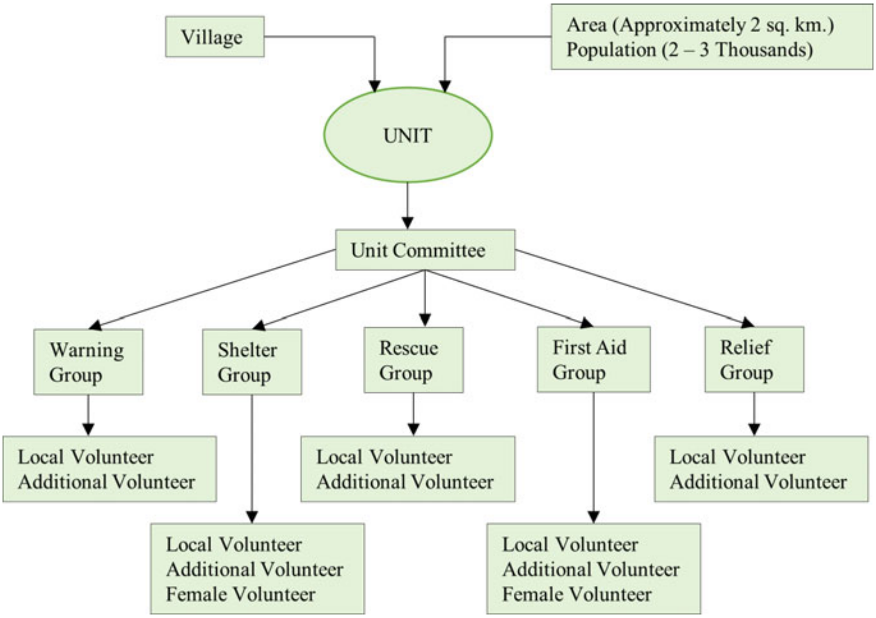


Fig. 1 Flowchart of volunteer structure of CPP (Cyclone Preparedness Program) team. There are 2760 units and 33,120 volunteers all over the coastal zones (BRCS 2005)

Table 2 Characteristics of the tropical disturbances in the Bay of Bengal

Stages of disturbances	Radius of disturbances	Maximum sustained wind
Low pressure or low	–	Less than or equal to 31 km/h (17 kts)
Well marked low	–	32–39 km/h (18–21Kts)
Depression	44 km (24NM)	40–50 km/h (22–27Kts)
Deep depression	48 km (26NM)	51–60 km/h (28–33Kts)
Cyclonic storm	54 km (30NM)	61–88 km/h (34–47Kts)
Severe cyclonic storm	64 km (35NM)	89–117 km/h(48–63Kts)
Severe cyclonic storm with a core of hurricane wind	74 km (40NM)	118–219 km/h(64–118Kts)
Super cyclone	84 km (45NM)	220 km/h or over (119 Kts or more)

Source Asian Disaster Reduction Center 2008

surprised and unprotected when *Sidr* hit, but immense force was devastating. The government estimated that assets worth $1.16 billion were damaged, almost all in housing and other infrastructure. Losses of $517 million were expected earlier on. It could have been far worse if the country had not learned from earlier tragedies and if the warning system would not work properly in advance.

2.2 Institutions for Dissemination of Forecasts and Warnings

Most of the institutions disseminating cyclone warning and conducting cyclone forecast tasks are from national government in Bangladesh. However, sometime the national institutions exchange information and rely on other countries to predict the cyclone track and to predict landfalls. The international cooperation is happening when the cyclone forms in Indian Ocean and usually when it approaches towards Bangladeshi coastal areas.

2.3 National Institutions

Bangladesh Meteorological Department (BMD) is the source of cyclone warning in Bangladesh. BMD generates the warning and passes this on to public media and preparedness units for dissemination and follow-up action at periodic intervals. There are separate warning system for maritime ports and river ports. The Storm Warning Center (SWC) of BMD detect and monitors depression or cyclones formation until landfall and forecasting the cyclone's future track and storm surge height. Modern technology has provided the means for early detection and constant tracking of cyclone and storm surge at BMD.

The Standing Orders for Cyclone (SOC) proclaimed by the Government of Bangladesh (GOB) as of November, 1985 and updated thereafter constitute the basic plan for coping with cyclone disaster. SOC laid down the guidelines for action at various stages of disaster by all government agencies to cope with situation arising out of cyclone havoc. Within the framework of SOC, concerned authorities are required to deal with unforeseen and complex situations swiftly using initiative and imagination. The local authorities are required to take necessary action to prevent or reduce loss or damage to life and property by making maximum use of local resources instead of waiting for external assistance.

The guidelines for disaster preparedness and management under SOC is organized into 5 stages as follows:

(a) Pre-disaster stage: Off-cyclone season
(b) Alert stage: Signal no I, II and III
(c) Warning stage: Signal no IV
(d) Disaster stage: Signal no V, VI, VII, VIII, IX, X
(e) Post-disaster stage: immediately after the cyclone till normalcy is attained.

As per the Standing Order of the Government, Cyclone Warning messages are issued as follows:

(a) Warning Stage: 24 h in advance.
(b) Danger Stage: Minimum 18 h in advance.
(c) Great Danger Stage: Minimum 10 h in advance.

The Storm Warning Centre (SWC) is a specialised body of the BMD, responsible for weather forecasting and issuing warnings to sea and river ports, public, non-governmental organisations (NGOs), relief and rehabilitation authorities and local level administrative officials. The standing order for cyclones are to be disseminated to all concerned Ministries, Divisions, Departments, NGOs and also to press the public to be ready to discharge their duties in a speedy and systematic manner to handle the situation efficiently. More frequent contact is maintained between BMD and Betar (Radio), and television transmission hours are extended as and when danger signals or great danger signals are hoisted. The warning message dissemination system of SWC, the national weather forecast center is as follows (see also Fig. 2):

Five interconnected subdivisions; observations, communications, display and manipulations, analysis and preparation of forecast are coordinated by Storm Warning Center (SWC) of Bangladesh Meteorological Department (BMD) for providing all kind of forecasts and disasters warning (Haque 1997). The following Fig. 3 is showing the whole process of warning message dissemination system which is administrated by Bangladesh Meteorological Department Bangladesh. The technical works and analysis is done by the BMD experts to assess probable threats and hazard risk of the cyclone. Afterward, it passes information to SWC who is formally responsible to issue warnings. SWC issues warning and disseminate information electronically and officially (signed letter document) to newspaper, television, relief control, national coordination center, Cyclone Preparedness Program (CPP), radio Bangladesh, and other concerned ministries. Some organizations are directly connected to SWC which are connected with bold lines in Fig. 3. Some organizations are indirectly connected to get the warning messages issued by SWC which are connected through dotted lines in Fig. 3. In each segment

Fig. 2 Cyclone warning message dissemination system through SWC (Storm Warning Center) (Extracted from: DBM 2010)

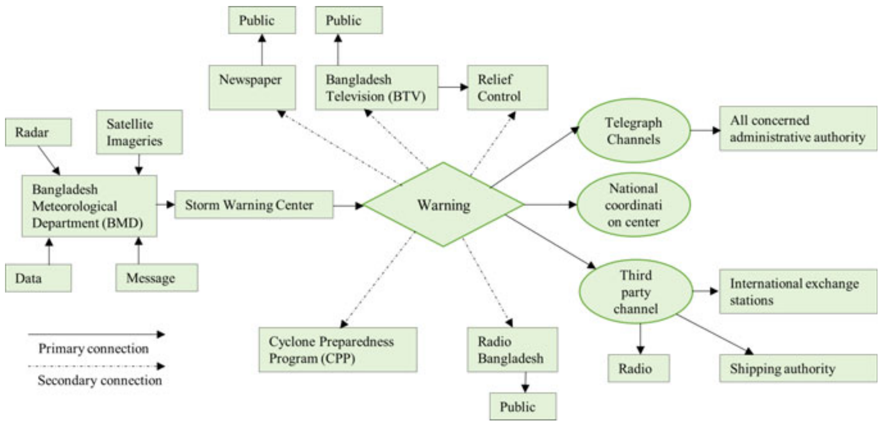


Fig. 3 Warning message dissemination system administrated by the BMD (Adopted from Haque 1997)

ended in public, there are volunteers who are assigned with responsibilities to inform local people through their own strategies managed by CPP and by the local government organizations. The tasks of the volunteers include the arduous wide dissemination of warnings by bicycle, walking, using megaphones, sirens, signal lights, and signal flags (Paul 2009). The cyclone warning flags are hoisted in port, cyclone shelters, public buildings, community centres, or local government organisations in coastal areas following a warning from the BMD to communicate an impending cyclone. The CPP volunteers ensure the hoisting of flags. One flag is hoisted for caution, two flags for danger and three flags for great danger. Along with this, religion centers (i.e., mosques) are informing people to take necessary strategies to avoid loss of lives and properties.

Port and shipping authority receives different signal systems to inform relevant people about the havoc and precautions. Both radio and television are telecasting the warning placed for maritime port authorities simultaneously. Table 3 summarizes the maritime port's warning signals depending on the wind speed. However, the inland water ports are receiving different signals due to their locations. The new signal system has been developed on wind speeds and the signal number will increase with the increasing wind of the impending cyclone, besides maritime and riverine signals are incorporated in the new system to avoid confusion.

Since one of the major cyclones in 1991, the warning and dissemination system is working well throughout the country. As a result, there were less number of casualties in cyclone SIDR (2007). One of the important components in this warning system was the volunteers who informed the local people to leave home and took shelter in higher areas to avoid storm surge havoc. It proved that the forecasting and warning system would not work properly without the hard work done by the volunteers at grass root level. At this stage, after experiencing severe damages over time, especially in the coastal areas, the country demands an

Table 3 Signal system for maritime ports in Bangladesh

Signals	Explanations
Distance cautionary signal number—I	There is a region of squally weather in which a storm may be forming (well-marked low or depression) with surface winds up to 61 km/h.
Distance warning signal number—II	A storm has formed (cyclonic storm with surface winds 62–87 km/h)
Local cautionary signal number—III	The port is threatened by squally weather (cyclonic circulation with surface winds 40–50 km/h or squalls due Nor'westers)
Local warning signal number—IV	The port is threatened by a storm, but it does not appear that the danger is as yet sufficiently great to justify extreme measures of precaution (cyclonic circulation) with surface winds 51–61 km/h
Danger signal—VI	The port will experience severe weather from a cyclonic storm of moderate intensity (cyclonic storm with surface winds 62–88 km/h)
Great danger signal —VIII	The port will experience severe weather from a storm of very great intensity (severe cyclonic storm with surface winds 89–117 km/h)
Great danger signal —IX	The port will experience severe weather from a storm of very great intensity (severe cyclonic storm with a core of Hurricane winds with surface wind 118–170 km/h)
Great danger signal —X	The port will experience severe weather from a storm of very great intensity (severe cyclonic storm with a core of Hurricane winds with surface winds 171 km/h or above)

Source BMD 2007

integrated approach to tackle future devastation of cyclones and water surges. In doing this, the existing capacity for weather forecasting techniques as well as dissemination system should be updated regularly.

2.4 Regional Institutions/Organizations

In Bangladesh, the major missions and visions of the government for the disaster management (including warning, forecast and information dissemination) have been addressed in the National Plan for Disaster management 2010–2015 (NPDM). The NPDM was developed in coordination with various national and international institutes and agencies. Strategic goals for the comprehensive disaster management plan 2010–2015 are drawn from South Asian Association for Regional Cooperation Disaster Management Framework 2006–2015 (SAARC-DMF 2006–2015). Other institutes and policies that have an impact on the NPDM are the Millennium Development Goals for Bangladesh, the Poverty Reduction Strategy Paper (PRSP), Bangladesh, and Hyogo Framework for Action (HFA) 2005–2015, the United Nations Framework Convention on Climate Change (UNFCCC), and the Bangladesh Climate Change Strategy and Action Plan 2009. According to the opinions received from the experts of different entities in government institutions, almost all of the respondents mentioned that they did not have any known cooperation with international agencies through bi-lateral commitment or through other assistance from any countries, technical institutions or universities for developing warning systems or improving forecasting techniques. However, BMD, Flood Forecasting and Warning Center (FFWC) and Disaster Management Bureau (DMB) have strong commitment and relationships with the United Nations and other meteorological departments (other countries) who have keen interest to predict cyclones in the Bay of Bengal and in the Indian Ocean.

South Asian Association of Regional Cooperation (SAARC) also set up strategic goals to plan for regional disaster management framework (including cyclone and coastal inundation) that includes the following major goals:

Goal 1: professionalizing the disaster management system
Goal 2: mainstreaming risk reduction
Goal 3: strengthening institutional mechanisms
Goal 4: empowering at risk communities
Goal 5: expanding risk reduction programming
Goal 6: strengthening emergency response systems
Goal 7: developing and strengthening networks.

2.5 *Major Stakeholders Involved in Disaster Management*

Government organizations, NGOs (National and International), Community Based Organizations (CBOs), United Nations, Citizen's groups, Academia, Researchers are being considered as major stakeholders for disaster management efforts with special focus on cyclone and coastal inundation.

Bangladesh has disaster management mechanism at both national and sub-national levels nationally. Figure 4 illustrates the position, activity and authorities involved in disaster management structure of Bangladesh at national level in which each of the organizations and committees has its own responsibility.

(a) National Disaster Management Council (NDMC) headed by the Honorable Prime Minister to formulate and review the disaster management policies and issue directives to all concerns.
(b) Inter-Ministerial Disaster Management Co-ordination Committee (IMDMCC) headed by the Honorable Minter in charge of the Disaster Management and Relief Division (DM&RD) to implement disaster management policies and decisions of NDMC/Government.
(c) National Disaster Management Advisory Committee (NDMAC) headed by an experienced person having been nominated by the Honorable Prime Minister.
(d) National Platform for Disaster Risk Reduction (NPDRR) headed by Secretary, DM&RD and DG (Deputy General), DMB functions as the member secretary. This platform shall coordinate and provide necessary facilitation to the relevant stakeholders.

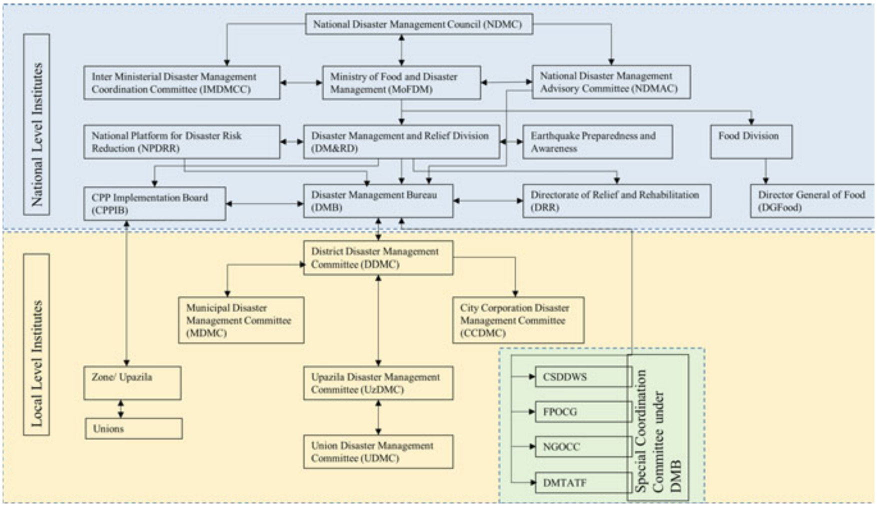


Fig. 4 Disaster management institutions in Bangladesh (*Source* Shaw et al. 2013)

(e) Earthquake Preparedness and Awareness Committee (EPAC) headed by Honorable Minister for MoFDM and DG, DMB act as member secretary.

(f) Cyclone Preparedness Program Implementation Board (CPPIB) headed by the Secretary, Disaster Management and Relief Division to review the preparedness activities in the face of initial stage of an impending cyclone.

(g) Cyclone Preparedness Program (CPP) Policy committee headed by Honorable Minister, MoFDM and secretary, DM&RD act as a member secretary. Disaster Management Training and Public Awareness Building Task Force (DMTATF) headed by the Director General of Disaster Management Bureau (DMB) to coordinate the disaster related training and public awareness activities of the Government, NGOs and other organizations.

(h) Focal Point Operation Coordination Group of Disaster Management (FPOGC) headed by the Director General of DMB to review and coordinate the activities of various departments/agencies related to disaster management and also to review the Contingency Plan prepared by concerned department.

(i) NGO Coordination Committee on Disaster Management (NGOCC) headed by the Director General of DMB to review and coordinate the activities of concerned NGOs in the country.

(j) Committee for Speedy Dissemination of Disaster Related Warning/Signals (CSDDWS) headed by the Director General of DMB to examine, ensure and find out the ways and means for the speedy dissemination of warning/signals among the people.

Disaster management structure of Bangladesh at sub-national level is as follows:

(a) District Disaster Management Committee (DDMC) headed by the Deputy Commissioner (DC) to coordinate and review the disaster management activities at district level.
(b) Upazila Disaster Management Committee (UZDMC) headed by the Upazila Nirbahi Officer (UNO) to coordinate and review the disaster management activities at the Upazila level.
(c) Union Disaster Management Committee (UDMC) headed by Chairman of the Union Parishad (the bottom level governing body) to coordinate, review and implement the disaster management activities of the concerned Union.
(d) Paurashava Disaster Management Committee (PDMC) headed by Chairman (Mayor) of Paurashava (Municipality) to coordinate, review and implement the disaster management activities within its area of jurisdiction.
(e) City Corporation Disaster Management Committee (CCDMC) headed by the Mayor of City Corporations to coordinate, review and implement the disaster management activities within its area of jurisdiction.

2.6 Coordination Process and Responsibilities of Each Institution

Bangladesh has an elaborate structure of disaster management. The Standing Order on Disaster (SOD) has assigned specified roles and responsibilities to the government and other relevant agencies as well as to the Disaster Management Committees (DMCs) at all levels from central government to local government. A series of institutions at both national and sub-national levels have been created to ensure effective planning and coordination of disaster management activities. Coordination are being carried out by:

(a) National Level: At the national level, there are the National Disaster Management Committee (NDMC). The Inter-Ministerial Disaster Management Coordination Committee (IMDMCC) and National Disaster Management Advisory Committee (NDMAC). The NDMC, headed by the Prime Minister, is composed of 30 members including cabinet ministers of nine different ministries and secretaries of 12 ministries. The responsibilities of the council are to formulate and review disaster management policies and issue directives to all concerned. Under the Council, there is the IMDMCC with 30 members drawn from 20 different ministries. Headed by the minister responsible for the Ministry of Food and Disaster Management (MFDM), the responsibilities of the IMDMCC include implementation of disaster management policies of the government and decisions of the NDMC and ensuring coordination of activities of all ministries, government agencies and the private sector. The National Disaster Management Advisory Committee (NDMAC), headed by the disaster management specialist, regulates the various activities to disaster preparedness, mitigation and emergency management

(b) Sub-national level/local level: There are disaster management committees at District, Upazila and Union Levels. These committees are headed by the Deputy Commissioner, the Upazila Nirbahi Officer (UNO) and the elected Chairman respectively. In addition, there are disaster management committees in all the city corporations and municipalities, headed by the elected mayors. These committees are composed of members drawn from government and non-government organizations, the private sector, and social organizations. The responsibilities of these committees are to plan, coordinate, review and implement disaster management activities within their respective areas of jurisdiction.

(c) International level: The World Meteorological Organization (WMO) provides real time data and information through the Global Telecommunication System (GTS) to the BMD and also provides expertise and guidance materials to BMD and the Department of Hydrology. The World Health Organization (WHO) provides help and advice to the governmental and non-governmental health sectors, through its Country Office in Dhaka, Bangladesh. The International Red Cross and Crescent Societies, through the Bangladesh Red Crescent Society (BDRCS), administer the Cyclone Preparedness Program (CPP), in cooperation with the DMB.

2.7 Warning Response System and Emergency Preparedness

The Meteorological Department under the Ministry of Defense broadcasts weather forecasts, e.g. cyclones. The Cyclone Preparedness Program (CPP) provides an early warning system for 35 million people in 19 coastal districts (Swiss Agency for Development 2010). It is a joint program of the Government of Bangladesh and the Bangladesh Red Crescent Society, which was established after the 1970 Cyclone. Activities of CPP in regard to warning response and emergency preparedness can be summarized as:

a. Disseminate cyclone warning signals issued by the BMD to the community people;
b. Assist people in taking shelter;
c. Rescue distressed people affected by a cyclone;
d. Provide first aid to the people injured by cyclone;
e. Assist in relief aid and rehabilitation operation;
f. Assist in the implementation of the BDRCS disaster preparedness plan;
g. Assist in participatory community capacity build-up activities; and
h. Assist in the co-ordination of disaster management and development activities.

To carry out the warning and preparedness management, wide range of equipment are widely used to inform people through the volunteers are: transistor radios, torch lights, megaphones, hand sirens, life jacket, rain coat, gum boat (mud boot), hard hats, first aid kits and rescue kits. The following figure shows structural arrangement of warning response system and emergency preparedness responsibilities to different management people under the CPP program.

All signals and warning information are transferred to specific committees at different level of government organizations to administer and supervise early preparedness system. They seek help from non-government organizations and from local communities to warn people to leave for cyclone shelters.

Usually, Dhaka is considered as the head quarter to disseminate information and warning signals to all the zonal and community offices in coastal areas using telephone and high frequency radio. Nowadays cell phones are distributed among the volunteers so that they can easily receive voice and smart message systems in their cell phone to spread out the signals for early preparation. The total system works within few minutes to disseminate information from head-quarter to the grassroots community people. Based on the emergency of the early preparation, the signals are dispatched as quickly as possible but in three different cases, the warning stages are allowed a time frame so that early preparation can be taken place in time as mentioned by Habib et al. (2012):

(a) Warning: 24 h before.
(b) Danger: at least 18 h before.
(c) Great danger: at least 10 h before.

2.8 Public Education for Awareness Generation and Capacity Building

Education and awareness are prerequisites for preparedness of cyclone and coastal surges in Bangladesh. Disaster preparedness education is provided through formal and non-formal means by both government and NGO programs.

Figure 5 shows the structure of the education programs exist in Bangladesh right now with special focus on disaster management. The government—operated programs provide disaster preparedness education through the Campaign for Popular Education (adult literacy program) and primary level school curriculum. There are also several awareness—building programs regarding disaster preparedness. Approximately 2000 NGOs work in Bangladesh of which about 190 are foreign NGOs (Khan 2008). NGOs play important role in rural and national development which comprises disaster management and relief aid dissemination. Leading NGOs in disaster management and education are:

(a) Bangladesh Rural Advancement Commission (BRAC);
(b) Proshika;

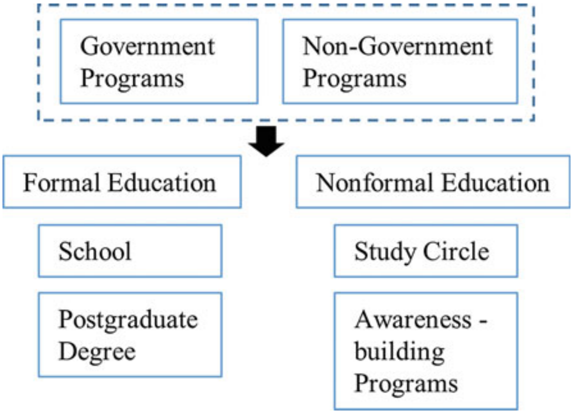


Fig. 5 Formal and non-formal education structure in Bangladesh for disaster management (*Source* Khan 2008)

(c) Gono Sahajjyo Shongstha (GSS);
(d) Dhaka Ahsania Mission; and
(e) Disaster Management Forum (DMF).

Formal Education
Formal education in disaster preparedness is provided at the primary school level and postgraduate level. At the primary school level, topics are specially focusing on general awareness about different types of disasters and the pre-, post- and during disaster tips. At the postgraduate level, degrees (Certificate, Diploma and Master) in Disaster Management are offered to prepare professionals (BRAC University 2006). Course contents related to three main aspects:

- Pre-disaster preparedness and vulnerability reduction;
- Post-disaster response, relief and rehabilitation; and
- Disaster mitigation and long-term development.

Non-formal education
The government-initiated public awareness and training program is mainly conducted by the DMB. The objective of this program is to promote an informed, alert, self-reliant and sustainable community that can actively cooperate in all disaster management activities. At the local level, the program is particularly addressed to the local-level disaster management committee members, CPP volunteers, school teachers, professionals in the relevant fields, women and children.

3 Conclusion

Bangladesh has proven its ability to manage several disasters successfully with the help of local people, volunteers, and other national and international stakeholders since the independence of the country. However, in the early 80's the management system did not work so well which can be seen nowadays. Local people played important role to improve the system at different level such as; information dissemination, building awareness among community members, willingness to help neighbours during disaster events, and overall, building the trust among stakeholders. On the other hand, government played important and pivotal role to ensure a regulatory framework through good governance to increase community resilience. Whether governance system could be seen weaker and not functioning properly in many sectors of the country, disaster management systems brought trusts of people and the governance system might be a successful team work with the participation of local people in case of Bangladesh. This example can set up a success story of disaster management system in south Asia as well.

References

Ahmed AU (2004) Adaptation to climate change in Bangladesh: learning by doing. Conference Proceedings of UNFCCC workshop on adaptation, Bonn, Germany, 18 June 2004

Asian Disaster Reduction Center (2008) Total disaster risk reduction—good practices. Asian Disaster Reduction Center

BRAC University (2006) Postgraduate programs in disaster management. Dhaka, Bangladesh. www.bracuniversity.ac.bd. Accessed Oct 3 2013

BRCS (2005) Cyclone preparedness program at a glance. Bangladesh Red Crescent Society, Newsletter 3(30)

Climate Change Cell (2009) Department of Environment. Ministry of Environment and Forest, Dhaka, Bangladesh

DBM (2010) National Plan for Disaster Management. Government of Bangladesh, Disaster Management Bureau, Dhaka, Bangladesh

Habib A, Shalauddin M, Ahmed D (2012) The Bangladesh cyclone preparedness program. A vital component of the Nation's Multi-Hazard early warning system, Institutional Partnership in Multi-Hazard Early Warning System. Springer, pp 29–62

Haque CE (1997) Atmospheric hazards preparedness in Bangladesh: a study of warning, adjustments and recovery from the April 1991 cyclone. Nat Hazards 16:181–202

Harmeling (2009) Global Climate Risk index. Briefing Paper, Germanwatch, Bonn, 24 p

JCOMM Symposium (2007) Develop methodologies to project changes in storm surge climate over the next century, The 1st JCOMM Symposium on Storm Surges, 2–6 Oct 2007, Conference Proceedings, Seoul, Korea

Karim M, Mimura N (2008) Impacts of climate change and sea-level rise on cyclonic storm surge floods in Bangladesh. Glob Environ Change 18:490–500 (Elsevier Science)

Khan M (2008) Disaster preparedness for sustainable development in Bangladesh. J Disaster Prev Manag, Emerald 17(5):662–671

Miah G, Bari M, Rahman A (2010) Resource degradation and livelihood in the coastal region of Bangladesh. Front Earth Sci, China 4(4):427–437

Miyan M (2010) Cyclone disaster mitigation in Bangladesh. World Meteorological

Organization Technical Document (WMO/TD-No 1272). Tropical Cyclone Programme, Report No. TCP-51

Paul BK (2009) Why relatively fewer people died? The case of Bangladesh's cyclone Sidr. Nat Hazards 50(2):289–304

Paul BK, Rashid H, Islam M, Hunt L (2010) Cyclone evacuation in Bangladesh: tropical cyclones Gorky (1991) vs. Sidr (2007). Environmental Hazard 9:89–101

Rogers D, Tsirkunov V (2010) Costs and benefits of early warning systems. Global assessment report of disaster risk reduction, The World Bank
Shaw R, Islam A, Mallick F (2013) National perspectives of disaster risk reduction in Bangladesh. Springer, pp 45–62
Swiss Agency for Development (2010) Disaster risk reduction program for Bangladesh 2010–2012, Switzerland

Directions and Avenues of Geotourism—With Particular View to Nepal

Jörn H. Kruhl

Abstract The paper briefly presents foundations and advantages of geotourism in theory and praxis. Research is mostly financed by public money and, therefore, the public should be informed about results of research. Such transfer needs to follow didactic rules. Beyond seminar rooms, geotourism is mainly based on geo-museums, geotopes and national and global geoparks. Geotourism as part of ecotourism and educational tourism is regarded as driving force behind the economic and cultural development of regions. Specifically a country like Nepal, with a limited industrial fundament, should make advantage of its rich geo-heritage. The paper reviews the geoscientific, economic and structural basis of geotourism in Nepal and its necessary design with respect to geo-hazards. Suggestions are made how geoscience transfer to the public can be performed, with special view on the Global Geopark Network, and which practical steps for successfully establishing geotourism in Nepal can be made. Finally, a key object is presented, which could serve as geotouristic focus of attraction: The Great Wall of Kathmandu.

Keywords Geotourism · Geopark · Geodidactics · Science transfer
Nepal

1 Introduction

The definition and use of the term geotourism goes back to the United Kingdom and the early 1990s (Hose 1995, 2008, 2012). From there it developed to its current concept and range of application. Originating from the idea of protection and conservation of geosites and, subsequently, the explanation and presentation of the history of geological objects, increasing importance was attached to the interpre-

J.H. Kruhl (✉)
Department of Civil, Geo and Environmental Engineering,
Technische Universität München, Munich, Germany
e-mail: kruhl@tum.de

J.H. Kruhl et al. (eds.), *Living Under the Threat of Earthquakes*,
Springer Natural Hazards, https://doi.org/10.1007/978-3-319-68044-6_15

tation not only of geo-objects but of the wide range of geological processes and their importance for the development of nature and for the human society.

Although in the beginning single geosites (or geotopes) formed the backbone of presenting geoscience to the public, quickly a process of concentration and expansion started. Geotopes, grouped in certain regions, were connected to national geoparks and geopark networks, to transnational and finally to global geopark networks. Simultaneously, regulation and formalization gathered strength and culminated in the establishment of the Global Geopark Network under the management of the United Nations Educational, Scientific and Cultural Organization (UNESCO 2016a).

National and global geoparks have proven as one of the main pillars of geotourism that, during the last years, became an important part of worldwide tourism and gained increasing economic significance (UNWTO 2016). Several reasons for this development exist. (i) Although tourists are still seeking recreation and entertainment, they increasingly set a high value on education and new experiences ('educational leave'). (ii) Environmental problems directed attention to the importance of environment for humans and societies. This generated the desire to 'understand' nature and natural processes. (iii) Based on the increased global reporting, natural disasters moved into the focus of public interest. (iv) Again based on the wide distribution of information, people realize and understand the importance of the Earth's crust, i.e. of rocks, for nearly all aspects of life.

The economic significance of geotourism gives point to a closer inspection of the foundations of geotourism, its establishment and promotion specifically in countries without strong economy like Nepal, and of the didactic aspects of transferring science to a 'non-scientific' public.

2 Transferring Geoscience to the Public

Science is financed by public money and, therefore, scientists are obligated to inform the public about the results of their research—also for their own benefit. After all, a continuous flow of money is needed, which not only ensures the infrastructure of research and its maintenance but also the scientists' jobs. However, it is even more important to make the public understand why the results of scientific research are generally significant for human societies.

In order to successfully transfer science to the public, scientific results need to be comprehensible for non-professionals. For that reason, a few rules have to be considered (Birkenhauer 1996): (i) The presentation of science must not be designed on the knowledge level of experts. (ii) It has to match the laypersons' knowledge and, even more important, their patterns of thinking. (iii) The questions of laypersons should be answered, not the questions of the experts. (iv) The appointment with science should be original and unmediated. Objects, suitable for such appointment, should show several characteristics: a 'problem content', straightforwardness, conciseness, impressiveness, structuredness, emotional cognition, contextuality (Birkenhauer 2003).

The importance of geoscience is based on the fact that they offer an immediate experience of nature and its importance, and can communicate that nature is beautiful, vulnerable and worth protecting. Such mediation is performed best at extracurricular geosites (Birkenhauer 1995): museums, special exhibitions, show caves, show mines, or outdoors in geotopes, along nature trails, and in geoparks.

Above all, these ‘open’ geosites are important. Only beyond classrooms or lecture halls, it is possible to conceive dimensions and time of our surrounding world (Kruhl 2007). Worlds (of experience) are between looking at an image on-screen in a dark seminar room and observing a landscape outdoors, walking through a quarry, trekking in a valley, touching rough or smooth rock surfaces, or listening the scrunching of gravel under the shoes. In nature, one learns with many senses. In addition, outdoors larger objects can be observed and investigated than indoors. Certain geological structures and processes become accessible only on large scale or can be simulated only outdoors.

In geoparks, for example, geological structures and processes can be impressively related to landscape, animate nature, and the cultural and historic environment of humans. They offer insights to geological processes and awaken understanding of the development of landscapes and of the necessity of maintenance and conservation. “You conserve what you love.” In geoparks an interdisciplinary approach to the geosciences is possible. This facilitates forming networks of knowledge and, consequently, supports processing and storing knowledge.

As a general advantage, geosites are (in most cases) ‘visitor-resilient’. Abandoned quarries, the bottom of cliffs, road cuts, boulder fields, etc., provide enough space for many people, can be treated by hammers in most cases, and are resistant against noise and many soles of shoes. In the case of geosites ‘discovering learning’ (Neber 1975) has priority. It is outstandingly suitable for transferring geoscience to the public. Or vice versa: The geosciences represent an excellent field for applying ‘learning by doing’.

In geoparks km-scale structures can be combed and thus conceived. This aspect of geoparks gains specific importance with respect to the partly extreme spatial extension of geological structures (from the scale of atoms to lithospheric plates). The morphologies of landscapes may be considered as a first example. They are formed by various geological processes and often laypersons’ questions focus on them. Mountain ridges and lowlands are characteristic landforms, which catch the observer’s eye and provoke questions about their forms and formations (Fig. 1).

Many geological structures are scale-independent (Mandelbrot 1982) and, therefore, can be presented without lack of information on any scale, thus small enough for the classroom. Nevertheless, size matters. The object size always bears relation to our own size. Thereby the impression of the object on ourselves changes (Gehl 2010). A boulder or quarry face, which overtower us and contain dm- or even m-large crystals (Fig. 2) impress us much more than a fist-sized piece of rock with mm-sized crystals, although the geological message is possibly the same.

Fig. 1 Landscape in Lower Mustang (Nepal), with horizontally layered sedimentary rocks of the Tethyan Himalayan Sequence (Chukh Group) in the foreground; Kagbeni at the Kali Gandaki river. Photo JH Kruhl (2013)

Fig. 2 Carbonate vein with m-large amphibole columns; Tribulation Quarry, Mt. Isa Inlier (Queensland, Australia); person for scale. Photo JH Kruhl (1993)

Geological objects can ‘talk for themselves’. Their beauty and esthetics impress without further explanations. This may wake the wish to learn more about these geo-objects. However, different types of media are required to cause appreciation and inseminate knowledge. Digital and interactive tools offer new possibilities of flexible, instructive and stimulating representations of geological structures and geoscientific processes. They specifically allow laypersons an easier access to geoscientific facts (Lansigu et al. 2014). Still, the geosciences are preferentially communicated verbally or visually, with the aid of an intensive technical terminology and of diagrams, sketches, photos, etc., which are coined by specific scientific concepts and patterns of thinking.

The rigid geoscientific terminology, however, makes it difficult for laypersons to gain access to even simple geoscientific facts. Often it is used by the experts to seal themselves off from non-experts. Also the visual representation of scientific facts is shaped by a specific symbolism and distinct abstract concepts. The representation of measurements in histograms or X-Y coordinate systems is difficult to understand for non-scientists. Geological maps and profiles, even more, demand to be familiar with specific notations. Already topographic maps give many people a riddle. Even more, geological maps are based on concepts that need to be known, in order to make the information of these maps accessible.

The large spatial and temporal range of investigations is specific of the geosciences—from atomic scale to the size of mountain ranges and lithospheric plates, from processes spanning only seconds, such as earthquakes, to the deformation of rocks, which may be as slow as the growth rate of fingernails.

These problems of verbal and visual science representation and of the use of technical concepts require to approach geoscience representations suitable for laypersons. Geosites, in combination with guided tours, posters, booklets, electronic audio-systems, etc., are one of the most powerful and effective tools we have. Such transfer of geoscience should follow certain rules (Birkenhauer 1996; Hughes and Ballantyne 2010; Kruhl 2007):

- Write (and speak) interestingly, clearly, concisely and elegant.
- Reduce the geoscientific language to the absolutely necessary minimum.
- Use simple and catchy representations and examples—'less is more'.
- Explain the specific geoscientific symbolism or replace it by ordinary symbols.
- Balance verbal and visual representations.
- Answer the questions of laypersons—not your questions!—and take yourself to the niveau of laypersons.
- Perform actions.

All technical representations at geosites require repeated evaluations—by experts as well as by laypersons (Dos Reis and Henriques 2009). Because in the geosciences didactics is not sufficiently established, except in geography, such evaluations are necessary. Technically good, comprehensible and inspiring representations to the public are too important for the geosciences to be done solely intuitively and without evaluation from outside. Furthermore, the efficacy of collaboration between institutions and persons, involved in establishing and conducting geotouristic activities, should be evaluated on a regular and scientifically profound basis (Pforr and Megerle 2010).

The growing number of such representations, mostly books and booklets—Clarke (1990), Cwojdziński and Kozdrój (2007), Fritsche and Sulzenbacher (2003), Gall (2009), Huber (1989), Lottermoser et al. (2008), Upton (2004), Wagenbreth and Steiner (1982), just to mention a few—indicates that geoscientists all over the world are increasingly aware of the importance of geoscience transfer to the public in an adequate form.

3 Foundations of Geotourism

Geotourism is based on various types of geosites, mostly geo-museums, show caves, show mines, geotopes, geoparks and their networks. A geotope is generally seen as "the geological component of the abiotic matrix present in an ecotope. Example geotopes might be: an exposed outcrop of rocks, an erratic boulder, a grotto or ravine, a cave, an old stone wall marking a property boundary, and so forth" (Wikipedia 2016). The term goes back to Wiedenbein (1994). In a similar way, a geopark is regarded as "a unified area that advances the protection and use of geological heritage in a sustainable way, and promotes the economic well-being of the people who live there" (Wikipedia 2016; after McKeever and Zouros 2005).

Since the 1990s, in numerous countries geotopes were designated and processed from scientific and didactic perspectives, by scientific associations as well as governmental institutions. This regionally led to partly extremely well documented and presented, and politically supported dense networks of geotopes (Lagally and Loth 2016).

Parallel and on the basis of numerous, spatially connected geotopes, national geoparks were established (Jones 2008) and extended to transregional geopark networks (Zouros 2004), e.g., in 2000 to the European Geopark Network (EGN 2016) and to the Asia Pacific Geopark Network (APGN 2016). In 2004 the Global Geoparks Network (GGN 2016) was formed. This increasing interconnection led to an intensive exchange of information in the form of conferences, scientific publications, and newsletters and to focusing and, therefore, strengthening of numerous activities in individual geoparks.

From the beginning, geosites and geoparks aimed at several purposes. The early geosites often represented natural monuments where the concept of protection had priority. Their grouping into geoparks, accompanied by an increased attraction for visitors, based on the concept to bring the geological aspects of nature into the focus of the public and make them available to a wider auditorium. Consequently, special emphasis was laid on geo-didactic and touristic issues. In general, geoparks ideationally and economically rest on three columns: (i) protection and conservation of earth heritage, (ii) transfer of geoscience to the public, based on a variety of educational activities, (iii) geotourism, related to sustainable development.

Beyond their connection to the abiotic nature, geoparks can be also closely linked to human economic and industrial activities, as exemplified by the Ruhr Area National Geopark (Wrede and Mügge-Bartolović 2012). This shows the flexibility of the geopark concept and its wide range of possible installations.

In 2015 the UNESCO General Assembly ratified the label "UNESCO Global Geoparks", which expresses "governmental recognition of the importance of managing outstanding geological sites and landscapes in a holistic manner" (UNESCO 2016b). Currently, the global geopark network consists of 120 geoparks, mostly in Europe and Eastern Asia (Fig. 3).

UNESCO Global Geoparks are defined as "single, unified geographical areas where sites and landscapes of international geological significance are managed with a holistic concept of protection, education and sustainable development." They use "geological heritage, in connection with all other aspects of the area's natural and cultural heritage, to enhance awareness and understanding of key issues facing society, such as using our earth's resources sustainably, mitigating the effects of climate change and reducing natural disasters-related risks" (UNESCO 2016b). Geoparks are considered not so much as a conglomeration of important and worth protecting geosites but as regions, in which nature, culture and economy are linked in a comprehensive way, namely with respect to education und sustainable development. That means that only larger, uninterrupted regions that are settled and have a cultural history are qualified as UNESCO Global Geoparks. Consequently, national parks with their differing structure and intention are in contrast, or even in competition to the Global Geoparks.

UNESCO Global Geoparks comprise ten focus areas: natural resources, geological hazards, climate change, education, science, culture, women, sustainable development, local and indigenous knowledge, geoconservation (UNESCO 2016c). Amongst many other topics and urgent problems, the UNESCO declaration about Global Geoparks underlines climate change and natural disasters as key issues. However, this may be owed to the currently strong presence of these topics in the media.

The definition of the UNESCO Global Geoparks justifiably emphasizes the fundamental importance of our geo-environment for the human civilization. The geological heritage is of intangible value, forms the basis of our culture and economy and comprehensively influences all parts of human life.

Fig. 3 UNESCO Global Geopark Network, including approx. 120 geoparks mostly in Europe and eastern Asia. *Black circle*: established geopark; *gray circle*: application for UNESCO geopark; modified and supplemented after Júlio Reis (2008) and UNESCO (2016a)

Furthermore, geotourism is regarded as driving force behind the economic and cultural development of the region. This approach points to the fact that conservation of nature and economic development do not compete but that the conservation of geological heritage is a precondition of and driving force for development. This, again, is important for obtaining acceptance by the local population. Consequently, establishment and preservation of a geopark require a 'bottom-up' approach. "UNESCO Global Geoparks are established through a bottom-up process involving all relevant local and regional stakeholders and authorities in the area (e.g. land owners, community groups, tourism providers, indigenous people, and local organizations). This process requires firm commitment by the local communities, a strong local multiple partnership with long-term public and political support, and the development of a comprehensive strategy that will meet all of the communities' goals while showcasing and protecting the area's geological heritage" (UNESCO 2016b).

It follows that the Global Geopark Network—based on individual geosites, geo-museums, and geoparks—forms an excellent fundament for building and developing regional geotourism. The establishment of geotourism on this basis is relatively independent of the local situation. It does not need a fully developed infrastructure or larger financial resources. It mainly builds on the commitment of individual scientists and non-experts and on the enthusiasm and support of the local population. Thereby, the building of geotourism does not so much represent a technical and administrative problem but mainly rests on persuasiveness and visibility of advantages and the immaterial value for the local population.

Nevertheless, building a geopark needs a certain number of steps on a geoscientific level:

(i) The entire geological situation has to be prepared scientifically and comprehensively. Such preparation is mostly available in countries with a long-lasting geological survey. In those countries with limited or only large-scale survey, fundamental geological work has to be done. Such work mainly requires scientists from research institutions.

(ii) Geosites that form the basis of a geopark have to be investigated not only geoscientifically but also with respect to their usefulness for a non-geoscientific auditorium.

(iii) A central drop-in-center for visitors is needed. Ideally, it not only represents a 'visitor Center' that provides touristic and general-scientific information but also a 'Science Center', where interactive and 'hands on' actions can be extensively performed and where 'learning by doing' has priority. Although geological objects and presentations are often relatively inexpensive, such a science center generally requires the considerably highest amount of money in the geopark.

(iv) In general, the geoscientific information needs to be prepared for laypersons in a didactically sophisticated way, with respect to verbal as well as graphical representation. Naturally, as many media as possibly should be utilized, particularly digital media.

The specific requirements for and boundary conditions of a UNESCO Global Geopark have been already mentioned. However, they are not mandatory preconditions for a geopark that forms the basis of regional geotourism.

4 Advantages of Geotourism

Worldwide, tourism increases continuously since many years. In 2015, more than one billion tourists traveled internationally, more than half of them in Europe and nearly one quarter in Asia and the Pacific region. Tourism accounts for nearly 10% of the world's gross domestic product (GDP) and 6% of the global trade. Every eleventh job in the world is located in tourism and tourism is one of the most resilient economic sectors (UNWTO 2016).

It is increasingly realized that tourism is a key driver for sustainable, economic growth and for "… the promotion of … full and productive employment and decent work for all." The United Nations have declared 2017 as "International Year of Sustainable Tourism for Development" (UNWTO 2016). Furthermore, the importance of education and training for tourism are regarded and the necessity to create "… stronger links between the private sector, the public sector and education and training institutions to close the gap between the needs of the market and education programmes" (UNWTO 2016).

In the same way as tourism, geotourism plays an increasing role for sustainable regional development (Megerle 2006) and, specifically for the economy of countries without a strong industrial basis. Geotourism is part of the increasing 'educational tourism' that primarily appeals people who wish to experience a country and get to know its culture, history, traditions, architecture, nature, etc. In contrast to educational tourism, geotourism show several crucial advantages.

(i) Geoscience-related touristic activities can be designed environment-friendly.

- Distances between different geosites can be traveled afoot.
- Many activities are 'manual' (e.g. collecting minerals and fossils, or shaping rock samples) and do not need support by machines or energy in general.
- In contrast to e.g. biotopes, rocks or outcrops are 'visitor-resistant'. They tolerate even high numbers of visitors. Touristic activities rarely affect and nearly never destroy them.
- Mostly, the value of a geosite or geotope is not constituted of the uniqueness of the rocks or their structures but of their didactically favorable peculiarity. Easy accessibility, or excellent exposure. If a geosite is destroyed by constructional or other activities is is often relatively easy to find a similar geosite somewhere else.

(ii) Geology-related tourist activities do not need large infrastructure, i.e., are cost-efficient.

- Except museums that had to be established, everything can be taken as it is present: each manifestation of abiotic nature (mountains, cliffs, gorges, morphological features, depositions, etc.) or abandoned mines and quarries, road-cuts, etc.
- Often geosites are created by constructional and industrial activities (road-cuts, quarries, open mines) and, in contrast to biotopes, are not destroyed by them.
- Geosites or geoparks can be established even in close connection to still existing or former areas of industrial activities (Wrede and Mügge-Bartolović 2012).
- In general, only wall charts or information signs are cost factors. But the increasing digitalization and digital interconnection provide the opportunity to make information available in a flexible way and without much costs (Cayla 2014).
- In addition, geosites do not need maintenance or only a minor one. Over decades or even longer they remain in their original conditions.
- If, however, the original condition is changed by geological processes (e.g. by erosion) the new condition may likewise (or even better) serve the geotourism. Geosites can develop and, in this way, point to the importance of time for processes in nature (Fig. 4).

Fig. 4 "Twelve Apostles" at the coast of Port Campbell National Park (Victoria, Australia). These limestone stacks are formed by erosion of the neighboring headland cliff. During the years, the initially twelve stacks were reduced to currently nine. The tenth collapsed in 2005. But erosion may form new stacks in the future. Photo JH Kruhl (2010)

(iii) Geology-related tourist activities can be based on partly already performed regional research and complemented by local scientific research. Different types of geoscientific research form the basis for geotourism.

- Geological maps of different scales provide information about occurrence and stratification of various rocks and about large-scale structures. Already geological mapping on a local scale leads to the detection and designation of most geosites that are of interest for geotourism.
- Measurements in the field and collected samples provide data and material, on which further specialized investigations can build.
- Such investigations from various fields of the geosciences should also help answering the questions of tourists: How old are the rocks? Which history did they experience? In which way the structures were formed? How the landforms and colors? But above all: Which geological processes are behind all this?

(iv) Geoscience-related tourist activities create new jobs in an ambitious sector of tourism.

- In addition to scientists, local laborers can be employed, who take care of the construction and maintenance of roads and trails and of the preservation of small geosites, e.g. by keeping them clear from vegetation. They can be also trained as local guides.
- Numerous activities can be created for visitors of various age: collecting fossils and minerals in show quarries; gold panning; guided tours through show mines; or search and discovery of Earthcaches (GSA 2016) as part of Geocaching.
- Not least geotourism creates further jobs in various economic fields—through accommodation, preparation of print and video material, tour guidance, etc.

Consequently, geotourism offers excellent opportunities specifically for developing countries. It needs only minor investments, can be built mostly based on the economic resources available within the country, supports education of local laborers, relatively quickly leads to additional jobs, and represents a stable and environmental-friendly type of tourism.

5 Geotourism in a Country with Geo-Hazards—Nepal

Nepal is a country strongly exposed to natural hazards. However, the other side of the coin is represented by the highly interesting and partly unique geological situation in a large mountain chain still under construction, which leads to nature monuments of extra-ordinary beauty and high geo-didactic value. The geological heritage of the country can serve as an additional pillar of tourism with advantages as described above. Geotourism would be a further, important component of an ecologically oriented tourism that is already established in Nepal (Bhatt 2006).

In addition, geotourism can be established in all parts of the country, mostly outside the Kathmandu Valley. Therefore, it can work against the extreme centralization and contribute to rural development. A more evenly distributed economic growth would support the general development of the country and would help stabilizing democracy (Hagen 2012).

After the 2015-earthquake, the numbers of visitors to Nepal dramatically dropped and only slowly recovered (Government of Nepal 2015). Although this seems to indicate a negative effect of natural hazards or geo-hazards on tourism, in the medium to long term geo-hazards potentially can have positive effects on tourism and use of this should be made. Definitely, tourists have a certain interest in a 'moderate' type of 'geo-catastrophes', for example hang-slides or rock avalanches, if they can be observed riskless from the distance (Kathmandu Post 2016-02-08). What 'big cat watching' is in wildlife tourism, 'avalanche watching' could be in geotourism in Nepal.

Some principles and boundary conditions should be considered for building up geotourism in Nepal.

- The geological situation of the country is characterized by the subduction of the Indian sub-continent, as part of the Indian-Australian lithospheric plate, under the Eurasian lithospheric plate. The relative motion between India and Eurasia of ca. 4 cm/year leads to a current horizontal shortening of roughly 2 cm/year in central and eastern Nepal (Bettinelli et al. 2006; Jade et al. 2014).
- This collision leads to uplift of the Himalayas with zones of different geology and elevation, ranging from less than two hundred meters in the Ganga Plain to more than 8000 m at the Tibetan border. This zoning forms the basis of zones of different morphology, climate, vegetation, agriculture, culture, etc.
- Nepal extends parallel to these zones, specifically to the zones of different geology (Fig. 5).
- Although many locations of extraordinarily beautiful nature with impressive geology exist throughout the country, geotourism should be related mainly to the very special general situation, e.g. to processes directly related to the rapid uplift of the Himalayas (or indirectly linked to them through other processes, such as climate change). These processes are mainly, but not always, connected to various types of geo-disasters, such as earthquakes (Sakai et al. 2015), rock falls and avalanches (Fig. 6), landslides (Dahal et al. 2009; Gerrard 1994; Hasegawa et al. 2009; Timilsina et al. 2014; Thapa 2018), or floods (Mool 1995; Reynolds 1995; Benn et al. 2012), with which the country has to battle.
- However, the point is only partly that risks and causes of these geo-disasters are represented and that the public awareness of georisks is increased. Instead, it needs to be shown, in which way the country deals with these threats (Gautam et al. 2016; Tuladhar et al. 2015) and how, nevertheless, living in security and with economic stability is possible (Joshi and Joshi 2018).
- For example, the feasibility of geo-disaster resistant traffic routes (e.g. ropeways, Gyawali et al. 2004) or the great potential of hydropower (Pokharel 2001) should be represented.

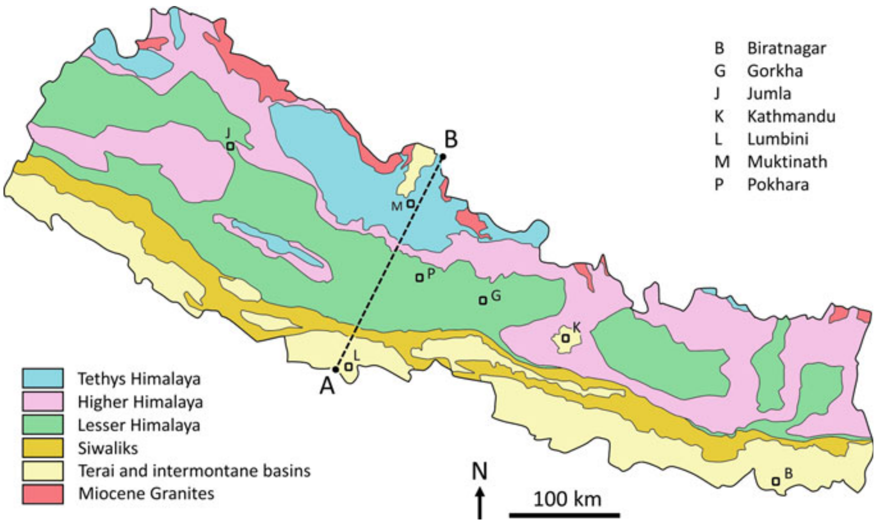


Fig. 5 Large-scale geological structure of Nepal. Broken line = location of the geological cross-section that serves as a basis for the Great Wall of Kathmandu (Fig. 7). Modified after Dhital (2015)

Fig. 6 Large rock fall north of Tatopani, Bhudi Gandaki Valley, Nepal. Photo JH Kruhl (2017)

- Nevertheless, lessons learned from other regions with respect to conflicts between tourism and natural risks should be considered (Karkut 2010).
- Ca. S-N oriented profiles provide the best insight into the rapid changes across the mountain chain. Geosites and tours restricted to the high mountain regions

cannot give this type of information. Therefore, geosites should be preferentially located along such profiles and, with respect to touristic tours, should be connected in terms of content.

- Such tours should be established not only in the central parts of the country but also in the western, eastern and southern ones. This would ensure a more even distribution of geotourism over the country.
- At the moment, tourism is mainly concentrated in the Kathmandu Valley and the high mountain regions. At first, geotourism would be established in these two regions, already for reasons of convenience. However, in the medium term all parts of the country should be included, namely Lesser Himalaya, Siwaliks and Terai. In these regions, many interesting geosites could be established. For example, in Siwaliks and Terai outcrops of the large thrusts can be observed (Main Boundary Thrust MBT, Main Frontal Thrust MFT—Sapkota et al. 2013; Thakur 2013), the deeper sections of which, namely the Main Himalayan Thrust (MHT), are affected by displacements that led to the larger earthquakes.
- From the beginning, the establishment of geoparks should follow the standards of Global Geoparks given by the UNESCO (UNESCO 2016b, c). Specifically, the holistic concept of protection, education and sustainable development should be taken into account. In Nepal, where geology and geo-hazards have impact not only on landscape and its changes but also on various parts of society, geoparks can comprehensively represent the implications of geo-disasters and how the society deals with them. This is also an important aspect of the concept of Global Geoparks (UNESCO 2016d). It appears reasonable to include additional aspects in the framework of geology and geo-disasters: (i) the effects of disasters on economy and infrastructure in general and, specifically, on the economic situation of the people; (ii) the demands on technical and medical aid (Brodmann Maeder and Pun 2018), on administration, politics, legal system (Meyer and Stelzer 2018); (iii) aspects of reconstruction, including the reconstruction of destroyed or damaged World Heritage Sites (Dorka 2018; Guragain et al. 2018; Manhart 2018); (iv) the psychological and emotional effects of disasters (Fothergill and Squier 2018); and (v) how the society prepares for future threats (Tuladhar et al. 2015; Schneider and Witting 2018).

Only a comprehensive and integral representation of all these aspects of life under constant threat by geo-hazards can sufficiently illustrate what living in a ‘hazardous country’ really means. Geoparks should represent the strong impact of abiotic nature on human life. Such representation forms the essential significance and value of geoparks.

In Nepal, geotourism can base on firm foundations.

- Except the monsoon period, geotourism would be possible all over the year.
- A well-constructed network of trekking trails with numerous accommodation facilities exists, however, mostly in the Higher Himalayas.
- Since many years, national parks as well as local museums are established.

- The country holds several geo-institutions, however, nearly all of them in the Kathmandu Valley.
- Local geoscientists are experienced in various fields of geosciences.
- Numerous tourist guides are available, who are well trained, however, not adequately in the geosciences.
- The population is aware of the importance of geoscience and tourism for the country.

Nevertheless, these foundations could be highly enlarged and strengthened, given all the possibilities that are present in the country.

6 What to Do in Nepal

The successful establishment of geotourism in Nepal will mainly depend on the cooperation of different geo-institutions, e.g. Department of Mines and Geology, Department of Survey, Geo-Departments of Tribhuvan University and Kathmandu University, National Academy of Science and Technology (NAST), Research Center of Applied Science and Technology (RECAST), The Open University, and tourism-related institutions in the country, such as Ministry of Tourism and Nepal Tourism Board. Furthermore, the support of the hotel and catering industry and of local institutions, such as Rotary or Lions Club, is needed.

Geotourism in Nepal has to be based on what is currently available, with respect to natural and human resources, and what could be made available in the near future without high costs. It has to consider Nepal's special situation in relation to infrastructure and available resources. In general, several subsequent steps are required.

During an early stage, a national platform should be established for the discussion of all essential questions with regard to geotourism in Nepal. Based on this platform, a group/board has to be formed, which coordinates and supervises all further steps, specifically:

- Collection and evaluation of information with respect to possible geosites in various parts of the country; generation of additional data if necessary
- Selection of geosites with respect to geological value, geo-didactic usefulness, range of topics, accessibility, and scientific and economic effort of establishment
- Preparation of the information for non-experts; generation of websites and an electronic data bank; generation of tourism-related documents (printed and/or electronic)
- Establishment of further tourism-related information and activities, such as Earthcaches (GSA 2016) or webcams at sites of landslides or possible rock avalanches
- Establishment of a time table of installation
- Calculation of costs of scientific and technical work; fund raising

- Getting media and local population involved; recruitment of personnel for voluntary as well as paid work
- Design of concepts for geoscientific and geodidactic education of tourist guides (geo-guides); concepts for continuous supervision of geo-guides
- Installation of university courses in geotourism and study and preservation of geosites, as already established elsewhere (Manyuk 2016; MSU 2016; Slomka and Mayer 2010).

In the medium term, larger sites or regions of specific geological interest should be transformed to national geoparks and, finally, installed as part of the UNESCO-supported Global Geopark Network (UNESCO 2016b). This network performs a strict acceptance procedure and, through various regulations, guarantees high quality in relation to international geoscientific as well as geo-didactic standards. Vice versa, being member of the network requires continuous quality evaluation and increases the international visibility. Consequently, such membership is advantageous with respect to national acceptance of the geoparks and commercialization of geotourism in Nepal on the international tourism market.

In principle, all activities related to building regional geotourism can be ideally and financially supported by the United Nations World Trade Organisation (UNWTO 2016).

7 The Great Wall of Kathmandu

Geotourism, although related to various geo-sites and geo-regions all over the country, should have and need to have a focus—a central object with extraordinary scientific and visual properties, where tourists as well as locals see at a glance the main geo-situation of Nepal. This site should be located in Kathmandu where most tourists start their time in the country or from where they leave the county. Seeing the geo-situation of Nepal at a glance means grasping the main structure of the Himalayan mountain chain. Due to the approximate WNW-ESE elongation of the mountain chain, such structure is presented best as a cross-section in NNE-SSW through the central Himalayas displaying morphology, geology and structures: *The Great Wall of Kathmandu* (Fig. 7).

The location should be easily accessible and visible and should fulfill several scientific and technical conditions:

- The section should be situated geologically where the structures of the mountain chain are most prominent and clear.
- All rocks and large-scale structures should be as variable as possible.
- The region should be well studied, so that the relevant information is available without much further investigations.
- A SSW-NNE oriented cross-section east of the northern Kali Gandaki Valley, with a total extension of ca. 220 km, appears suitable.

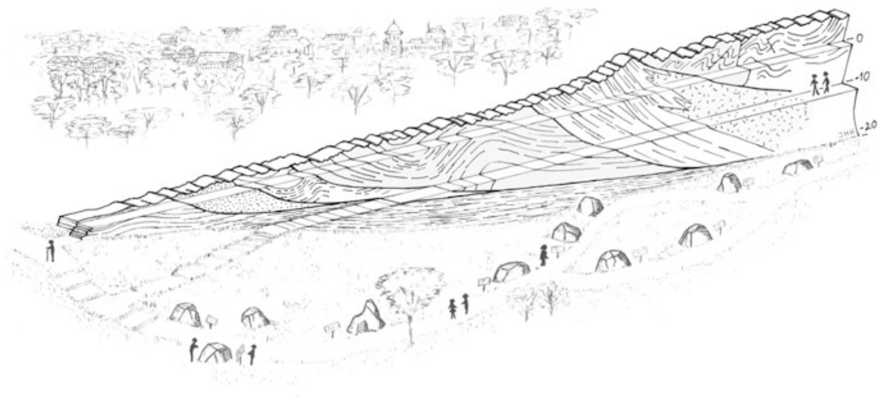


Fig. 7 The Great Wall of Kathmandu. Model of a 110 m long and up to 15 m high wall, which represents a 220 km long and up to 20 km high/deep, roughly SSW-NNE oriented geological cross section through Nepal (location shown in Fig. 5). The scale is 1:2000. Larger structures (thrusts, folds, layering) are indicated. The cross section extends from the Indian border close to Lumbini, over Butwal, Baglung and the Annapurna massif, to the Tibetan border north of Muktinath. In reality, the wall will be built from rock plates equivalent to the various rock layers in nature. The wall is surrounded by an exhibition area with one to several meter sized boulders that represent the main rocks of the country. Steps on one side at 0 km and -10 km level allow accessibility. Geology and structures of the cross-section modified and simplified after Paudel and Arita (2000, 2006a, b), Searle (2010) and Elliot et al. (2016)

- This cross section extends from the Indian border close to Lumbini, over Butwal, Baglung and the Annapurna massif, to the Tibetan border north of Muktinath (Fig. 5).
- For better visualization of large-scale thrust and nappe structures, it reaches to depths of ca. 20 km as a minimum.
- In order to guarantee good visibility, the wall is built on a scale of 1:2000, i.e. extends over a distance of ca. 110 m.
- The orientation of the wall and of the geological cross-section should coincide.
- Horizontal and vertical scaling is equal. Consequently, at its maximum rise the wall is roughly 14 m high.
- Steps on one side at –10 km and 0 km level, i.e. at up to 5 and 10 m height, allow accessibility and, therefore, a better view on the smaller-scale structures.
- This, together with requirements of stability, leads to a minimum width of 6 m at the base and 2 m at the top.
- Independently of its supporting construction, the outer faces of the wall show the main geological units of the cross-section built from rock plates, equivalent to the various rock layers in nature. The plates are decimeter-sized and placed in such a way that the rock structures are in agreement with the orientation of the structures in nature.
- The wall is surrounded by an exhibition area with one to several meter sized boulders that represent the main rocks of the country.

- A visitor center provides fundamental as well as more detailed information about the geology of Nepal and geo-hazards and informs about all geoscience-related topics.
- All construction work is performed by local craftsmen. The rock plates are transported by local laborers from exactly the regions transect by the geological cross-section.
- The Great Wall should be placed in the central part of Kathmandu, close to main touristic destinations. For example, space would be available in Ratna Park and its surroundings. But other places are also conceivable.

In general, beyond providing geoscientific information in a comprehensible and clear way, it is the main purpose of the Great Wall to represent a geo-monument that is not only impressive but also of artistic value. It would serve as a geo-monument of international visibility.

8 Conclusions

Advantage can be taken of the exposure of Nepal to natural hazards. Such hazards are the expression of a highly interesting and partly unique geological situation in a large mountain chain still under construction. During the last millions of years, this situation led to nature monuments of extra-ordinary beauty and high geo-didactic value. The geological heritage of the country can serve as a main pillar of geotourism.

Geotourism, as part of ecotourism, can be of great economic significance, specifically in a country like Nepal with only weak industrial fundament. Compared to other types of tourism, geotourism offers several advantages. (i) Geoscience-related touristic activities can be designed environmental-friendly. (ii) They do not need large infrastructure, i.e. are cost-efficient. (iii) Geoscience-related touristic activities can be based on partly already conducted regional research and complemented by local scientific research. (iv) Such activities create new jobs.

As a first step, the fundament of geotourism has to be built and made available to the public: geosites, geomuseums, show quarries, and geoparks. In Nepal, where geology and geo-hazards have impact not only on landscape and its changes but also on various parts of society, geoparks can comprehensively represent the implications of geo-disasters and how the society deals with them. All geotouristic sites and activities require repeated evaluations—by experts as well as by laypersons.

In the medium term, larger sites or regions of specific geological interest should be transformed to national geoparks and, finally, installed as part of the UNESCO-supported Global Geopark Network. These geoparks should follow the standards of UNESCO Global Geoparks with a holistic concept of protection, education and sustainable development.

Last but not least geotourism in Nepal should have a focus—a key object with extraordinary scientific and visual properties, where tourists as well as locals see at a glance the main geo-situation of Nepal. Such an object is presented best as a cross-section through the central Himalayas displaying morphology, geology and structures: *The Great Wall of Kathmandu*.

Acknowledgements The present paper originated from a lecture given at the international conference (Humboldt Kolleg) "Living under Threat of Earthquake", Kathmandu, February 2016, which was financially supported by the Alexander von Humboldt Foundation. In addition, it is partly based on teaching and research activities funded by the German Academic Exchange Service (DAAD). During earlier years, the author strongly benefitted from Joseph Birkenhauer's research on geodidactics and his great experience in and enthusiasm for transferring geoscience to the public.

References

APGN (2016) Asia Pacific Geopark Network. http://asiapacificgeoparks.org/. Accessed 8 Dec 2016

Benn DI, Bolch T, Hands K, Gulley J, Luckman A, Nicholson LI, Quincey D, Thompson S, Toumi R, Wiseman S (2012) Response of debris-covered glaciers in the Mount Everest region to recent warming, and implications for outburst flood hazards. Earth-Sci Rev 114(1–2):156–174

Bettinelli P, Avouac J-P, Flouzat M, Jouanne F, Bollinger L, Willis P, Chitrakar GR (2006) Plate motion of India and interseismic strain in the Nepal Himalaya from GPS and DORIS measurements. J Geod 80:567–589

Bhatt DP (2006) Ecotourism in Nepal. A Bhatt Publ, Kathmandu

Birkenhauer J (1995) Außerschulische Lernorte. In: Birkenhauer J (ed) Außerschulische Lernorte. Geographiedidaktische Forschungen 26, Hochschulverband für Geographie und ihre Didaktik, Nürnberg

Birkenhauer J (1996) Lehrpfade. Münchner Studien zur Didaktik der Geographie 7, Ludwig-Maximilians-Universität München

Birkenhauer J (2003) Geodidaktik—einige Überlegungen und Grundsätze. In: Kruhl JH, Birkenhauer J, Lagally U, Lehrberger G (eds) Geowissenschaften und Öffentlichkeit. Schriftenreihe der Deutschen Geologischen Gesellschaft 29, pp 95–101

Brodmann Maeder M, Pun M (2018) Medical aspects of the Gorkha earthquake 2015: disaster preparedness and response. In: Kruhl JH, Adhikari R, Dorka UE (eds) Living under the Threat of Earthquakes—Short and Long-term Management of Earthquake Risk and Damage Prevention in Nepal, Springer, Berlin, p 155–173

Cayla N (2014) An overview of new technologies applied to the management of geoheritage. Geoheritage 6:91–102. doi:10.1007/s12371-014-0113-0

Clarke MH (1990) Oman's Geological Heritage. Stacey Intern Publ, London, Petrol Develop Oman

Cwojdziński S, Kozdrój W (2007) Geotourist Road Maps of Poland 1:25000—The Sudetes Geotourist Guide. Polish Geological Institute, Warsaw

Dahal RK, Hasegawa S, Yamanaka M, Dhakal S, Bhandary NP, Yatabe R (2009) Comparative analysis of contributing parameters for rainfall-triggered landslides in the Lesser Himalaya of Nepal. Eviron Geol 58:567–586. doi:10.1007/s00254-008-1531-6

Dhital MR (2015) Geology of the Nepal Himalaya. Springer, Cham Heidelberg New York. doi:10.1007/978-3-319-02496-7

Dorka UE (2018) Can we prevent structural failure under earthquakes? In: Kruhl JH, Adhikari R, Dorka UE (eds) Living under the Threat of Earthquakes—Short and Long-term Management of Earthquake Risk and Damage Prevention in Nepal, Springer, Berlin p 117–127

Dos Reis PR, Henriques MH (2009) Approaching an integrated qualification and evaluation system for geological heritage. Geoheritage 1:1–10. doi:10.1007/s12371-009-0002-0

EGN (2016) European Geopark Network. http://www.europeangeoparks.org/. Accessed 8 Dec 2016

Elliott JR, Jolivet R, González PJ, Avouac JP, Hollingsworth J, Searle MP, Stevens VL (2016) Himalayan megathrust geometry and relation to topography revealed by the Gorkha earthquake. Nat Geosci 9:174–180

Fothergill A, Squier E (2018) Women and children in the 2015 earthquake in Nepal. In: Kruhl JH, Adhikari R, Dorka UE (eds) Living under the Threat of Earthquakes—Short and Long-term Management of Earthquake Risk and Damage Prevention in Nepal, Springer, Berlin, p 253–271

Fritsche E, Sulzenbacher G (eds) (2003) Georeise in die Alpen: zur Geschichte der Erde. Folio Verlag Wien, Bozen, der Gesteine und Gebirge. Didaktische Materialien des Naturmuseums Südtirol

Gall Q (2009) A Walking Guide. Ottawa's Building and Monument Stones. Geol Soc Canada Miscell Publ 7, Ottawa

Gautam D, Prajapati J, Paterno KV, Bhetwal KK, Neupane P (2016) Disaster resilient vernacular housing technology in Nepal. Geoenvironmental Disasters 3(1):1–14. doi:10.1186/s40677-016-0036-y

Gehl J (2010) Cities for People. Island Press, Washington, Covelo, London

GSA (2016) Geological Society of America: Earthcache. http://www.geosociety.org/earthcache. Accessed 28 Dec 2016

Gerrard J (1994) The landslide hazard in the Himalayas: geological control and human action. Geomorphology 10:221–230

GGN (2016) Global Geopark Network. http://globalgeoparksnetwork.org/. Accessed 8 Dec 2016

Government of Nepal (2015) Nepal Tourism Statistics 2015. http://www.tourism.gov.np/images/download/Nepal_Tourism_Statistics_2015_forwebsite_edited1.pdf. Accessed 2 Jan 2017

Guragain R, Shrestha SN, Maharjan DK, Pradhan S (2018) Lessons from building damage patterns during April 25, 2015 Gorkha Earthquake in Nepal. In: Kruhl JH, Adhikari R, Dorka UE (eds) Living under the Threat of Earthquakes—Short and Long-term Management of Earthquake Risk and Damage Prevention in Nepal, Springer, Berlin, p 79–93

Gyawali D, Dixit A, Upadhya M (eds) (2004) Ropeways in Nepal—Context Constraints and Co-evolution. Nepal Water Conservation Foundation, Lalitpur

Hagen T (2012) Decentralization and Development. The role of Democratic Principles. HimalAsia Foundation and RP Bhandar Publ Kathmandu

Hasegawa S, Dahal RK, Yamanaka M, Bhandary NP, Yatabe R, Inagaki H (2009) Causes of large-scale landslides in the Lesser Himalaya of central Nepal. Environ Geol 57:1423–1434. doi:10.1007/s00254-008-1420-z

Hose TA (1995) Selling the story of Britain's stone. Env Interpret 10(2):16–17

Hose TA (2008) Towards a history of geotourism: definitions, antecedents and the future. Geol Soc Lond Spec Publ 300:37–60

Hose TA (2012) 3G's for modern geotourism. Geoheritage 4:7–24

Huber NK (1989) The Geologic Story of Yosemite National Park. U.S. Geol Surv Bull 1595

Hughes K, Ballantyne R (2010) Interpretation rocks! Designing signs for geotourism sites. In: Newsome D and Dowling RK (eds) Geotourism—The Tourism of Geology and Landscape, Goodfellow Publ Oxford, pp 184–199

Jade S, Mukul M, Gaur VK, Kumar K, Shrungeshwar TS, Satyal GS, Dumka RK, Jagannathan S, Ananda MB, Kumar PD, Banerjee S (2014) Contemporary deformation in the Kashmir-Himachal, Garhwal and Kumaon Himalaya: significant insights from 1995–2008 GPS time series. J Geod 88:539–557

Jones C (2008) History of geoparks. Geol Soc Spec Publ 300:273–277

Joshi GR, Joshi NB (2018) Economic loss from earthquake in Nepal and strategies for recovery and resilience building. In: Kruhl JH, Adhikari R, Dorka UE (eds) Living under the Threat of Earthquakes—Short and Long-term Management of Earthquake Risk and Damage Prevention in Nepal, Springer, Berlin, p 195–209

Karkut J (2010) Reconsidering the boundaries and applications of geotourism—lessons learnt from tourism at Mount Vesuvius. In: Newsome D and Dowling RK (eds) Geotourism—The Tourism of Geology and Landscape, Goodfellow Publ Oxford, pp 88–99

Kruhl JH (2007) General framework of geotope and geopark related didactics (in German). In: Vogt J, Megerle A (eds) Geopark- und Geotourismusforschung. Regionalwissenschaftliche Forschungen 31, Regionalwissenschaftlicher Fachverlag (RWFV) Frickenhausen, pp 41–49

Lagally U, Loth G (2016) Experiencing Bavarias geological heritage—the Project “Hundred Masterpieces”. Geoheritage X: 1–13. doi:10.1007/s12371-016-0209-9

Lansigu C, Bosse-Lansigu V, Le Hebel F (2014) Tools and methods used to represent geologicaly processes and geosites: graphic and animated media as a means to popularize the scientific content and value of geoheritage. Geoheritage 6:159–168. doi:10.1007/s12371-014-0101-4

Lottermoser BG, Whitehead PW, Nelson PN, Beaman R (2008) Rocks, landscapes & resources of the wet tropic. Geol Soc Australia, Queensland Division Brisbane

Mandelbrot BB (1982) The Fractal Geometry of Nature. Freeman, San Francisco

Manhart C (2018) Nepal post earthquake cultural heritage rehabilitation. In: Kruhl JH, Adhikari R, Dorka UE (eds) Living under the Threat of Earthquakes—Short and Long-term Management of Earthquake Risk and Damage Prevention in Nepal, Springer, Berlin p 95–99

Manyuk V (2016) Study and preservation of geosites: a training course for geology students in the Ukraine. Geoheritage 8(2):181–187

McKeever PJ, Zouros N (2005) Geoparks: celebrating earth heritage, sustaining local communities. Episodes 28(4):274–278

Megerle H (ed) (2006) Geotourism: innovative approaches to a touristic valorization and sustainable regional development (in German). Geographie in Wissenschaft 1, Wissenschaftlicher Verlag Rottenburg a.N

Meyer LH, Stelzer H (2018) Assessing policies of responding to the risk of earthquakes from a justice perspective. In: Kruhl JH, Adhikari R, Dorka UE (eds) Living under the Threat of Earthquakes—Short and Long-term Management of Earthquake Risk and Damage Prevention in Nepal, Springer, Berlin, p 293–302

Mool PK (1995) Glacier lake outburst floods in Nepal. J Nepal Geol Soc 11:273–280

MSU (2016) Missouri State University BS Four-Year Degree Plan: Geotourism Track. http://geosciences.missouristate.edu/Geography/Geotourism-Four-Year.htm. Accessed Jan 3, 2017

Neber H (ed) (1975) Entdeckendes Lernen. Beltz Weinheim, Basel

Paudel LP, Arita K (2000) Tectonic and polymetamorphic history of the Lesser Himalaya in central Nepal. J Asian Earth Sci 18:561–584

Paudel LP, Arita K (2006a) The b-spacing values of white micas and their metamorphic implications in the Lesser Himalaya, central Nepal. J Asian Earth Sci 27:10–24

Paudel LP, Arita K (2006b) Thermal evolution of the Lesser Himalaya, central Nepal: Insights from K-white micas compositional variation. Gondwana Res 9:409–425

Pforr C, Megerle A (2010) Management of geotourism stakeholders—experiences from the Network History of the Earth. In: Newsome D and Dowling RK (eds) Geotourism—The Tourism of Geology and Landscape, Goodfellow Publ Oxford, pp 100–113

Pokharel S (2001) Hydropower for energy in Nepal. Mt Res Dev 21(1):4–9

Reis J (2008) World locator map for geoparks. https://commons.wikimedia.org/wiki/File:International_Network_of_Geoparks_map.jpg. Accessed 6 Jan 2017

Reynolds JM (1995) Glacier-lake outburst floods in the Himalayas; an example of hazard mitigation from Nepal. Geoscience and Development 2:6–8

Sakai T, Gajurel AP, Tabata H (2015) Seismites in the Pleistocene succession and recurrence period of large earthquakes in the Kathmandu Valley. Nepal. Geoenvironmental Disasters 2:25. doi:10.1186/s40677-015-0033-6

Sapkota SN, Bollinger L, Klinger Y, Tapponier P, Gaudemer Y, Tiwari D (2013) Primary surface ruptures of the great Himalayan earthquakes in 1934 and 1255. Nat Geosci 6:71–76
Searle MP (2010) Low-angle normal faults in the compressional Himalayan orogen: Evidence from the Annapurna-Dhaulagiri Himalaya. Nepal. Geosphere 6:296–315
Slomka T, Mayer W (2010) Geotourism and geotourist education in Poland. In: Newsome D and Dowling RK (eds) Geotourism—The Tourism of Geology and Landscape, Goodfellow Publ Oxford, pp 142–157
Schneider V, Witting A (2018) Earthquake preparedness policy in Nepal. In: Kruhl JH, Adhikari R, Dorka UE (eds) Living under the Threat of Earthquakes—Short and Long-term Management of Earthquake Risk and Damage Prevention in Nepal, Springer, Berlin, p 303–326
Thakur VC (2013) Active tectonics of Himalayan Frontal Fault system. Int J Earth Sci (Geol Rundsch) 102:1791–1810. doi:10.1007/s00531-013-0891-7
Thapa PB (2018) Analysis of landslides triggered by the 2015 Gorkha Earthquake, Nepal. In: Kruhl JH, Adhikari R, Dorka UE (eds) Living under the Threat of Earthquakes—Short and Long-term Management of Earthquake Risk and Damage Prevention in Nepal, Springer, Berlin, p 45–63
Timilsina M, Bhandary NP, Dahal RK, Yatabe R (2014) Distribution probability of large-scale landslides in central Nepal. Geomorphology 226:236–248. doi:10.1016/j.geomorph.2014.05.031
Tuladhar G, Yatabe R, Dahal RK, Bhandary NP (2015) Disaster risk reduction knowledge of local people in Nepal. Geoenvironmental Disasters 2:5. doi:10.1186/s40677-014-0011-4
UNESCO (2016a) List of UNESCO Global Geoparks. © UNESCO. global-geoparks/list-of-unesco-global-geoparks/. Accessed 6 Jan 2017
UNESCO (2016b) UNESCO Global Geoparks. © UNESCO. http://www.unesco.org/new/en/natural-sciences/environment/earth-sciences/unesco-global-geoparks/, accessed 6 Jan 2017
UNESCO (2016c) Top 10 Focus Areas of UNESCO Global Geoparks. © UNESCO. http://www.unesco.org/new/en/natural-sciences/environment/earth-sciences/unesco-global-geoparks/top-10-focus-areas/. Accessed 6 Jan 2017
UNESCO (2016d) UNESCO Global Geopark and Geo-Hazards. © UNESCO. http://www.unesco.org/new/en/natural-sciences/environment/earth-sciences/unesco. Accessed 6 Jan 2017
UNWTO (2016) World Tourism Organisation, UNWTO Annual Report 2015. UNWTO, Madrid
Upton B (2004) Volcanoes and the Making of Scotland. Dunedin Academic Press, Edinburgh
Wagenbreth O, Steiner W (1982) Geologische Streifzüge. Deutscher Verlag für Grundstoffindustrie Leipzig, Landschaft und Erdgeschichte zwischen Kap Arkona und Fichtelberg
Wiedenbein FW (1994) Origin and use of the term 'geotope' in German-speaking countries. In: O'Halloran D, Green C, Harley M, Knill J (eds) Geological and Landscape Conservation. Geological Society London, pp 117–120
Wikipedia.org (2016) https://en.wikipedia.org/wiki/Geotope and https://en.wikipedia.org/wiki/Geopark. Accessed 8 Dec 2016
Wrede V, Mügge-Bartolović V (2012) GeoRoute Ruhr—a network of geotrails in the Ruhr Area National GeoPark. Germany. Geoheritage 4(1–2):109–114. doi:10.1007/s12371-012-0057-1
Zouros N (2004) The European Geoparks Network. Geological heritage protection and local development. Episodes 27(3):165–171

Part IV
Living with Earthquake Risk

Women and Children in the 2015 Earthquake in Nepal

Alice Fothergill and Emma Squier

Abstract Disasters do not affect individuals and communities indiscriminately; indeed, some groups of people are more vulnerable before, during, and after the disaster. Globally, research has found that children, youth, and women are often more vulnerable to disasters due to fewer economic resources, lack of political voice, risk of sexual assault and exploitation, household labor responsibilities, and gender and age discrimination. In this paper we examine the experiences of women and children in Nepal, which was struck by a devastating earthquake and aftershock in the spring of 2015. We discuss how the disaster impacted their lives, including their shelter and housing, education, labor, personal safety, and health. In Nepal, as is the case elsewhere, some groups of women and children are even more vulnerable than others. Women and children with disabilities, those belonging to an ethnic or racial minority group, female-headed households, elderly women, and children separated from families, or without families, face particular risks. We consider how children and women were faring in Nepal a year after the earthquake and propose some recommendations to reduce losses in the future.

Keywords Children · Women · Vulnerability · Disaster · Recovery
Nepal · Earthquake

1 Introduction

Vulnerability is not evenly distributed in disasters. Those most vulnerable are those who are the most susceptible to harm and losses and face obstacles in recovery. As Wisner and colleagues (1994) stated, those most vulnerable to disaster are those who are not able to anticipate, cope with, resist, and recover from a disaster. More

A. Fothergill (✉) · E. Squier
Department of Sociology, University of Vermont, Burlington, USA
e-mail: Alice.Fothergill@uvm.edu

J.H. Kruhl et al. (eds.), *Living Under the Threat of Earthquakes*,
Springer Natural Hazards, https://doi.org/10.1007/978-3-319-68044-6_16

recently Wisner (2016) has argued this definition should also include issues of power relations, intentionality, and institutional failures. Two groups particularly vulnerable around the globe to disasters are women and children. Past research has found that both groups of people are particularly vulnerable due to a variety of factors, including resources, power, and threats of violence (Phillips et al. 2010; Thomas et al. 2013). Disasters lower women's life expectancy more than men's, according to data from 141 countries affected by disaster between 1981 and 2002. Women, boys, and girls are 14 times more likely than men to die during a disaster (United Nations 2010).

Around the globe, women have been found to be vulnerable in times of disaster. The root causes of this vulnerability are a lack of resources—such as income, education, health, and social networks—that allow people to cope with hazardous events. Oftentimes, access to these assets may be gendered, with women having less control over these assets than men (Bradshaw and Fordham 2013). Most disasters place an immense amount of stress on women who are responsible for unpaid work such as providing care, water, and food for households (United Nations 2010). In addition to the immediate effects of a natural disaster, as the primary caretakers for their households, women experience an increase in their workload as well as an additional emotional burden. The familial responsibilities that women have before a disaster are only magnified by the onset of that disaster, as they have significantly less support and resources. Women play a paramount role within the family, meeting the immediate survival needs of family members as well as managing the home (Enarson et al. 2006; Humanitarian Coalition 2016). In addition, following a disaster, it is more likely that women will be victims of domestic and sexual violence; many even avoid using shelters for fear of being sexually assaulted (United Nations 2010).

The secondary impacts on women that arise from disasters represent a 'double disaster' for them. Aside from the loss of home, lack of resources, and insecurity that is experienced after a disaster, a major impact felt by many women is a drastic increase of hours in the working day, which affects their mental and physical well-being. Despite the great importance of women's labor within their family and the community, this work is often devalued because it does not generate any income. Women's responsibility for unpaid care work can make them dependent on men for access to economic resources and may add to their economic vulnerability. In addition, vulnerability is closely linked to poverty, which can make recovery and rebuilding after a disaster even more of a challenge, especially in a country like Nepal (Fothergill and Peek 2004). By understanding the experiences and challenges faced by women in disasters, we can learn to address these issues in the reconstruction process, and re-build in a way that enhances the rights of women.

Children and youth have also been found to be a vulnerable group in disasters (Peek 2013). The number of children living in poverty around the world, including in developed countries such as the United States, is staggering. Many children are enduring lives of deprivation, living without adequate nutrition, poor housing, unsafe neighborhoods, or continued education. Thus many children are indeed living in crisis before the disaster strikes, and the disaster adds to their existing vulnerability. This creates a "cumulative vulnerability" making children at great risk to a "declining trajectory" and negative outcomes after the disaster in some or all spheres of their lives, including education, emotional and physical health, friendships, and family. Disasters can be frightening and disorienting for all children, and displacement from one place to another presents numerous challenges for children, such as loss of schooling and separation from family members (Fothergill and Peek 2015).

Some women and children are more vulnerable to disasters and their aftermaths than others. Women and children who belong to an ethnic or racial minority group, those with disabilities, those in single female-headed households, elderly women, and children who are separated from families in the disaster—or who do not have families—face particular and significant risks. In the following sections we will examine the experiences of women and children in Nepal after the earthquake struck on April 25, 2015, and the aftershock in May. For the section on women, we present the findings from a study conducted by this chapter's second author, Squier (2016), and for the discussion on children, we draw from relevant literature and data collected by non-governmental organizations, such as UNICEF and Save the Children, that specialize in children and disaster. The article's first author Fothergill had to opportunity to visit Nepal in February 2016. During this trip, she observed the earthquake damage, and learned about children's experiences from discussions with Nepalese scholars, students, volunteers, trekking guides, and government officials, as well as from international rescue workers and researchers.

2 Women's Experiences

The qualitative study by Squier on women in the earthquake was conducted during the month of April 2016 in the Sindhupalchok district of Nepal. The sample included forty-five women, ages ranging from nineteen to seventy-three years who lived in several villages in the Helambu region. Squier, with the help of two translators, conducted in-depth interviews with each woman in the villages, and some women were interviewed multiple times. The women often welcomed Squier into their homes to talk with them, offering her food and tea. Other times, she would interview the women while they were working in the fields. Every interview was recorded with an audio device, interview notes were taken in a field notebook, and then later transcribed onto the computer.

Based on the data collected in the interviews, a series of issues arose as the most critical to consider in the women's experiences in this disaster. These are food and water, shelter and reconstruction, increase in workload, female-headed households, income, education, and health. We will examine each of these seven components of women's lives in the sections that follow.

2.1 Food and Water

Two of the most basic and practical needs, food and water, tend to be in short supply after many disasters causing great concern for people who are in need of them. The earthquake in Nepal was no different, and many people were in need of immediate assistance. For many of the women, aside from the need for safe housing, attaining food was the biggest immediate challenge. One year after the earthquake, every woman interviewed was still eating the food that was donated by the government or other organizations. One of the biggest problems for these women was the fact that, in many cases, the first floor of their homes served as a storage place for all of their food. With their houses completely crumbled to the ground, this food became inaccessible and they had to wait for donations. Many said that the government food donations stopped just a couple months after the earthquake, but they were very thankful for the donations from all of the other organizations.

Most of the women in this study did not have major challenges with accessing water a year after the disaster. For those who did experience water difficulties, it seemed to be a result of landslides that were blocking the water from reaching them. In any case, the women expressed that these issues were not of major concern and were something that could be handled.

Looking to the future, Squier asked the women what they thought would happen when the food donations from organizations ran out. Some were concerned that it would be a challenge, while others believed that they would be able to get food the way they always had: they would exchange the potatoes that they grew for rice with people from nearby villages, and if that did not work, they would have to find a way to purchase it.

2.2 Shelter and Reconstruction

With nearly 900,000 homes destroyed or damaged due to the earthquake, shelter became Nepal's most pressing need and was something that the women interviewed said had been their greatest challenge (see Fig. 1). A year after the earthquake, all the women interviewed were still living in temporary shelter. Living in such a confined space, where exposure to extreme weather was a constant concern, increased the stress they experienced after the catastrophic earthquake. It is not safe for people to be living in a weak structure for any amount of time, let alone an entire year (Jackson 2015). Nearly every woman stated that the greatest challenge for them following the earthquake as well as one year later had been shelter and housing.

Some families were able to hire workers to construct their temporary homes for them, but for many it was too expensive. In addition, there was a shortage of workers because so many people were building and re-building their temporary homes. Another difficulty arose from the fact that the majority of the tin structures

Fig. 1 A woman stands inside what used to be the kitchen in her badly damaged and uninhabitable home

consisted of one rather tiny room, maybe two, if the family had the materials. This lack of space was a great challenge for the women, with their entire families and the rest of their belongings crammed into one small space. In addition, there was the constant fear of big storms. Many women expressed fears that their home would fall apart due to the storms. It was difficult trying to sleep through a violent thunderstorm when the only thing separating them and a bolt of lightning was a thin sheet of tin. Women in the study noted that their temporary shelters were very cold in the winter and unbearably hot in the summer.

Ideally, these women and their families would be able to build back better than before, using earthquake-resistant materials, but they were not able to change the design of their homes because they did not have the money. Perhaps even more difficult than the inability to build back a stronger home was the loss of the homes that these women had before the earthquake. With the destruction of their homes, these women saw their lives crumble before their eyes, watching memories from their childhood and their children's lives disappear. It was more than just the loss of a home; it was the loss of all of the irreplaceable memories that went along with it. The difficulty of losing meaningful and sentimental belongings that were links to both the past and the future has been documented in other disasters (Erikson 1978; Fothergill 2004).

2.3 *Increase in Workload*

In disasters, women are responsible for such varied work roles involving productive, reproductive, and community labor (Enarson et al. 2006). In addition to all of the household and childcare duties that women are responsible for in everyday life, when a disaster strikes, these duties increase and women often times find themselves with an overwhelming amount of work. This creates an emotional and stressful burden for them.

The Nepal earthquake was no exception, and nearly every woman in this study felt that the amount of work that they were responsible for had increased afterwards. For a majority of the women, losing their homes was the biggest factor in their increased labor. In addition to cooking, cleaning, caring for their children, and farming, as can be seen in Fig. 2, women now had to sort through the rubble to rescue their belongings and plan the relocation of a temporary home, all while remaining strong for those dependent upon them. These women were dealing with a tremendous amount of work and stress and they expressed that they did not even know where to begin with all the work to be done. Many of them felt as though their lives were incomplete. The amount of work surrounding these women's settlements was never-ending. These women's lives were already busy maintaining their crops everyday while taking care of their household, and living in temporary shelters added to the stress and workload. Most of the women did not have enough money to hire workers to build a stronger home. Another stressor mentioned by some was that they had no storage for their potatoes, so their main source of sustenance was rotting and becoming inedible. The tremendous extra labor and stress was common for all the women and was even more of a challenge for women who were the head of their households.

Fig. 2 Women of one village working together to harvest wheat

2.4 Female-Headed Households

Many of the women in this study were not living with their husbands at the time of the earthquake, either because their spouse had died, or their spouses were living outside of Nepal, migrating to other countries for work. Nepal has a large migration remittance economy, as Nepalese citizens go to other countries for work and send their wages back to family members in Nepal. The villages affected by the earthquake had a high level of out-migration. Thus, villages were often populated by children, elderly, and female-headed households. For the women who did not have a husband at home with them, their everyday roles become even more of a challenge and all of the responsibilities of managing the household fell on them. With the rise in males migrating elsewhere for work, the number of female-headed households and women farmers had increased. With their husbands gone, the role of farming had fallen completely to the women and they become more reliant on agriculture for their livelihoods (Jackson 2015). Household management in poor communities is difficult even in the best of times, but for female-headed households after a disaster; it becomes even more difficult (Enarson et al. 2006).

The Nepalese women in the study who headed their households faced many challenges in the disaster aftermath. Many had to raise and care for children on their own, while also farming. For one woman interviewed in the study, life after the earthquake was particularly difficult. Like everyone else in her village, her home was rendered unlivable by the earthquake, and one year later she still did not even have a temporary shelter. Her husband spent most of the year in Ladakh doing construction work, leaving her alone in her village for a majority of the year. Her husband returned home once a year, and their communication was very limited. This took a great toll on her, leaving her to do all of the farming and other various chores. She stated that she could not rebuild her home until her husband returned to the village. In the year after the earthquake, several women in her village opened up their homes to her, giving her shelter and a place to stay. The earthquake greatly affected everyone, but for female-headed households, life became even more challenging.

2.5 Income

Women faced challenges in earning a sustainable income for themselves and their families and dealing with absent family members participating in the remittance economy. For many villagers, one of the only ways they could earn income was by selling their potatoes to villages that were unable to grow them. Before the earthquake they relied on exchanging their potatoes with people from other villages for rice, or if it was a good year, they were able to sell one kilogram of potatoes for seventy rupees. Since the earthquake, fewer people had been coming to buy or exchange potatoes, and this was the cause of a lot of difficulty and stress for the women in the study and their families. The women stated that the price for one kilogram of potatoes had dropped down to fifty rupees due to effects from the earthquake.

Many women did not farm immediately after the earthquake due to their fear of another earthquake. There came a point when they had to continue, though, because farming was their livelihood and a main source of food for their families. Financial instability was one of the greatest concerns for these women—especially since the earthquake—and although there was not a huge economy in these villages, earning more money would give these women the resources they need to build, among other things, a new home.

Another post-earthquake challenge related to income was the remittance economy. A large number of the women in Squier's study had daughters who were working abroad in Dubai; most of them were housekeepers. With a lack of opportunity and skill, there were no other options for many of these young women. For some, it was preferable to be cooking and cleaning abroad and earning money than to stay at home earning relatively no significant income. Cleaning and taking care of another person's home earned them more money than if they stayed in their village and farmed. The options for women in these villages were extremely limited.

2.6 Education

A lack of education contributes to gendered disaster vulnerability and greatly reduces women's opportunities in life. In Nepal, it is estimated that over half of women are illiterate, a higher illiteracy rate than for Nepalese men (UNESCO 2016). Nearly every woman interviewed in Squier's study had no formal education, due largely in part to the fact that there were no schools nearby when they were growing up. Some of the younger women, however, were still unable to go to school due to financial reasons. One young mother had the opportunity to go to school up until class ten, but then she failed one of her subjects and never thought to re-enroll. For most of the women, though, education was an opportunity that was not presented to them.

Another young mother of two daughters, ages two years old and eight months, had only completed two grades of school when she was forced to drop out due to financial reasons. She hoped to be able to send her children to school one day, affording them the opportunity she was not given. Despite not having had an education themselves, all of the women recognized the importance of education in terms of jobs and other life opportunities. These women cared deeply about their children and wanted to give them the best future possible.

For the majority of these women and even some of their children, going to school was not a feasible option. Many wished for the opportunity to do something more than farming but without the skill or financial means it was not possible, which was the reality for the woman in Fig. 3. As a result, many of their children

Fig. 3 Standing in the kitchen of her new home, a woman wishes she could get an education and find a job that would bring in more income than farming

were following in their parents' footsteps as farmers, doing construction work, or in some cases, traveling abroad to do housework. Thus, in the disaster aftermath, the women had fewer options because of their lack of education.

2.7 Health

In villages where the lack of healthcare is already of great concern in everyday life, these concerns worsen when a disaster strikes. With no nearby hospitals in these villages, this created problems for individuals who were injured in the earthquake. Other health issues to consider are the emotional health of the women and the potential risk of domestic violence.

Since a majority of the women were outside their homes farming in the fields during the actual earthquake they were spared any serious injury. For those who were injured it was a challenge getting medical attention. Roads were completely blocked after the earthquake due to landslides. This made getting help for the injured even more difficult. For those who were badly injured, a helicopter was able to come and take them to a hospital in Kathmandu a few days later.

A devastating loss as a result of the earthquake occurred to a young woman who was three months pregnant at the time. She was in her house when the earthquake struck, crushing her and her unborn child. She was able to get helicoptered out and she survived, but tragically, her baby did not. After the research interview, she shared photographs of her wedding, which took place just a few years earlier at the nearby monastery. One year after the earthquake life was far from normal, but she had her family, a roof over her head, and was six months pregnant. Pregnant women are one of the most vulnerable populations after a disaster and require even more attention in these emergency situations (Norlha 2015). Some villages have female community health volunteers, who are able to help care for and save the lives of women, newborn babies, and children, such as the mother and her infant in Fig. 4.

Finally, it is important to consider psychological health, as women in Nepal expressed being under a great deal of stress and worry. Additionally, it has been found that women may face the risk to domestic violence in disaster aftermaths, by strangers or by male partners (Fothergill 2004). Nepal has a great deal of gender-based violence, such as women beaten by their husbands, despite the efforts of many women's rights organizations, because it is seen as a private family matter and has fairly wide social approval.

Fig. 4 A young mother in one village cradles her three-month-old baby

3 Children's Experiences

Globally, children and youth are often vulnerable in disaster situations. In Nepal, children make up 40% of the country's total population and in the April 25, 2015 earthquake and the May 12, 2015 aftershock in Nepal, 1.1 million children were affected. Approximately 3000 children were killed and thousands of children were injured (UNICEF 2016). Of those killed, 2000 were under ten years old (Petricic 2016). Children's homes, schools, and health clinics were damaged or destroyed completely. An estimated 3.2 million children were displaced because of the disaster (Save the Children 2016). Children and youth were also affected by the restrictions of the movement of supplies in Nepal. In this section we examine several aspects of children's lives: families and family separation; education and schools; housing and neighborhoods; health and wellbeing; and risk of exploitation.

3.1 Family

One of the most serious issues for children in a disaster is being separated from parents, guardians, or others who provide care for them (Fothergill and Peek 2015). In Nepal, this was a concern after the earthquake. National child welfare authorities, along with UNICEF and other agencies, worked to prevent family separation. When possible, they avoided placing children in orphanages and helped to reunite children with their families. There were fears that children might be adopted improperly across Nepal's borders after the earthquakes. This has been documented in other disasters, as children are adopted by people outside the country hastily and without following proper procedures, such in as in Haiti after the earthquake in 2010 (Dambach and Baglietto 2010). Because of these concerns, the Nepalese government stopped children adoptions for three months after the earthquake.

Families faced increased workload after a disaster. As we mentioned earlier, women faced an overwhelming amount of work as they prepared food, farmed, cared for children, and tried to maintain family life in temporary housing. It was found that children and youth also had increased work after the disaster in Nepal, such as collecting water, performing household chores, and working in manual labor (Fievet et al. 2016). This additional family-based work for children meant that they often missed schooling.

3.2 Education and Schooling

Children and youth need schools that are safe in disasters, and in the disaster aftermath, they need to be able to have educational continuity so they do not lose valuable time in the classroom. In Nepal, many children were at risk in their schools, especially in the aftershock, and many of them had a loss of schooling in the year after the disaster, such as these children (Fig. 5). Research prior to the earthquake found the majority of the 644 schools in the Kathmandu Valley in Nepal needed retrofitting to meet safety standards and none of the schools had emergency response plans (Shaw and Kobayashi 2001).

Schools in Nepal were hit hard, with 35,000 classrooms destroyed or damaged (UNICEF 2016). More than 7000 schools needed to be rebuilt (Save the Children 2016). In some locations in Nepal, children had been taught to get under their desks during an earthquake. As the earthquake happened on a Saturday, children were not in school and many were outside their homes. Feeling the earthquake, some children ran into their schools since they had learned that the safest place to be was under their desks. Some children were hurt or killed because they took this action. This illustrates that children can learn how to react to disasters and also the need to make sure the curriculum on disaster actions is thorough and context-specific. For example, in this case, children needed to be taught that if you in your classroom, then take cover under a desk or table, but if are outside, that is the safest place to be and they should stay there. In the major aftershock earthquake in May, schools were in session and many children were injured or killed in their schools; thus, because of the timing, the aftershock was actually worse in some ways than the original earthquake.

According to Save the Children (2016), education in Nepal "came to a standstill" after the April earthquake. Many children lost out on valuable educational time. In disaster affected areas, many children went back to school on May 31, 2015 in temporary schools. Even though children returned to school, many were there less

Fig. 5 Children in Nepal, such as these in one village in Helambu, faced the risk of education discontinuity in the disaster aftermath

frequently in 2016 because of their increased workload at home (Fievet et al. 2016). Getting back into the school setting and the regular routine of the school day is often a central part of children's recovery. It is important that children not miss much of their education and get back on track as quickly as possible. Children also need the support and care of their teachers to help deal with the emotional distress (Fothergill and Peek 2015). In Nepal, thousands of teachers were trained to give psychosocial support to children (UNICEF 2015; Save the Children 2016).

A year after the disaster many children were attending school in temporary learning centers and no permanent schools had been built yet (UNICEF 2016). Many structural assessments were done of the schools in affected districts. Many children, a year later, studied in unsafe structures. Around the globe, there has been documented evidence of school structures not being built well enough to withstand earthquakes. This is a problem that extends beyond Nepal. In China, for example, many schools collapsed in the Great Sichuan Earthquake in 2008 due to unsound building construction.

3.3 Housing and Neighborhoods

Studies on children and disaster find that housing is key to their safety during a disaster and a critical part of their recovery. Hundreds of children lost their housing in the earthquake in Nepal. One year after the earthquake, many children and their families were sleeping in temporary, makeshift housing, sometimes near their old homes. Many others lived in structures that leaked when it rained or were cold in winter and at times, winds blew off their temporary tin roofs.

One study that examined almost 700 children in the most severely earthquake-affected districts in Nepal found that for children and youth in temporary housing a year later, they had no space and no privacy, and this was a particular problem for girls during menstruation (Fievet et al. 2016). Many children did not have enough space at home to do their schoolwork. Children expressed that they had concerns about safety and comfort as it was so crowded and uncomfortable at night in their temporary housing.

In addition to examining children's own homes, it is also important to evaluate children and youth's neighborhoods, villages, and larger communities. Children need to be in safe surroundings, both in buildings and outside (see Fig. 6). Research has found that children often lose places to play in disasters, as parks or natural areas are destroyed. Children need safe and healthy neighborhoods and places for recreation after a disaster, but that is often low on the list of priorities when a community is recovering. On a positive note, it was found that children and youth earthquake survivors in Nepal were active volunteers helping others in the community after the earthquake (Devkota et al. 2016).

Fig. 6 Children playing outside near Kathmandu a year after earthquake

3.4 Health and Wellbeing

It is critical to examine children and youth's health and wellbeing, both physical and emotional, in a disaster situation. Children are particularly vulnerable to the impacts of disasters and climate instability. They are more vulnerable to heat and other exposures, and are more likely to contract diseases in disasters and more likely to die in disasters. Children and youth can suffer emotional distress after a disaster, especially if they suffer large losses, such as the death of a family member, or they are exposed to the intensity of the event and its aftermath. Children and youth also may not reveal to adults the full extent of their emotional distress so as not to further burden them (Fothergill and Peek 2015). In Nepal, there is evidence that children faced both physical and emotional challenges in the disaster aftermath.

In Nepal, the earthquake destroyed many water supply systems, so basic water, hygiene, and sanitation was compromised; all are needed to keep children and their families healthy and free from cholera and diarrhea. It was found that there was a lack of toilets in schools, and children were suffering from diarrhea and respiratory problems, and had trouble accessing the medicines that they needed (Fievet et al. 2016). Children were vulnerable to malnutrition and disease in the months after the earthquake and at risk to extreme cold in the winter following the earthquake. To prevent polio, there was a nationwide polio immunization campaign to 3.6 million children who were under the age of five at the time (UNICEF 2016). The nutrition of children after the earthquake was a huge concern. Many children and their families were not receiving adequate nutrition before the earthquake hit. According to UNICEF (2016), four out of ten children in Nepal suffered from chronic malnutrition. It was found that after the disaster there was a reduction in the number of meals that children regularly consumed (Fievet et al. 2016). A year after the earthquakes, many health clinics were being run in tents (UNICEF 2016). When winter arrived, women and children suffered through cold weather and a lack of warm clothing and blankets. Children are more at risk of winter-related illnesses. Often, children with pre-existing illnesses or disabilities are at greatest risk for poor health outcomes, so future assessments in Nepal should be mindful of those children and their needs.

Children are also vulnerable to emotional impacts in disasters. In Nepal, many children experienced anxiety and fear, and some felt traumatized (UNICEF 2016). They had feelings of insecurity, had trouble sleeping because they feared another earthquake would occur, and they had overreactions to loud noises. Many dealt with grief and sadness over the death of family and friends. Many had trouble concentrating in schools and worried about passing their exams (Fievet et al. 2016). Some teachers were trained in a curriculum that helped children express their feelings through drawing (Save the Children 2016).

3.5 Exploitation and Abuse

Children and youth may be exploited or abused by others in a disaster aftermath. The exploitation may include children being the victims of physical or sexual abuse, placed involuntarily into dangerous working conditions, sold as domestic slaves or prostitutes, or forced into child marriages. Children are also at risk to violence within their families or communities.

In Nepal trafficking was a problem before the earthquake. The risk of trafficking is severe, especially for girls, in disaster aftermaths. Because families with few resources suffer greatly in disasters, they and their families are great risk to exploitation. In Nepal, there were concerns that poor families would place their children in situations where they would have to do difficult labor or enter into the sex industry. According the one report, three months after the earthquakes at least 245 children had been intercepted from traffickers, and that was just the “tip of a growing iceberg” (UNICEF 2015). Indeed, UNICEF stated trafficking was the biggest threat to Nepal’s children in the disaster aftermath; they found that girls were taken into prostitution or sold as domestic slaves, and boys were taken into forced labor. Because of the dire living conditions and the dismal futures, parents were convinced by traffickers that their children would be better off if they let them go. Traffickers promised their children would get an education, food, and have a better future than if they stayed in their villages (UNICEF 2015). The Nepalese police force established an anti-trafficking network to deal with this problem, and they reported that they intercepted 1851 people (women, men, children) from trafficking.

When children in one study were asked about their concerns after the earthquake, most talked about the increased risk of abuse and exploitation. Girls especially spoke of worries about these issues (Fievet et al. 2016). In one village a 17-year-old girl was raped by a man from another village after the earthquake; the community pressured her to marry him when it was discovered that she was pregnant (Petricic 2016). Within families and communities, children reported seeing adults yell at or beat children, and they saw drunk adults fighting. Boys were at risk to migrating for work and engaging in hazardous labor. Many young boys worked in the brickworks, loading and unloading bricks, for low wages (Petricic 2016). Girls were vulnerable to trafficking, sexual violence, and child, early, and forced marriages. Because of the sexual violence and assault targeted to girls and women in disaster and conflict situations, parents sometimes decided that early marriage was a safer option for their daughters. Children who were orphaned in the earthquakes were especially at risk to violence and abuse as they were on the streets or staying in unsafe shelters. Additionally, there was a weak child protection system at the community level in Nepal (Fievet et al. 2016), and that must be strengthened.

4 Conclusion

The experiences of vulnerable groups in any disaster are deserving of attention and research. With careful documentation of the challenges and ongoing hardships, steps can be made to reduce suffering. At the same time that many people are vulnerable in disasters, they also demonstrate enormous resilience, perseverance, and capabilities. Let us briefly discuss both the vulnerability and the capacities of women and children in Nepal in the 2015 earthquakes.

It is clear from the data gathered that large numbers of women, youth, and children in Nepal suffered losses in the earthquake and struggled with recovery and reconstruction. Large numbers died, were injured, lost loved ones, and were traumatized. Women's labor responsibilities increased to an almost impossible level. Children lost valuable educational instruction, and continued to miss school time for an extended period of time because of increased chores, such as the collection of safe water. They had trouble concentrating in school, and sometimes missed school, because of issues with health, food, water, and hygiene/menstruation. Many women and children lived in unsafe and unhealthy housing and many lost valuable and meaningful possessions. They were at increased risk to family violence, sexual violence, and exploitation.

As has been seen in disasters globally, an individual's social location—such as their race, gender, access to resources, age, amount of power, income, education level, community status—prior to a disaster often largely influences her or his ability to regain stability and wellbeing and have other positive outcomes in the long run.

It is important to consider the environment before and after a disaster, to see how children, women, and their families may experience cumulative vulnerability, or an accumulation of risk, such as poverty, isolation, few educational opportunities, and lack of sustainable work and income. A disaster crisis may happen on top of other crises, such as an epidemic or the death of a family member. In Nepal, many communities were struggling with poverty, a lack of educational opportunities, and families separated by the realities of a remittance economy before the earthquakes, so it was a truly a crisis on top of many other struggles.

Concurrently, women and children demonstrated incredible capabilities and strengths, and provided assistance to others. In her study, Squier documented the tremendous perseverance, hard work, and problem solving skills of the women in Nepal villages. These women worked for their communities, all while maintaining their homes, cooking, caring for children and elderly, and farming. They dealt with the increased workload after the earthquake and found strategies to manage the stress and worry of their homelessness. Many wanted to do work other than farming, but had no other options, so they continued with the work. The first year after the earthquake was a difficult year filled with more setbacks than positives, but the women from Helambu demonstrated profound strength. The women in the villages often helped each other, by assisting each other with farming, rebuilding each other's homes, and providing shelter to one another.

Children and youth also make significant contributions to their families and communities and demonstrate enormous capacities, altruism, and a solid work ethic in disaster situations and aftermaths. This has been documented in many disasters. In Nepal, Squier observed children and youth helping to rebuild shelters in their villages, and also helping with cooking and cleaning in their temporary shelters. Children also assisted with work in the fields, fed buffaloes, and took on household chores and watched younger siblings. In another instance after the disaster, schoolchildren held the hands and comforted their classmates who lay injured on stretchers on the ground awaiting medical help.

Fothergill observed numerous children, aged approximately seven to twelve years old, helping adults move debris in one village hit hard by the earthquake. These children pushed wheelbarrows full of bricks and other materials to help clear roads and begin rebuilding, perhaps helping with their own homes or earning money for their families. Many relief agencies found in their work that children and youth stated that they would like more opportunities to be able to contribute to disaster risk reduction and recovery efforts.

We would like to close with several recommendations. We believe that children's and women's well-being needs to be a priority in disaster risk reduction, disaster preparedness, and disaster recovery and that they should be part of the processes. Children have reported that they are not consulted by decision makers and humanitarian responders and would like to be. Children, youth, and women should be consulted on their views and their voices should be listened to in preparedness and recovery.

We advocate for the use of a human rights perspective. The United Nations Convention on the Rights of the Child states that children have the right to adequate shelter, food, water, and education, and that they have to right to be protected from abuse, exploitation, and are entitled to a safe environment. Furthermore, it stipulates that adults—including policy makers and those determining budgets—should do what is best for children. These rights need to be ensured in disasters. A top priority should be safe homes and schools. School buildings need to be retrofitted and should be earthquake resistant, and children should not be in classrooms until they are determined to be absolutely safe. Schools should teach disaster education, which will help create a prevention culture and earthquake resilient communities.

Finally, children and women should have access to safe housing, health clinics, and adequate nutrition in a disaster. There should be support for the social services, so that they can respond effectively to those affected by disasters. Finally, women and children have capacities, skills, and knowledge that contribute to both disaster risk reduction and disaster recovery for their families and their communities. These should be acknowledged and supported, as they can lessen vulnerability, reduce losses, and increase resilience for their families and communities.

Acknowledgements Alice Fothergill would like to thank the Alexander von Humboldt Foundation for bringing her to Nepal in February 2016 to participate in the earthquake symposium in Kathmandu. This meeting provided her the opportunity to learn first-hand about the disaster and to meet many individuals who have been documenting and researching the disaster from a wide range of fields and are working to reduce the suffering in Nepal in future disasters.

Emma Squier would like to thank the School for International Training (SIT) faculty and staff in Nepal for their support and guidance on her study abroad program. She is also grateful to her host families in Nepal for their generosity and opening their homes to her, and to her Nepalese translators who provided critical assistance with her research project. Emma also thanks her parents for their love and support.

References

Bradshaw S, Fordham M (2013) Women, girls, and disasters. Department for International Development UK. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/236656/women-girls-disasters.pdf. Accessed 22 Apr 2016

Dambach M, Baglietto C (2010) Haiti: 'expediting' intercountry adoptions in the aftermath of a natural disaster: preventing future harm. International Social Service (ISS), Geneva

Devkota BP, Doberstein B, Nepal SK (2016) Social capital and natural disaster: local responses to 2015 earthquake in Kathmandu. Int J Mass Emergencies Disasters 34(3):439–466

Enarson E, Fothergill A, Peek L (2006) Gender and disaster: foundations and directions. In: Havidan R, Quarantelli EL, Dynes RR (eds) Handbook of disaster research. Springer, New York

Erikson K (1978) Everything in its path: destruction of community in the buffalo creek flood. Simon & Schuster

Fievet V, Singh K, Davis A, Delchambre M (2016) Children's voices, children's rights: one year after the Nepal earthquake. Report on behalf of Plan International, Save the Children, Terre des hommes, UNICEF, and World Vision International

Fothergill A (2004) Heads above water: gender, class, and family in the grand forks flood. State University of New York (SUNY) Press, Albany, NY
Fothergill A, Peek L (2004) Poverty and disasters in the United States: a review of recent sociological findings. Nat Hazards 32:89–110
Fothergill A, Peek L (2015) Children of Katrina. University of Texas Press, Austin
Humanitarian Coalition (2016) Women and disaster relief. http://humanitariancoalition.ca/info-portal/factsheets/women-and-disaster-relief. Accessed 24 Apr 2016
Jackson R (2015) Rebuilding a more resilient Nepal. OXFAM. https://www.oxfam.org/en/research/rebuilding-more-resilient-nepal, Accessed Oct 2015
Norlha (2015) Impact of natural disasters on girls and women. http://norlha.org/en/home/. Accessed 10 Sept 2016
Peek L (2013) Age. In: Thomas DSK, Phillips BD, Lovekamp WE, Fothergill A (eds) Social vulnerability to disasters. 2nd edn. CRC Press, Taylor & Francis, Boca Raton, FL
Petricic S (2016) Nepal one year after the earthquake: child labour, child brides, homeless kids. Canadian Broadcasting Corporation (CBC). http://www.cbc.ca/news/world/nepal-earthquake-anniversary-children-sasa-petricic-1.3548955. Accessed 29 Aug 2016
Phillips BD, Thomas DSK, Fothergill A, Blinn-Pike L (eds) (2010) Social vulnerability to disasters. CRC Press, Taylor & Francis, Boca Raton, FL
Save the Children (2016) Save the children's earthquake response in Nepal: a special one-year progress report. www.savethechildren.org. Accessed Apr 2016
Shaw R, Kobayashi M (2001) The role of schools in creating earthquake-safer environment. OECD Workshop, Thessaloniki
Squier E (2016) The women of helambu: life after the 2015 earthquake. Research paper submitted to SIT Study Abroad Program, Nepal, Tibetan and Himalayan Peoples
Thomas DSK, Phillips BD, Lovekamp WE, Fothergill A (eds) (2013) Social vulnerability to disasters, 2nd edn. CRC Press/Taylor & Francis Group, New York
UNESCO (2016) National Literacy Campaign. Country Profile, Nepal. http://www.unesco.org/uil/litbase/?menu=14&programme=122. Accessed 23 Oct 2016
UNICEF (United Nations Children's Fund) (2015) Exploitation the new danger for Nepal's children. http://www.unicef.org.au/blog/july-2015/exploitation-the-new-danger-for-nepal-s-children. Accessed 10 Oct 2016
UNICEF (United Nations Children's Fund) (2016) Nepal earthquakes: one year later: moving on. Report by United Nations Children's Fund (UNICEF) Nepal Country Office. Published by Communications Section, UNICEF Nepal, Lalitpur, Nepal, April 25 2016
United Nations Development Programme (2010) Gender and disasters. Bureau for Crisis Prevention and Recovery. http://www.undp.org/content/dam/undp/library/crisis%20prevention/disaster/7Disaster%20Risk%20Reduction%20-%20Gender.pdf. Accessed 9 Sept 2016
Wisner B (2016) UNISDR needs a better definition of 'vulnerability'. Global Network of Civil Society Organisations for Disaster Reduction (GNDR). http://www.gndr.org. Accessed 22 Oct 2016
Wisner B, Blaikie PC, Davis IT (1994) At risk: natural hazards, people's vulnerability and disasters. Routledge, London

Emotional Care in Social Work

Ram Chandra Paudel

Abstract We normally do not care about our emotional and mental health condition. There is less research on disaster impact on people's life focusing on emotional health. Many people hide their emotional stress, which can lead to difficult situations later on. Nepal has gone through a period of violent conflict where many people were killed, abducted, displaced and jailed and loss their loved ones and belongings. In addition, people were affected mentally and physically by the devastating earthquakes in April and May 2015. Emotional health can be taken cared in two ways: one in personal level and next in group or team level. Psychological counseling, Peace Way workshops, Applied Improvisation are some of the ways to overcome the mental stress.

Keywords Earthquake 2015 · Mental health · Emotional care
Social work

1 Introduction

Normally we go to the doctor when we have physical pain but, generally, we do not see a social worker or a health professional when we feel emotional pain: guilt, loss, loneliness. Many of us never think about practicing emotional hygiene—taking care of our emotions, our minds, with the same diligence we take care of our bodies. We sustain psychological injuries even more often than we do physical ones, injuries like failure or rejection or loneliness. They can also get worse if we ignore them and they can impact our lives in dramatic ways.

R.C. Paudel (✉)
Executive Director/Founder President of CHILDREN-Nepal
and Lead Facilitator of Bikalpa Training Center, Pokhara, Nepal
e-mail: rampokhara@yahoo.com

J.H. Kruhl et al. (eds.), *Living Under the Threat of Earthquakes*,
Springer Natural Hazards, https://doi.org/10.1007/978-3-319-68044-6_17

2 The Context

Nepali people suffered from 10 years civil war, which damaged mental health badly. Nepal has gone through a period of violent conflict where many people were killed, abducted, displaced and jailed and loss their loved ones and belongings. In addition, people were affected mentally and physically by the devastating earthquakes in April and May 2015. Before getting relief from the devastation, heavy monsoon started in July. Much of the cracked landscape and infrastructure was wiped out by heavy rain and flood.

At the end of the September, when the monsoon was over strike in flat land Terai–boarder side to India started, followed by Indian border blockage. This led to lack of fuel for vehicles and gas for cooking. Because of this and additional shortage of food, medicines and vaccines, many people were suffering. Likewise, books were not printed and children's schools were closed for longer periods. The blockade badly affected supplies of essential commodities, including construction and raw materials needed to run local industries. This strongly obstructed post-earthquake reconstruction. People were really in stuck! On the top of that, discrimination is happening everywhere in Nepal, even in village and school, based on gender, social status, caste, intelligence and disability.

Neither the United Nations convention nor the law are respected much within the Nepali community. The lower castes people are routinely denied to access to wells, festivals, religious sites etc. They face resistance to inter-caste marriages, refusal by higher castes to accept water touched by them and many other forms of caste discrimination (Amnesty International, Nepal Report 2013; Human Rights Watch World Report 2015; Amnesty International 2014–15 report).

The Gender Inequality Index (GII) reflects gender-based inequalities in three dimensions: reproductive health, empowerment and economic activity. Nepal has a GII value of 0.485 (Nepal HDR report 2013) ranking it 102 out of 148 countries in the 2012 index. In comparison, Afghanistan ranks 147 in this index. Across the country, the gender-based violence is a serious barrier to the progress of the Nepali women (Tracking Cases of Gender-Based Violence in Nepal, UNPFA 2013). According to Nepal 2011 Demographic and Health Survey More than 2 in 10 women (22%) in Nepal have suffered from physical violence at some point since age 15. The same survey states that 60% of the women have never told anyone about the violence, and very few have sought help from any source. The violence against women and harmful traditional practices are stoppers for promoting gender equality and women's empowerment.

In village and city schools there is a culture of discrimination towards children from Dalit families, disabled children, and less endowed children. Many girls are not allowed to attend school or finish their education. It is very common for women and girls to work harder than men, often in physically demanding jobs. However, men and women are not measured equally on their salaries, credit and work appreciation, neither at domestic nor in the working environment (NEPAL LIVING STANDARDS SURVEY 2010/11, Statistical Report, Vol.2).

Human rights, women's rights and children's rights are often violated. Torture of people in the hands of police is widespread (Amnesty International, Nepal Report 2013). Women are the victims of domestic violence (Tracking Cases of Gender-Based Violence in Nepal, UNPFA 2013) and children face abuse and violence both at home and in schools (Violence Against Children in Nepal, UNICEF and CEVICT 2004) as the culture of violence is still applied in educational system.

The human right situation in Nepal has not improved much since the Comprehensive Peace Accord was signed, as the INSEC yearbook documents (Human Rights Yearbook 2015, INSEC). Furthermore, there has been an increase in the violence towards women. Most were victims of rape, domestic violence, dowry violence or inhuman behavior on the allegation of practicing witchcraft.

There is a clear negative impact on general people, including children, from the practices of the political parties. Schools are frequently closed by strikes (sometimes for more than a month), facilities are occupied for political gatherings, and children are used on the events and acts.

According to the Human Development Index Report 2014, Nepal has a low human development index and is among the poorest countries in the world, ranking as number 145 of 187 countries. On the top of the poverty and discrimination practices in Nepali society, the natural and cultural disaster has been happening one after another. But, devastated earth quake 2015 has destroyed more physical property, lives and effect highly at the psychological aspect of people. Nepali people are very sad and angry at the same time. People are also traumatized and need psychological, emotional and other healing support as a part of social work.

3 Coping the Situation

Anyone even educated from school and University in Nepal, most of the things she/he learned, can't be used in her/his work or in life in general. The teaching methods in Nepal are based on rote learning from textbooks, with the aim of the students being able to repeat the materials in the examination situation. Anyone grown up in violent environment at home, school and workplace, has faced corporal punishment in childhood. This situation has been affecting the way she/he thinks and sees the world.

Hard times and extreme conflicts, however, can be turned through art of living into a peaceful life. These conflicts can be great opportunities for development if we could manage them well. When devastated earthquake happened, earthquake survivals are greatly united, showed solidarity and helped each other. It has helped self-identity and social transformation. Through the different action, it is possible to turn pains, humiliation, regrets, frustration and conflict to enthusiasm and development. Non-profit and non-governmental organizations can play a vital role to make it happen.

An example:

CHILDREN-Nepal (CN) was founded in 1995 by a group of Nepali persons who were also experiencing difficult situations as children. They were concerned about the number of children living on the margins of society, out of reach from existing social institutions. Some of the main factors contributing to the situation of these children are:

- The inability of their family to provide basic needs such as food, clothing, education, and health care.
- The inability of parents to provide emotional care, due to their own disadvantaged backgrounds
- Lack of access to social services

As a result, many of these children are exploited and exposed to physical and mental abuse as well as crime.

CN facilitates processes that empower working children, youth and their families to assume an active and decisive role in solving their own problems by strengthening their life skills, improving their confidence and utilizing their existing capacity, which will result in the most effective long-term improvements of their living conditions.

The major program and activities are shown in Table 1. Both are interconnected and interdependent. In this way, the organization has a holistic approach of work. It seeks resources within the person, family and community and integrate them to solve the problem. CN believes that in order to achieve improvements in children's conditions, the family must be absolutely tied into the effort. These program activities has been improving the life situation of the children and their families, as a result they are also contributing to the society.

4 Emotional Care in Post-earthquake Times

Due to the earthquake the number of deaths was reported to 8856, number of injuries was 22,309 and the number of houses destroyed was 602,257 where people could no longer stay in these houses (Daily Mail 2016). Which has resulted in the emotional health situation of these affected people.

As we observe that children below 5 years mostly innocent and could not recognize what happened actually, children between 6 and 18 are the children who recognize the situation and are more aware of the situation and consequences.

As 35,000 classrooms destroyed and thousands of schools are cracked, nearly one million children left with no school for many days (Daily Mail 2016). It was tense situation for them how to cope with it. After few months there is a opportunity to go to school study at temporary learning centre but was more risky for the because of frequent aftershocks. Still, the schools are not rebuild completely and

Table 1 CN program and activities

Program	Activities	Purpose
Children and youth Service	School inclusion for children and youth	Many of the poorest children such as low caste, child labors, abused and street children are able to study in schools and colleges
	Child/youth Self Help Groups	Provides children/youth with the opportunity to learn from each other and to become responsible for their rights and duties
	Career counseling for youth	Provide career counseling for professional support to choose profession, education or training related to their interest and abilities
	Vocational training for youth	Provides support youth of skill training opportunities and job placement
	Capacity building training workshops	Organize various training workshops, visit, art, music for the empowerment of children and youth
Family Service	Family counseling	Resolving conflicts between family members, teaching skills, and helping them to have access to the services around them
	Family organizations	Organizing family Self-help Group to be united to raise a stronger voice for their rights
	Income generation	Establishing cooperatives and helping families through loans to run small scale business for their income Producing fair trade handicrafts selling to the market
	Emotional health care support	Helping children and families to link with health care facilities around them
Community Service	Fulbari Resource Centre	Organizing training, workshop for children, youth, parents, teachers in a holistic way
	Alternative to Violence Program	For promoting the peace in schools we have been providing alternative to violence training for teachers and children
Networking and solidarity	Global community connection	Networking at local, National and International levels

they do not have opportunity study and play. They have fear of unsuccessful and worried about their future.

700,000 people pushed into poverty by the quake and 200,000 families who lived in high-altitude temporary shelters through winter (Daily Mail 2016). The earthquake has affected different socioeconomic sector of the country overall. The catastrophic event destroyed houses and animal shelters, livestock, crops, seeds, and food stores as well as social infrastructures such as schools, health centres, banks, business centres, microenterprises, roads and trails. Therefore, the result is much stressful and disturbing as it has severely affected health, threatened food security, and disrupted production, employment, business, trade and services (ICIMOD 2015; Ulak 2015)

The earthquake has created many social problems and caused psychological trauma. Many people were compelled to live outside in tents and open sky for many days to months including children and girls putting them in an especially vulnerable position. There have been reports on trafficking of women and children. Hence, the scenario leaded to mental and physical pressure, which had directly increased stress levels and estimated to have long-term health impacts. Vulnerable groups such as women, children, disabled, the elderly and ethnic minorities remain higher risks to be excluded (ICIMOD 2015; Ulak 2015).

According to TPO Annual Report (2015), after the earthquake the most common psychosocial and mental problems were related to difficulties with sleeping at night, poor appetite, loss of self-esteem, feeling distressed, feeling less energetic, pessimism, hopelessness, wandering around aimlessly, and forgetfulness. It was found that due to these problems, the people has difficulties in carrying out their day-to-day activities, like praying, doing household chores, and taking care of animals. Similarly, feeling insecure, difficulties in sleeping, dizziness, and constant headache were some of the other impacts seen in the senior citizens. Family disharmony, alcohol abuse, and poor economic status were identified as risk factors, whereas community support, closeness with family members, and spending time with other senior citizens were reported to be the protective factors.

As 956 hospitals and clinics damaged, people has less access to health facility. According to an article published in Annapurna National Daily 2017, it is reported that in earthquake affected areas, due to the mental tension and scarcity created from the earthquake, people has changed eating habits which has resulted in Gastritis problem.

The positive side of the earthquake is that people were helping each other regardless of caste, class and reach and poor. Many cases all kinds of people sharing tent to sleep, cooking food, eating together. It has raised awareness and developed harmony and holistic view of human being-born, live and die! There was positive forced created, that resulted political parties joined together to announce new constitution of Nepal which has open up the development of Nepal.

5 Ways for Effective Emotional Health

There are different practices for effective emotional health care. Some of the practices applied in Nepal are discussed below. Through these practices, people are relieved and cared for improving their life situations and livelihood.

5.1 Peace Ways Workshops

Present skills that can enable individuals to build successful interpersonal interactions, gain insights into themselves and find new and positive approaches to their lives. The response of participants are very positive—"life changing events". Harmony and a safer environment have been created. These skills are especially helpful in the Nepali context where the schools often use physical punishment and unequal treatment of the children (Paudel et al. 2011; AVP 2016).

Peace Ways workshops offer experiential workshops that empower people to lead nonviolent lives through affirmation, respect, community building, cooperation and trust (Paudel 2015).

The Peace Ways workshops use the shared experiences of participants, interactive exercises, games and role-plays to examine the ways in which we respond to situations where injustice, disaster, prejudice, frustration and anger can lead to aggressive behavior and violence or depression (Paudel et al. 2011).

Thus, these workshops can help individual to:

- manage strong feelings such as anger and fear
- deal more effectively with risk and danger
- build good relationships with other people
- communicate well in difficult situations
- recognize the skills you already have and learn new ones
- be true to yourself while respecting other people

Figure 1 shows the components of transforming power which is within us. Practicing these components by respecting self, caring others, thinking before reacting, looking for a non-violent path to solve the problem and expecting the best; we will care our emotional health AVP (2016).

Fig. 1 Components of transforming power

5.2 Psychosocial Counseling

It is a set of interventions used to meet a person's emotional, social, mental, and spiritual needs which is very important for healthy development of all children and critical for orphaned and vulnerable children. It provides clients with the necessary tools for good health and positive development (UNICEF 2000).

Figure 2 shows that small intervention can bring a big changes of the life of the victim.

5.3 Applied Improvisation

It provides opportunities for collaborating better, expressing themselves better, being more self-sufficient, boosting spontaneity and all of its benefits: more openness, creativity, fun and positivity in groups.

The Fig. 3 shows a summary of improvisation principles which are (Driel RV 2013):

1. Be present, connected and in the moment.
2. Experiment. Dare to make mistakes in order to make progress, Just do it.
3. Be open to others, allow yourself and your way of working to be changed,
4. Say YES to the New and to the Unexpected, build upon each other's ideas, make the other look good, and

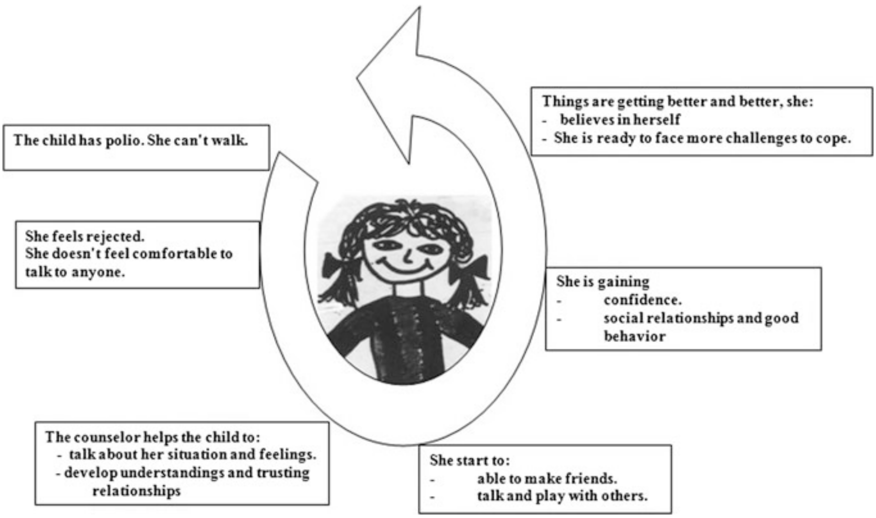


Fig. 2 An example: psychosocial counseling

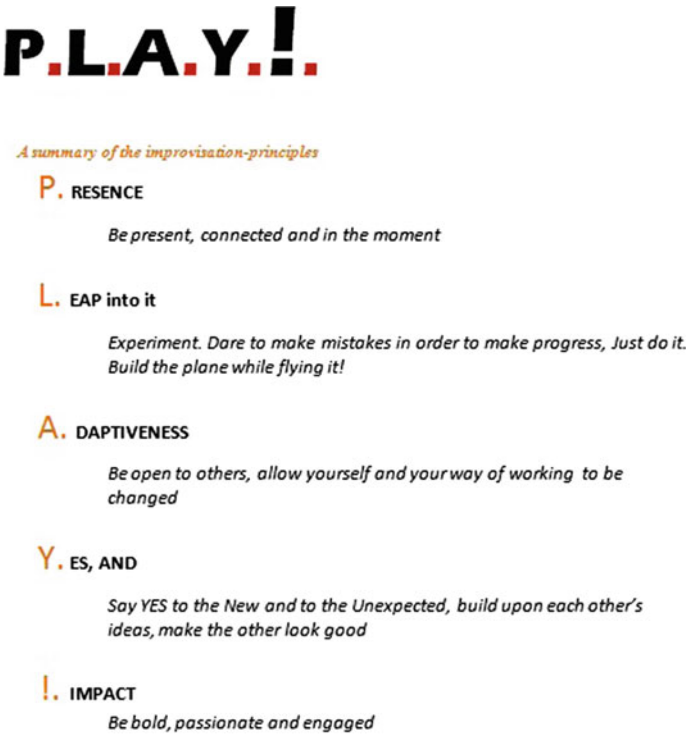


Fig. 3 Improvisation principles

5. Be bold, passionate and engaged.

5.4 Career Counseling

It provides professional support to youth and families to choose profession, education or training related to their interest and abilities. The main objectives of career counseling is to help youths to choose education/training, vocation or profession based on their interest and aptitude. Engaging in career counseling, youth and families will be capable to identify their interest and aptitude, set their life goal according to their family and vocational situation and identify the alternative situation to tackle their difficulties while reaching their goal. Career counseling do not provide advice and guidance, it empowers to find the career path of their life (Career Counseling Facilitator's Guide Manual 2014).

5.5 *In Personal Level, Winch (2014) Recommend to Practice the Following to Reboot Emotional Health Care*

“We are expected to just “get over” psychological wounds—when as anyone who’s ever ruminated over rejection or agonized over a failure knows only too well, emotional injuries can be just as crippling as physical ones. We need to learn how to practice emotional first aid. Here are 7 ways to do so:

- **Pay attention to emotional pain—recognize it when it happens and work to treat it before it feels all-encompassing.**
- **Redirect our gut reaction when we fail.**
  We need learn to ignore the post-failure “gut” reaction of feeling helpless and demoralized, and make a list of factors that we can control to try again. This kind of exercise will reduce feelings of helplessness and improve our chances of future success.
- **Monitor and protect our self-esteem. When we feel like putting our self down, take a moment to be compassionate to our self.**
  When we are feeling critical of our self, do the following exercise: imagine a dear friend is feeling bad about him or herself for similar reasons and write an email/letter expressing compassion and support. Then read the email/letter. Those are the messages we should be giving our self.
- **When negative thoughts are taking over, disrupt them with positive distraction.**
  The best way to disrupt unhealthy rumination is to distract our self by engaging in a task that requires concentration (for example, do a Sudoku, complete a crossword, try to recall the names of the kids in our fifth grade class). Studies show that even two minutes of distraction will reduce the urge to focus on the negative unhealthily.
- **Find meaning in loss.**
  The most important thing we can do to ease our pain and recover is to find meaning in the loss and derive purpose from it. Think of what we might have gained from the loss (for instance, “I lost my spouse but I’ve become much closer to my kids”).
- **Don’t let excessive guilt linger.**
  One of the best ways to resolve lingering guilt is to offer an effective apology. Our apology should focus less on explaining why we did, what we did and more on how our actions (or inactions) impacted the other person.
- **Learn what treatments for emotional wounds work for us.**
  Pay attention to our self and learn how we, personally, deal with common emotional wounds. For instance, do we shrug them off, get really upset but recover quickly, get upset and recover slowly, squelch your feelings, or …? Use this analysis to help ourself understand which emotional first aid treatments work best for us in various situations. Get into the habit of taking note of our

psychological health on a regular basis—and especially after a stressful, difficult, or emotionally painful situation.

6 Concluding Remarks

Emotional care is an untouched area in Nepalese context. There is less research on disaster impact on people's life focusing on emotional health. There are lots of people who are the real victim of emotional stress at home, school, workplace and society. We are less prepared to cope with it. So there is a real need of emotional health care. Many people hide their emotional stress, which can lead to difficult situations later on. So there is a real need of emotional health care and emotional health care through social work.

Emotional heath can be taken cared in two ways; one in personal level and next in group or team level. Practicing above mentioned ways for effective emotional health effected persons can be healed gradually. Recognizing loneliness, frustration, tension, anger, humiliation and greed and getting victory over them through regular practice is a key to overcome emotional stress. Likewise, there is no need to have large amount of money for real social service. The human sources of social services are the considerations, through and his/her human potentialities. Recognizing these and mobilizing them in the positive way can bring social changes.

A question arise on 'Are all social workers conscious about all these social and emotional problems?' 'Are they used to renouncing such habits and behavior in their real life?' A confident and self-dependent person can take up the challenges of life and society and is able to face new challenges in course of life. If you change yourself, others will be inspired from you.

References

AVP (2016) Alternatives to violence. AVP International. http://avp.international/the-avp-program/. Accessed 15 Oct 2016

Amnesty International (2014–15) https://www.amnesty.org/en/latest/research/2015/02/annual-report-201415/. Accessed 10 Oct 2016

Amnesty International, Nepal Report 2013 Annual Report (2014) http://children-nepal.net.np/fyr_2013_14.pdf. Accessed 15 Oct 2016

Career Counseling Facilitator's Guide Manual (2014) HELVETAS Swiss Interoperation CHILDREN-Nepal. Published by Employment Fund Secretariat, Antarang, Nepal

Daily Mail (2016) http://www.dailymail.co.uk/wires/ap/article-3551129/A-list-effects-Nepals-earthquake-1-year-ago.html#ixzz4cPdln8Ej. Accessed 26 Mar 2017

Driel RV (2013) PLAY! Applying improve in times of crisis. J Ass Manag Edu Develop pp 31–37

Human Rights Watch World Report (2015) https://www.hrw.org/sites/default/files/world_report_download/wr2015_web.pdf. Accessed 10 Oct 2016

Human Rights Yearbook (2015) INSEC. http://www.insec.org.np/pics/publication/1429808399,pdf. Accessed 5 Oct 2016

ICIMOD (2015) Strategic framework for resilient livelihoods in earthquake-affected areas of Nepal. Integrated Center for Mountains Development, Kathmandu

NEPAL LIVING STANDARDS SURVEY (2010/11) Statistical Report, vol 2. http://siteresources.worldbank.org/INTLSMS/Resources/3358986-1181743055198/3877319-1329489437402/Statistical_Report_Vol2.pdf. Accessed 5 Oct 2016

Nepal HDR Report (2013) http://hdr.undp.org/sites/default/files/reports/14/hdr2013_en_complete.pdf. Accessed on 26 Mar 2017

Paudel RC, Yoji, K, et al (2011) Practical peace education manual for youths. CHILDREN-Nepal, ADF-Japan

Paudel RC (2015) Peace Ways. Bikalpa Training Center, Pokhara, Nepal

TPO (2015) Nepal Annual Report 2015. http://ithubnepal.com/project/tpo-wp/wp-content/uploads/2017/03/TPO_Annual_Report_2015.pdf. Accessed 26 Mar 2017

UNPFA (2013) Tracking Cases of Gender-Based Violence in Nepal. http://nepal.unfpa.org/sites/asiapacific/files/pub-pdf/TrackingCasesofGBV.pdf. Accessed 4 Oct 2016

UNICEF (2000) Training manual on psychosocial counseling for children in especially difficult circumstances. UNICEF, Nepal

Ulak N (2015) Nepal's earthquake-2015: its impact on various sector. J Tour Hospital 7:58–86

UNICEF and CEVICT (2004) Violence against children in nepal

Winch G (2014) Emotional first aid healing rejection, guilt, failure. Penguin Group, New York

Earthquake and Earth Justice: Emergence of the Environmental Justice Movement and Its Relevance in Addressing Unanticipated Events

Ananda M. Bhattarai

Abstract The earthquake that shook Nepal in 2015 was a colossal event that not only destroyed human life, settlement and civilization in the Himalayan landscape but also showed the limitation of human knowledge, experience and ingenuity. In October of the same year, Nepal adopted a new constitution that prioritized socio-economic rights. Can unanticipated events such as the earthquake be examined from justice perspective, is the principal concern of this note. It takes resonance from the environmental justice movement and,with the help of environmental justice discourse developed in South Asia, argues that the logic of environmental justice and earth justice can be strategically used to mitigate the impact of colossal events such as the earthquake, global warming, ozone depletion, climate change, or the collapse of the Himalayan system, etc., provided they are actuated by real implementation on the ground.

Keywords Nepal · Earthquake · Right · Environment · Justice
Earth justice

1 Introduction

The catastrophic 7.6 magnitude earthquake of April 25, 2015, followed by more than 300 aftershocks greater than magnitude 4.0, caused over 8790 casualties and 22,300 injuries in Nepal. Life of eight million people (i.e., almost one-third of the population of Nepal) has been impacted by the earthquake. Thirty-one of the country's 75 districts have been affected, out of which 14 were declared critically affected. In the worst hit areas, entire settlements, including popular tourist destinations were swept away by landslides and avalanches. From the expected 5%, GDP growth dropped to 3.4% in 2014–15. An estimated 6.7 billion USD will supposedly be required to build back the loss and damage of property and heritage sites caused by the earthquake over a period of 5 years (NPC 2015).

A.M. Bhattarai (✉)
Supreme Court, Kathmandu, Nepal
e-mail: anandamohan77@gmail.com

J.H. Kruhl et al. (eds.), *Living Under the Threat of Earthquakes*,
Springer Natural Hazards, https://doi.org/10.1007/978-3-319-68044-6_18

Despite colossal damage to their life, property and environment, the survivors of the earthquake today are living a life of neglect. Their right to decent living is not respected. Even though the bold framework of socio- economic rights, including the right to a clean and healthy environment, health, food and social security, housing and education offers some hope, the right of the victims to get compensation, resettlement and rehabilitation is far from being realized. Against this backdrop, therefore, the author attempts to make an inquiry on whether the *Environmental Justice Movement* (henceforth EJM) that is in vogue in South Asia and elsewhere can be employed in addressing unanticipated events, such as the earthquake, tsunamis, or other human induced events of colossal nature, and prevent or minimize their impacts. Three basic questions come to the fore when one thinks about the EJM: Was EJM a response to unanticipated events? Or was it just a response to anticipated but neglected results because there was no voice to resist? Can environmental justice measures coupled with policies, planning, and coping and adaptive strategies prevent and minimize the impacts of unanticipated events? In order to find answer to these questions the author first presents an anecdotal understanding of EJM and evolving discourse in different countries, the issues raised there-in and the principles and strategic tools evolved. He then examines the contribution made by the movement to international and comparative law. In the final part, the author tries to find relevance of the EJM and discourse in addressing unanticipated nature and human induced events such as the earthquake.

2 Environmental Justice Movement and Environmental Justice

The EJM emerged in the late 1970s and 80s as an up-shoot of social justice movement in the US raising issues of social justice, equal protection, equity and an end to institutional discriminations. The resistance of the people in Warren County, North Carolina, to the spilling of oil and subsequent dumping of soil containing polychlorinated biphenyl(PCBs) is epitomized as a watershed event for the onset of the movement. Later the environmental justice advocates took up issues concerning unfair sharing of environmental benefits and burdens. The racial minorities, the low-income and impoverished groups especially the African Americans were at the forefront of this movement One study estimates the composition of the people in the surrounding of the dumping site as 69% non-white, 84% African Americans of this 20% of residents were people having incomes below the federal poverty level in 1982 (Environmental Justice 2016). The EJM also fought against ecological destruction. Theories of environment, environmental justice, policies, laws, planning, governance, aesthetic relations, and sacredness of mother earth cover different shades of the movement. The issuance of 17 Principles of Environmental Justice is one major achievement of the movement. The delegates to the First National People of Color Environmental Leadership Summit held on October 24–27, 1991, in

Washington DC, drafted and adopted 17 principles of Environmental Justice (Principles of Environmental Justice 1991). The Principles among others, extol sacredness of mother earth, demand public policies based on mutual respect and justice for all people free from bias and discrimination, and highlight the need to clean up and rebuild societies in balance with nature, and educate people for environmental cleanliness.

Even though environmental justice movement got prominence in the US, it is understood in diverse form in many countries. For instance, discrimination and marginalization of Romani people in different countries of Europe, issues such as poverty and environment, health inequality and social exclusion, child labor in cotton industry in the UK, the issue of climate change in France, emission of waste from mining and mining accidents and other work related issues in South Africa, citing of hazardous waste in Australia, substandard oil mining and toxic waste dumping in Ecuador, infrastructure development issues such as construction of 33 km long Saemangeum sea wall or Incheon canal in South Korea are studied from environmental justice perspectives(Environmental Justice 1980). Overtime, the EJM got North-South dimension in matters such as dumping of hazardous waste. One finds refrains of EJM in the law evolved to address the dumping of hazardous waste where principles of prior informed consent, and the sovereign right of each country (meaning developing countries as well) to ban the import of hazardous waste is recognized (UNEP 2014).

The EJM at a more philosophical level is credited for popularizing terms such as environmental racism, environmental equity and “environmental justice”. The US Environmental Protection Agency defined environmental justice to connote “the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.” (UN EPA 2016). A more comprehensive definition of environmental justice is given by Bunyan Bryiant as follows:

> Environmental justice … refers to those cultural norms and values, rules, regulations, behaviors, policies and decisions to support sustainable communities, where people can interact with confidence that their environment is safe, nurturing and productive. Environmental justice is served when people can realize their highest potential, without experiencing the “isms”. Environmental justice is supported by decent paying and safe jobs; quality schools and recreations; decent housing and adequate health care, democratic decision making and personal empowerment; communities free from violence, drugs, and poverty. These are communities where both cultural and biological diversity are respected and highly revered and where distributed justice prevails (Bryant, 1995).

As the low income and marginalized communities, due to poor housing conditions or due to the lack of education and sanitations are exposed to nature and human induced environmental hazards, desperate impact of pollution on them or the mistreatment and neglect meted out to them is put to sharp focus in the EJM discourse. Put briefly, equality is at the root of environmental justice and so it proscribes inequality and unequal treatment in every manifestation and tries to ensure fair treatment and same degree of protection. Transparency, accountability, greater public participation on decision making and improvement of quality of life through capacity building is prioritized by the movement. The EJM rejects environmental elitism, and focuses on fair and even handed enforcement of environmental laws. Equity, justice and mutual respect is the basis of partnership. Cultural integrity and fair access to resources are other important concerns of the movement.

From jurisprudential perspectives, environmental justice comprises three major components. The first is the value aspect. Here, environmental justice is understood as a value for bringing about social equilibrium, and environmental sanctity. The sacredness of mother earth, the cultural and religious values of societies that commemorate sacredness and other aesthetic variables comprise important component of environmental justice. Secondly, environmental justice brings within its sweep the distributive justice aspects in terms of fair distribution of environmental benefits and burdens. This is achieved through the enforcement of public duties. Laws recognizing substantive rights are thus crucial for promoting access to environmental benefits and shouldering of environmental burdens. The third component is the procedural justice that ensures access to review procedures through representative suits. This is made possible by liberalizing the rules of *standi,* and access to environmental information, and access to and participation in decision making and benefit sharing.

3 EJM and International Law

A clear linkage between EJM and international environmental law may not be always possible. But one finds the resonance of EJM in the continuous navigation of human person towards the center of environmental discourse. This in operational terms entails the propagation for equitable global partnership and cooperation, eradication of poverty and improvement of the quality of life, reduction and elimination of unsustainable patterns of production and consumption. Today, notions such as compensation to victims of pollution, relocation and transfer of activities and substances causing severe environmental degradation or harmful to human health are proscribed. Issues such as environmental impact assessment and internalization of environmental cost in project, capacity building and transfer of technology, have found space in international environmental law. A host of principles, such as the precautionary and polluter pays principle and principle of prior informed consent, have evolved as foundational principles in the environmental law. All of them have a bearing with the EJM.

4 Evolution of the Right Approach to Environment

The interaction between the human rights and environmental protection movement at the international level has facilitated the evolution of the "right approach to environment". That the protection of environment may work as a means to the end of fulfilling human rights standards, and that legal protection of environment human rights may be an effective means to achieving environmental protection (Anderson 1998) have been equally crucial for bringing the human person at the center of environmental discourse. In advocating the human rights approach to environment, basically three methods have been brought to the fore. First among them is the mobilization of existing rights to achieve environmental ends. Second is the reinterpretation of existing rights to include environmental concerns. And third, is the creation of new rights of an environmental character. Space will not permit this author to elaborate on them but suffice here to say that all three approaches seem to have been practiced by courts in South Asia.

5 Environmental Justice and South Asia: Approach, Strategies and Principles

At the initial stage, courts in South Asia ingeniously interpreted right to a clean and healthy environment as part of the right to a dignified life.[1] A few procedural rights such as the right to access to environmental information, and the right to participate in decision making, the right to environmental impact assessment were also taken up in the course. The courts questioned the arbitrariness of law and sought justness, fairness and reasonableness in law. For enhancing access to justice, they liberalized the principle of standi and highlighted on complementarities of fundamental rights and the directive principles. The emphasis on organic interpretation of rights helped them to look upon a clean environment as constitutive to the right to human dignity. Thanks to the judicial activism, later the right to a clean and healthy environment found a clear stipulation in some of the constitutions such as Maldives and Nepal (Maldives constitution 2008 and Nepal Constitution 2015).

A proactive approach in environmental adjudication is a special characteristic of the South Asian judiciaries. The courts have intervened in areas such as air, water, noise pollution and other issues pertaining to health and environment. Similarly,

---

[1]In India Subhash Kumar vs. State. of Bihar- (1991) 1 SCC 598, in Nepal, *Surya Sharma Dhungel v Godavari Marble Industries*, NKP 2052 (1995) Golden Jubilee Special Volume p 169; *In Pakistan, Shehla Zia v WAPDA*, PLD 1994 SC 693 and *Akbar Ali v State* 1991 SCMR 2114; in Bangladesh, *Dr. MohiuddinFarooque and Another v Bangladesh and Others*, 49 DLR(AD) 1 and 50 DLR(1998)84; *Dr. MohiuddinFarooque and Others v Bangladesh and Others*, 55 DLR(2003) 609, para 53 are noted cases where the courts extrapolated the right to life to include clean environment.

protection of natural resources such as the forests, underground water, and common property resources has been the concern of the courts. A number of novel strategies such as self-observation (Ratlam case, Dharahara case, Godavari case), constitution of fact finding and expert committees and even committees for the implementation of court orders have been adopted. The Courts have emphasized on education and compensation. More recently, the issuance of continuing mandamus has found space in South Asia in judicial handling environmental matters.

Another important aspect of judicial strategies adopted in South Asia is the invocation of environmental principles. Almost all the environmental principles such as the principle of sustainable development, the principle of intra-generational and intergenerational equity, the principle of public trust, the precautionary principle, polluter pays principle and the principle of absolute liability have been very effectively used by different courts in South Asia in handling environmental matters. Besides, a number of principles such as principle of non-regression, the principle of common but differentiated responsibility, the principle of regional cooperation, and notion such as accounting and payment for ecosystem service are discussed today in South Asia as candidate principles.

6 Environmental Justice and Earth Justice

At the first glance, both the terminologies seem synonymous. However, when one digs deeper the minor contours begin to surface.

As one can see, the term "earth justice" is more holistic in orientation. It acknowledges the natural process of change but attempts to offer sustainable solution to problems created due to wrong policy choices. Broader issues such as control of exploding population, introduction of sustainable land use policies, reform of land tenure laws, and improvement of existing agricultural policies and practices and improvement of decaying infrastructures are major concerns of earth justice. Earth justice emphasizes on the conservation of biodiversity and sustainable use of its components. It calls for safe habitat, safe land sites, open space, emergency services, health and the likes. Distributive justice is a major component of earth justice.

Disaster preparedness is a major agenda of earth justice. Disaster may be human induced or nature induced. If it is human induced, then preventive and punitive and rehabilitatory measures may come into play. However, if it is nature induced then our hands may be tied to some extent. As matter of fact, disaster does not occur with prior notice, nor does it target only the poor and down trodden. But like in environment justice related cases, the impact of disaster on the poor and downtrodden is more. As one can see in case of the earthquake in Nepal, human devastation would not have reached such a colossal scale if there were no uncontrolled and rampant interventions on fragile mountains or if there were no settlements on geologically hazardous and slide prone zones, or if building codes were honestly implemented while constructing houses in both rural and urban areas, or the judicial dictates on environmental conservation were honestly abided (Shrestha 2015). In cases where no disaster preparedness exists, human misery aggravates. Earth justice therefore emphasizes on preparedness to quickly respond, minimize the damage brought about by disasters and calamities and also offers long term solutions. Recourse to justice is made available at every stage from rescue to rehabilitation. Earth Justice also emphasizes that good governance would reduce desperate impact and save humanity from environmental injustice and disaster.

Apparently, the canvas of earth justice is much broader than environmental justice. But then, the principles, strategies and approaches evolved by the courts may be expanded to embrace the notion of earth justice. For instance, the judicial decisions in South Asia have played a crucial role in enunciating principles, carving rights on environment, evolving standards.[2] It is a common knowledge that our courts have questioned not only colored acquisition but also shunned the colored exercise of power be it related to law making or their execution. The rigorous conduct of environmental impact assessment and social impact assessment are strategies to rationalize the exercise of power that may cause significant environment damage. Though not very encouraging at the moment, the EIA/SIA are considered as important strategies for ensuring proper use of the natural capitals such as land, water and forests. Where a development project is likely to cause massive displacement of people, the courts have ordered for resettlement and rehabilitation of the project affected persons. These exercises are relevant for preventing or mitigating the impact of disaster and thus useful for earth justice. The courts have also ordered for long term planning for the protection of natural capital for the present as well as future generation. Of late, climate justice has emerged as one crucial element relevant for earth justice, though the road is still mostly unchartered.

7 Concluding Observations

The discussion began in the context of the earthquake that shook Nepal last year. The country, its legal system and its institutions were not prepared for such an unanticipated event. In the aftermath, the people in the legal sector began to connect threads and look into the possibility of using existing legal tools and machineries in addressing the effect of earthquake and mitigating their hardships. The adoption of a progressive constitution in the same year, that not only recognized a host of rights, but also called upon the state to take measures to prepare the country for such disasters, gave sufficient pretext to look into and revamp the legal structure so as to

[2]For instance, amendments to incorporate the right to education and information in India and Pakistan, Environment related rights in the Nepali and Bhutani Constitutions may be credited to the role played by the judiciaries of respective countries. Similarly and enactment of environmental Act and Rules in Nepal, the Forest Dwellers (recognition of Rights) Act 2006 and Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act 2013.

secure justice to the victims of earthquake. The examination of environmental justice and possibility of its extension to earth justice was made in this context. The discussion above made a quick review of EJM and earth justice, and examined their inter-connection. By way of conclusion, it can be argued that the answer to three basic questions may help one to identify the relevance of EJM to earth justice. Firstly, was the EJM a movement to address unanticipated events; secondly, can the EJM be used as foundational concept for earth justice; and finally, can earth justice be strategically used to mitigate the impact of colossal events such as the earthquake, global warming, ozone depletion or climate change, or the collapse of the Himalayan system, etc. The answer is an emphatic yes provided we work together for the colossal events have their basis on the law of nature and it is often said that in the Laws of Nature, there is no right nor wrong; there are no rewards nor punishments; there are only consequences.

References

Bryant Bunyan (ed) (1995) Environmental Justice Issues. Island Press, Policies and Solutions, p 6

Environmental Justice (2016) https://en.wikipedia.org/wiki/Environmental_justice, Accessed 30 April 2016

Environmental Justice (1980) https://en.wikipedia.org/wiki/Environmental_justice, Accessed 30 April 2016

NPC (2015) Post Disaster Needs Assessment (PDNA), Nepal Earthquake 2015. National Planning Commission, Government of Nepal, Kathmandu

Principles of Environmental Justice (1991) http://www.ejnet.org/ej/principles.html, Accessed 30 April 2016

UNEP (2014) Basel Convention on the Control of Trans-boundary Movements of Hazardous Wastes and their Disposal, http://www.basel.int/portals/4/basel%20convention/docs/text/baselconventiontext-e.pdf, Accessed 30 April 2016

UNEPA (2016) https://www.epa.gov/environmentaljustice, Accessed 30 April 2016

Anderson MR (1998) Human rights approaches to environmental protection: an overview. In: Anderson MR (ed) Boyle AE. Clarendon Press, Human Rights Approaches to Environmental Protection

Maldives constitution (2008) Art 23 "Right to a healthy and ecologically balanced environment" and Nepal constitution (2015) Art 30 "Right to a clean and healthy environment"

Shrestha, K (2015) Key Note Speech at the Fourth South Asia Environmental Justice. Roundtable, Kathmandu, Nov 28, 2015

The Constitution of Nepal (2015) The constitution was promulgated in 2015. It is published by Govt. of Nepal, Kathmandu

Assessing Policies of Responding to the Risk and Impacts of Earthquakes from a Justice Perspective

Lukas H. Meyer and Harald Stelzer

Abstract The paper addresses two important issues in assessing policies of responding to the risk of and the damages caused by earthquakes. First, the complex uncertainties concerning the occurrence and impacts of earthquakes raise difficult issues from the perspective of a philosophical theory of justice when assessing policies to reduce the impact of possible earthquakes. We propose a particular understanding of what justice requires, namely risk-averse weak sufficientarianism, and show how this understanding can justify the reduction of the imposition of risks of harms. Second, we address how one should respond to unavoided and unavoidable damages caused by earthquakes. Here we suggest that we should view such damages primarily as a reason for redistribution, and therefore as a matter of distributive justice.

Keywords Sufficientarianism · Risk · Uncertainty · Justice
Earthquakes · Climate change

1 Adaptation to the Risks of Possible Earthquakes from the Perspective of Sufficientarian Justice

In many regions of the world people live under the constant threat of earthquakes that may severely impact their well-being and livelihood. Information about potential catastrophic events refers in many cases to expert assumptions about the risk for earthquakes above a certain magnitude for different regions. The term 'risk' is often used for potentially bad outcomes. In a more narrow understanding it refers to probabilistic risk, i.e. potential bad outcomes to which we can assign a probability. However, it is often simply impossible to assign numeric values to either the probability or the expected disvalue of an outcome. In such cases of (Knightian) uncertainty we possess only partial or no probabilistic knowledge (Lempert 2002).

L.H. Meyer (✉) · H. Stelzer
Institute of Philosophy, University of Graz (Austria), Graz, Austria
e-mail: lukas.meyer@uni-graz.at

J.H. Kruhl et al. (eds.), *Living Under the Threat of Earthquakes*,
Springer Natural Hazards, https://doi.org/10.1007/978-3-319-68044-6_19

This may however not be the most severe form of uncertainty. In situations of ignorance we have no knowledge about all potential outcomes. All these forms of uncertainty play an important role also in the context of earthquakes. Here we face uncertainties of whether an earthquake will occur, and if so, when the earthquake will occur, the exact location of the earthquake, its magnitude, its environmental and socio-economic effects and the (distribution of the) resulting damages.

Apart from epistemic questions of how to establish reliable predictions of the occurrence of severe earthquakes in certain regions, we also face problems of assessing policies that aim to reduce the impact of such events on human well-being should they occur. Especially non-probabilistic risk causes difficulties to cost-benefit analysis (CBA), the main tool for policy-making. CBA relays on the expected utility framework by assuming that a social planer chooses an optimal policy to maximize the discounted stream of benefits and costs over long periods of time. However, in situations of uncertainty it may become extremely difficult to adequately apply such decision-making tools as we have no clear picture of the consequences of different alternatives making it (almost) impossible to weigh their costs and benefits (Ackerman et al. 2009; Füssel 2007; Lempert and Collins 2007).

Furthermore, if we are interested in human well-being not only possible internal deficits of CBA in regard to uncertainty might be seen as problematic but also their underlying utility assumption based on monetary values. Even if we had sufficient information about the probability of different outcomes, this does not automatically enable the attribution of monetary values to all benefits and burdens, including human life, physical security, subsistence and health (Shue 1993). As pointed out by Azar and Lindgren (2003), combining all damages in a monetary damage function might conceal ethical dilemmas and difficult value judgments.

However, also more normative approaches focusing on human well-being seem ill equipped to deal with the risks of harms since they do not differentiate between actual harms and the imposition of risks of harms. Even though we know that earthquakes imply severe risks for the basic well-being of people, we lack certainty of what the consequences of our actions and policies today will be in the future. The circumstance that we cannot say that we reduce harm on people living in the future, but rather reduce the imposition of risks of harms on them leads to much discussed questions in normative theory: How to determine the size of a risk of a harm? How to make trade-offs between risks of harms, considerable costs and forgone benefits? Can one say that the non-reduction of the imposition of risks harms future people, and if yes, in what way (Zimmerman 2006)? Does the non-reduction of the risks of harms constitute a rights violation (Thomson 1986; Finkelstein 2003; Perry 2007; Steigleder 2016)?

Answers to these questions will depend on the normative theory employed. In the following we will concentrate on intergenerational distributive justice by employing a sufficientarian conception (Meyer 2003, 2009a, b; Page 2006, 2007). Such a perspective can be based on the interpretation of possible harms as a set-back of basic interests of future people. This understanding attributes to persons a prima facie claim[1] against us that we do not perform intentional actions that constitute imposing risks of harms on them by threatening the fulfillment of their basic interests (Zimmerman 2006; Steigleder 2016) or do not undertake (adequate) measures to reduce such risks of harms. It interprets non-reduction of the imposition of such harms as rights violations according to the interest theory of rights (Raz 1986).

Sufficientarianism, as it is understood in the following, considers the protection and realization of basic interests to be of utmost importance. Benefits to people below a threshold have lexical (absolute) or very strong priority over benefits to people above the threshold (Shiffrin 1999; Meyer 2003). The protection and realization of the sufficientarian threshold is a matter of fulfilling requirements of justice. Falling below the threshold implies the infringement or violation of basic rights of persons. It can be assumed that from a sufficientarian perspective we should avoid risks with respect to basic interests of well-being. Of two outcomes with the same estimate in terms of well-being, it seems plausible to choose the one that does not exhibit uncertainty or exhibits less uncertainty. Additionally, a risk-averse interpretation of sufficientarianism is based on an asymmetry between potential losses and potential gains with respect to the basic well-being of persons. Potential losses weigh more heavily than potential gains. If more uncertainty means that there is a larger probability of falling below the threshold, then more uncertainty counts against a policy. This is so even if more uncertainty should also mean that there is a larger chance of attaining better (or very good) outcomes.

Even though such a risk-averse sufficientarianism can rejoin a rights-based approach with a consequentialist account, critics have pointed out several problems. Among them the following four:

First, if we look at two policies with different levels of uncertainty and where neither of the two policies extends below the sufficiency threshold, sufficientarianism as such does not justify risk-aversion. However, one can augment a sufficientarian view by adding an argument for risk aversion above the threshold. Such an argument would not reflect reasons of (sufficientarian) justice, but could be based upon, e.g., the ethical reason that we should avoid risking to waste resources. This reason might be among the general reasons for risk-aversion that are applicable below and above threshold risks.

For the second and third problem, much depends on how strong the priority is that we attribute to the violations of rights below the threshold. Here we consider strong sufficientarianism that attributes lexical priority to the avoidance of below threshold violations of rights. If the avoidance of rights violations below the threshold is being attributed lexical priority, there would be no point in weighing these violations against rights violations above the threshold. Lexical priority means that at any time the avoidance of rights violations below the threshold is more important than other claims; for this the number of people affected and the extent to

[1]That the claim is only prima facie means that it may not hold under all conditions as it could be overruled or defeated by a more pressing claim or the need to impose certain risks as a precondition for engaging in highly valuable activities.

which their other rights or benefits could be realized is irrelevant. This has three important consequences: (a) it prohibits weighing rights violations below the threshold against rights violations or the set back of other interests above the threshold; (b) if we assumed strict priority of rights violations below the threshold then we would have to secure these rights of only one person or a small number of people even if that required violating other rights of many people just above the threshold; (c) according to this understanding, reducing the well-being of people above the threshold for the sake of improving the position of people below the threshold does not count unless such reductions would bring these people below the threshold. However, the plausibility of attributing such strong priority to the rights claims below the threshold depends on the proponent of the view being able to provide a plausible substantive account of the special normative significance of people not being violated in these rights. This, of course, is the fundamental challenge to any notion of a normative threshold that has high priority and, in particular, to a threshold that enjoys lexical priority.

Thirdly, a strong interpretation of a rights-based sufficientarianism that gives the threshold lexical priority might be understood as categorically prohibiting the pursuance of any policy that comes with any probability of causing people to fall below the threshold or as prohibiting any policy that does not reduce to the fullest possible extent the probability of causing people to fall below the threshold. Such an interpretation of intergenerational justice by itself will not allow us to choose among policies in the context of responding to earthquakes since, realistically speaking, we have to assume that all policies that currently living people can pursue imply such risks and maximizing the reduction of such risks would be very or extremely expensive.

However, strong sufficentarianism can be understood in a more complex way and in a way that addresses this issue: We start with the claim that we ought to choose the policy with the least likelihood of causing people to fall below the threshold. Two further issues then are: Do numbers count? And: does it matter how far below the threshold? Both questions are plausibly answered positively on the basis of a priority view below the threshold: Yes, numbers count and it matters how bad people fare below the threshold. This more complex view can be stated in the following way (combining strong sufficientarianism with a negative priority view). The first two claims characterize strong sufficientarianism, the third and the fourth claim characterize the negative priority view: First, the avoidance of the imposition of the risk of rights violations in terms of people's sufficiency rights (and thus the risk of people falling below the threshold of sufficiency) has absolute or lexical priority. Second, both below and above the threshold it matters more to benefit persons the more persons are being benefited and the greater the benefits in question. But, tradeoffs between persons above and below the threshold are precluded. Third, if we cannot avoid the imposition of the risk of violating people's rights as specified by the sufficientarian threshold, to avoid risking people's sufficiency rights matters more (a) the worse off the person would be, (b) the more people are likely to be harmed and (c) the greater the weighted sum of rights violations. Fourth, analogously above the threshold: to avoid risking the violation of people's other rights or risking to harm their other claims matters more (a) the worse off the person would be, (b) the more people are likely to be wronged and (c) the greater the weighted sum of rights violations and harms caused.

Strong sufficientarianism can be criticized fourthly for not normatively distinguishing between the (non-reduction of the) imposition of risks of rights violations and the certain violation of the same rights. Despite the fact that there are cases, in which it is fully clear that imposing risks on others is impermissible, it often seems permissible or non-avoidable to impose certain risks on others (or not to fully reduce the imposition of risks), including sub-threshold risks. Giving the imposition of risks of rights violation below the threshold lexical priority, prohibits any action that comes with such risks (or does not fully reduce the imposition of such risks) if we have the option of avoiding the imposition of such risks. If we have the option of avoiding the imposition of such risks it is unclear how we should assess the differing likelihoods or uncertainty of rights violations.

These criticisms of strong sufficientarianism suggest, first, that the legitimacy of carrying out polices that do not reduce the imposition of risks of the violation of basic rights to the fullest degree possible depends on weighing all interests/rights both below and above the threshold that might be fulfilled or are under the threat of being violated. Second, given that we can often minimize risks only at considerable further costs, one needs to investigate how the imposition of larger risks of even below threshold rights violations can be justified.

If lexical priority is not adequate for cases of risk imposition, we have to consider more complex models for assigning an order of priority of certain rights. Birnbacher distinguishes two such models for the case of weighing the protection of actual claims (Birnbacher 2003): The first attributes fixed or relative weights to certain rights in order to receive an order of priority. The second more complex model also takes into account the extent, to which a right may be violated, if after weighing up the importance of all rights, the protection of another right (or other rights taken together) has priority in the case under consideration. This model presupposes the possibility of compromise. Taking into account the dimension of risk imposition, is likely to require an even more complex model of weighing rights. In response we should consider weak sufficientarianism that is a position that gives some, but not lexical priority to the risks of rights violations below the threshold.

The position of weak sufficientarianism can be described as follows and by including most of the features of the revised version of strong sufficientarianisms as delineated above:

- First, the avoidance of the imposition of the risk of rights violations in terms of people's sufficiency rights (and thus the risk of people falling below the threshold of sufficiency) has some priority.
- Second, both below and above the threshold it matters more to benefit and to avoid harm to persons (a) the more persons are being benefitted or suffer harm, (b) the higher the likelihood of the benefits (or harms) being realized (suffered) and (c) the greater the (benefits) harms in question. This means, that the determination of the normative weight of a risk of a rights violation depends on

basic criteria like the quality of the right and the quantity of the rights violation, i.e. the number of people affected by the risk of a rights violation as well as the number of rights that will possibly be violated. At the same time this also goes for possible benefits. Both below and above the threshold it matters more to benefit persons (a) the more persons are being benefited, (b) the higher the likelihood of the benefits being realized and (c) the greater the benefits in question. Such a position would allow for tradeoffs between persons above and below the threshold as well as between harms and benefits. Still, we would be able to assign special weight to risks of rights violations below the threshold. That means, that even though tradeoffs are possible, they would only be allowed in qualified situations and under consideration of the higher weight of risks of rights violations below the threshold and the higher weight of harms in comparison to benefits.

- Third, if we cannot avoid the imposition of the risk of violating people's rights as specified by the sufficientarian threshold, to avoid risking people's sufficiency rights matters more the worse off the person would be, the more people are likely to be wronged and the greater the weighted sum of rights violations.
- Fourth, above the threshold the avoidance of risking the violation of people's other rights or risking to harm their other claims matters more (a) the worse off the person is would be, (b) the more people are likely to be wronged and (c) the greater the weighted sum of rights violations and harms caused.

As the likelihood of a rights violation is an important part for such a position, we have to deal with difficult questions for unkown probabilities. In cases of Knightian uncertainty—where we cannot assign probabilities, probability ranges or levels of confidence to certain outcomes—risk aversion as such does not allow us to choose among options. In this context the question arises whether or not we have to equally weigh unspecified risks of harms and risks whose probability is known.

2 Responding to Unavoided Damage from the Perspective of Distributive Justice

Let us assume that risk-averse sufficientarianism allows us to assess policies of reducing the risks of possible earthquakes and that for a certain region a policy has been implemented that can be considered just. However, when an earthquake occurs it is likely to cause damage. As stated above a risk-averse sufficientarianism allows for people suffering damages that could have been avoided based on their position above the threshold or due to the circumstance that the costs for measures reducing the risk of these damages are considered to be too high. These damages are legitimately unavoided damages. Other damages can be considered unavoidable. Given the state of adaptation technology and people's options, in these cases there is no adaptation measure available to prevent people to suffer from damages caused by an earthquake above a certain magnitude.

How should we consider these damages? We will suggest that rather than regarding legitimately unavoided and unavoidable damages foremost as a reason for compensation for wrongdoing we should view them primarily as a reason for redistribution due to undeserved harms (Meyer and Roser 2010). One way to distinguish between the basic idea of redistribution and compensation starts with the premise that there is some baseline distribution of goods or well-being among people that is just. On the one hand this baseline distribution can be determined by a certain criterion, such as sufficientarianism or a more demanding understanding of justice. On the other hand we have to consider changes to the distribution which someone experiences as a result of his own responsible (and non-wrongful) choices, e.g. in an exchange of goods under conditions of a fair market. Let us assume that, before the earthquake occurred, the distribution of the relevant goods among the people in the society can be considered just.

Owing to the consequences of the earthquake, people will experience changes of their environmental or socio-economic circumstances and suffer from damages that will change the distribution of the relevant goods. If these damages are legitimately unavoided or unavoidable the reaction, the change calls for, is based on the idea of evening out undeserved harms (and possibly relative benefits) which are due to bad luck. This is a matter of (re-)distributive justice, not of compensation for wrongdoing.

However, if the damages caused by the earthquake could and should have been avoided we are facing a different situation. Here policies of reducing the risks of possible earthquakes cannot be considered just from the perspective of risk averse sufficientarianism. Rather, change to the distribution can be seen as the result of people's responsible wrongful choices, namely of having decided not to invest in the reduction of the imposition of risks of rights violations in the amount required by considerations of justice. In these cases the reaction, the change to the distribution calls for, is based on the wrongfulness of what occurred and we are operating in the realm of compensatory justice. The victims are owed compensation for their losses and by those who did wrong.

Of course, it will often be contested and very difficult to determine whether people acted wrongfully and by doing so contributed to the damages of an earthquake. People tend to disagree about how normatively to assess policies that aim at reducing the impact of possible earthquakes. Also, poor people tend to be more vulnerable to suffering from damages owing to changed circumstances caused by a natural catastrophe. Often the distribution of welfare among people in society before the earthquake is highly unequal; people tend to disagree about the causes of the inequality and whether the distribution can be considered just. If the unequal distribution is the result of other people's wrongful actions this by itself would justify claims to compensation and plausibly also additional claims to compensation when poor people suffer special damages as the effect of an earthquake.

Far from being experts for the empirical side of these questions in general and more specific for the situation of Nepal before and after the major earthquake in 2015, we see at least some factors that may provide claims for compensation. Nepal seems to be governed by a (a) general poverty of the population, combined with an unequal distribution of wealth, (b) which is sustained by a low level of education, that also has an impact on the lack of risk awareness towards potential impacts of natural catastrophes (including earthquakes), (c) a highly complicated and ineffective administration, that has failed to take (adequate) precautionary measures to the well-known high risk situation of potential catastrophic earthquakes in the region, and (d) a high level of corruption often decreasing the already limited resources for adaptation measures. From the perspective of justice these factors could speak in favor for owing compensation to damages that could and should have been avoided by those institutions responsible for the situation before the earthquake. The political feasibility of the fulfillment of such claims can, however, be questioned, due to the current political situation in the country.

Furthermore, as pointed out above, compensation (in the narrow sense of wrongdoers paying something to the wronged persons on the grounds of the injustice committed) is not the only kind of possible response to the damages people, and especially poor people suffer as the result of an earthquake. Given that many effects of an earthquake can be seen as undeserved harms, leveling off such effects on the basis of a concern for distributive justice is a plausible response. Whether, and if so, what principles of distributive justice apply at global level is a matter of dispute (Meyer and Sanklecha 2016). However, if at least minimally demanding principles do apply at global level—principles that attribute minimal positive universal and general welfare claims to all people against all other people —these cosmopolitan principles can also be applied to the distribution of duties to pay for measures of helping those who happen to suffer from earthquake damages, namely as a matter of, at least in part, bad luck.

Such an understanding would speak in favor of international aid for those who have been severely harmed and/or left off under the level of sufficiency after the earthquake in Nepal in 2015. Of course, whether aid provided by the international community and NGOs will find its way to those in need, is a further empirical question, for which we as philosophers do not claim expertise. Still, from the perspective of risk-averse sufficientarianism it is important to point out, that even if one holds parts of the political and administrative bodies responsible for avoidable damages, compensatory claims must not take priority over redistributive claims based on undeserved harms caused by legitimately unavoided and unavoidable damages. Especially in situations of severe need there exists the danger that responsibility is shifted from one side to the other, leaving the victims alone with their faith and worse off as they could be if either side would (at least partially) fulfill their duties based on compensatory as well as redistributive justice.

3 Conclusion

The paper addresses two central issues of a normative assessment of earthquakes and their impacts. First, we investigate into how we should reflect the complex uncertainties concerning the occurrence and impacts of earthquakes and of our normative assessment of policies to reduce the impact of possible earthquakes. Second, we ask how we should respond to unavoided and unavoidable damages caused by earthquakes.

One of the authors has argued elsewhere that sufficientarianism can be justified for the assessment of future-oriented policies (Meyer 2003; Meyer 2009a). In these previous publications it was also shown that a particular understanding of sufficientarianism can be justified, namely an understanding that attributes lexical priority to a rights-based threshold.

For the reasons given above we find that, owing to the complex uncertainties concerning the occurrence and impacts of earthquakes strong sufficientarianism is not adequate in assessing policies to reduce the impact of possible earthquakes. We propose to respond to these challenges on the basis of what we have called a risk-averse weak sufficientarianism. We submit a complex interpretation of such a view by suggesting that we should assess well-being both below and above the threshold in terms of a version of the priority view and by identifying several criteria for assessing the importance of the risks imposed. Such a view allows us to weigh risks of rights violations below as well as above the threshold and against each other as well as against possible benefits of an action or a policy, while at the same time one can assign special weight to risks of rights violations below the threshold. We think that such weighing is needed as the imposition of a risk will in most cases not have the same weight as a harm that will result with certainty.

However, the assessment of the complex risk-averse sufficientarianism as sketched in this paper will depend on having answered substantive questions. Among them, a central question is what rights should determine the threshold of well-being so that imposing the risk of violating these rights can be understood to be of particular normative relevance and, indeed, how important reaching the threshold or avoiding people falling below the threshold are. Also, while we identified criteria for assessing risks (among them, likelihood, number of people affected, seriousness of the harm and/or normative status of the rights violation) we have not attempted to specify how one should go about assessing differing risks of rights violations, setbacks of interests as well as not realizing benefits. A fully developed version of weak sufficientarianism would have to make important assumptions of the relative weight of interests/rights as well as risks of violating these rights, and would have to argue for the plausibility of these assumptions. It would further have to balance the different criteria for different cases.

Concerning the issue of how we should respond to unavoided and unavoidable damages caused by earthquakes we argue that we should view them primarily as a reason for redistribution due to undeserved harms and not as a reason for compensation in the narrow sense of wrongdoers having to pay something to the wronged persons on the grounds of the injustice committed. We do not exclude the possibility of wrongful action concerning the fair reduction of the risks of possible earthquakes and people's special vulnerabilities. However, we suggest that many effects of an earthquake can be seen as undeserved harms and that leveling off such effects on the basis of a concern for distributive justice is a plausible response.

References

Ackerman F, DeCanio SJ, Howarth RB, Sheeran K (2009) Limitations of integrated assement models of climate change. Clim Change 95:297–315

Azar C, Lindgren K (2003) Editorial commentary: catastrophic events and stochastic cost-benefit analysis of climate change. Clim Change 56:245–255

Birnbacher D (2003) Analytische Einführung in die Ethik. Walter de Gruyter, Berlin

Finkelstein C (2003) Is risk a harm? Univ Pennsylvania Law Rev 151:100–963

Füssel H-M (2007) Methodological and empirical flaws in the design and application of simple climate-economy models. Clim Change 81:161–185

Lempert RJ (2002) A new decision science for complex systems. Proc Natl Acad Sci USA 99:7309–7313

Lempert RJ, Collins MT (2007) Managing the risk of uncertain threshold responses: Comparison of robust, optimum, and precautionary approaches. Risk Anal 27:1009–1026

Meyer LH (2003) Past and future: the case for an identity-independent notion of harm. In: Meyer LH, Paulson SL, Pogge TW (eds) Rights, culture, and the law: themes from the legal and political philosophy of Joseph Raz. Oxford University Press, Oxford, England, pp 143–159

Meyer LH (2009a) Intergenerationelle Suffizienzgerechtigkeit. In: Goldschmidt N (ed) Generationengerechtigkeit. Ordnungsökonomische Konzepte, Mohr, pp 281–322

Meyer LH (2009b) Sufficientarianism. Both international and intergenerational? In: Schramm M et al (eds) Absolute poverty and global justice. Ashgate, London, pp 133–144

Meyer LH, Roser D (2010) Climate justice and historical emissions. Crit Rev Int Soc and polit philos 13:229–253

Meyer LH, Sanklecha P (2016) Philosophy of justice: extending liberal justice in space and time. In: Sabbagh C, Pogge M (eds) Handbook of social justice theory and research. Springer, New York, pp 15–35

Page EA (2006) Climate change, justice and future generations. Edward Elgar, Cheltenham

Page EA (2007) Justice between generations: investigating a sufficientarian approach. J Global Ethics 3:3–20

Perry S (2007) Risk, harm, interests, and rights. In: Lewens T (ed) Risk. Philosophical per-spectives, Routledge, pp 190–209

Raz J (1986) The morality of freedom. Clarendon Press, Oxford

Shiffrin S (1999) Wrongful life, procreative responsibility, and the significance of harm. Le-gal theory 5:117–148

Shue H (1993) Subsistence emissions and luxury emissions. Law and policy 15:39–59

Steigleder K (2016) Climate risks, climate economics, and the foundations of rights-based risk ethics. J Hum Rights 15:251–271

Thomson JJ (1986) Rights, restitution, and risk. Harvard University Press, Cambridge

Zimmermann MJ (2006) Risk, rights, and restitution. Philos Stud 128:285–311

Earthquake Preparedness Policy in Nepal

Volker Schneider and Antje Witting

Abstract Earthquake preparedness policy is described as a faltering policy process in Nepal. By reconstructing a chain of policy events at the national and international level, it is shown that relevant policy knowledge was already available by international networks in the early 1990s and was also used for national policy initiatives at that time. Effective building regulation, however, was introduced only late and inconsistently. The sluggish and faltering policy process is essentially explained by (1) a cultural and developmental context in which governments are overloaded with clashing problems, displacing creeping policy issues; (2) endemic policy discontinuity and inconsistency generated by political instability; (3) weak infrastructural power in which public administration is unable to implement policy choices on the ground; (4) rampant corruption, slowing down consistent policy enforcement and compliance with building regulation.

Keywords Public policy · Actor constellations · Policy networks
Building regulation · Policy discontinuity · Infrastructural power
Governance · Political instability · Corruption

1 Introduction

Politics cannot prevent earthquakes and other natural disasters, but effective public policy-making can improve the preparedness for such disasters and also their consequences. For instance, political and administrative intervention can formulate and implement infrastructural building programs and regulatory measures that support earthquake-proof construction and the retrofitting of buildings, schools, hospitals and other critical infrastructures. Also informative measures are of central importance which train people and increase attention for this type of constant threat.

V. Schneider (✉) · A. Witting
University of Konstanz, Konstanz, Germany
e-mail: volker.schneider@uni-konstanz.de

J.H. Kruhl et al. (eds.), *Living Under the Threat of Earthquakes*,
Springer Natural Hazards, https://doi.org/10.1007/978-3-319-68044-6_20

If governments fail to cope with such challenges, earthquakes may have severe "political aftershocks". They can lead to social unrest, changes of government, and even to the total collapse of political regimes. In this respect, earthquakes are of great political relevance. As the Lisbon earthquake of 1755 showed, large scale disasters can have extremely long-term effects on the political culture of societies. Nowadays such effects can have global ramifications. An astounding chain of effects was produced by the Fukushima earthquake in 2011. The earthquake triggered a tsunami, which then caused a nuclear disaster. This created a global media wave that arrived in Germany as a veritable "media tsunami" which strengthened the anti-nuclear movement in an unprecedented way. This resulted not only in a landslide victory of the Green Party in a Regional State in the South of Germany but also led to a complete turnaround in Germany's energy policy (Rinscheid 2015).

The present article does not deal with this kind of political consequences of earthquake disaster, but with the political capacities to be prepared for such kind of hazards, particularly by political and administrative measures and institutions that strengthen earthquake-related "Disaster Risk Reduction". Our case study is focused on Nepal's "pre-earthquake preparedness" in the narrow sense, and thus excludes questions regarding earthquake emergency response, disaster relief and reconstruction capacities (Malla et al. 2015). It explores the synchronic and diachronic patterns of political intervention to lower seismic risks after the 1988 earthquake. It traces the path from pre-seismic events to policy development and implementation. Our research question is, if and how the Nepalese society and its rather fragile political system were successful in developing specialized institutional devices to deal with the perception, anticipation and mitigation of earthquake hazards. This includes not only government and administration—as the core of the state—but the whole network of actors and stakeholder that are relevant for earthquake preparedness. This includes also a range of non-governmental actors, scientists and media, which participate in awareness-building, information exchange and knowledge pooling in this policy field. Our perspective thus goes beyond a mere administrative focus. It analyses the overall actor constellation and multi-level political processes that are involved in this policy process.

We outline Nepal's policy profile in a diachronic and synchronic perspective. In a first step we analyze the various policy events and actor involvements. In a second step we try to identify the various flaws and impairments to a timely and effective preparedness policy, before we draw some conclusions and discuss implications.

2 Earthquake Policy: Political Coping with Earthquake Hazards

As mentioned above, this paper does not deal with earthquake impacts, but looks for social, political and administrative capacities to anticipate the impact of earthquake hazards. We assume that this performance is a function of essentially three capacities: First, capacities of problem perception and agenda-setting. Second, decision-making power and expertise for program formulation. Third, administrative capacities of program implementation.

The focus will be on pre-disaster precautionary measures. In public policy research this means to study policy sequences in a diachronic perspective (1) when and how the creeping problem of seismic risk was recognized, acknowledged and defined as an urgent issue; (2) when and how the issue proceeded to the governmental agenda and public programs where formulated; and (3) when and how the programs and plans were implemented.

From a synchronous viewpoint, particular emphasis will be put on actor constellations in which the various policies were formulated and implemented. In this respect we apply a combination of perspectives in public policy analysis: (1) the policy subsystem approach emphasizing a specialized actor set involved in political problem solving, i.e. public policy-making in specific policy-sectors (Howlett and Ramesh 1995); (2) the policy network angle, emphasizing interrelatedness and the relational dimension of policy-making (Kenis and Schneider 1991; Schneider 2015); (3) a governance perspective of public policy, emphasizing an extended view of societal process-processing including not only national governmental actors and their specific political and administrative resources, but also non-governmental actors from civil society and also from the international level (Mayntz 2003; Schneider 2012).

Earthquakes imply a specific policy problem profile. In most cases earthquakes imply cascading effects, linking specific natural hazards to other disasters (Kumasaki et al. 2016). Earthquakes are not limited to earth movements but also trigger tsunamis, landslides, and lead to collapses of buildings and infrastructures and, as the Fukushima disaster showed, even to the breakdown of total techno-industrial complexes. Because of this network-like impact pattern, earthquake preparedness policy thus involves multiple policy sectors—including security, communication, infrastructure, and even health policy.

In a temporal perspective, earthquakes imply a particular risk profile that combines frequent light shocks with sporadic large-scale disasters. Also important is that earthquake hazards increase with population density. In the case of Nepal, both factors of risk are of particular importance. First, Nepal is located at the active boundary between the Indo-Australian and the Eurasian plates. The subduction of the Indian continental crust under the Eurasian continental crust not only led to the formation of the largest mountain chain on Earth but also continuously triggers seismic events of partly high magnitudes, such as the earthquakes in 1934, 1988 and 2015 (Pokhrel et al. 2009). Second, as one of the poorest countries in the world, Nepal is characterized by a high population growth as well as a high rate of urbanization. These are conditions that increase vulnerability and exposure to natural hazards (Liu et al. 2016). Today, an ever-growing part of the population lives in the Kathmandu Valley. Figures 1 and 2 are illustrating the development of both risk and vulnerability factors within the last two decades.

The diagram in Fig. 1 shows all earthquakes in the area of Nepal with a magnitude of greater than 4.5 within the last 30 years. It is produced on the basis of historical earthquake data (significant events, lists and maps by magnitude, year, and location) provided by the U.S. Geological Survey (USGS 2017). Two of these earthquakes have resulted in large numbers of lives lost at the time.

Figure 2 depicts the general increase of population (in percent) in the past 30 years and population growth in the largest city, i.e. Kathmandu. The data are

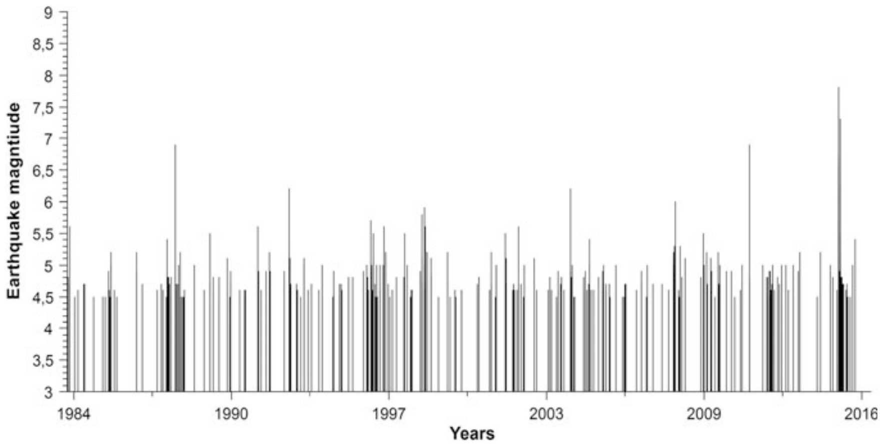


Fig. 1 Earthquakes in Nepal (1985–2015). Earthquakes in a magnitude of greater than 4.5

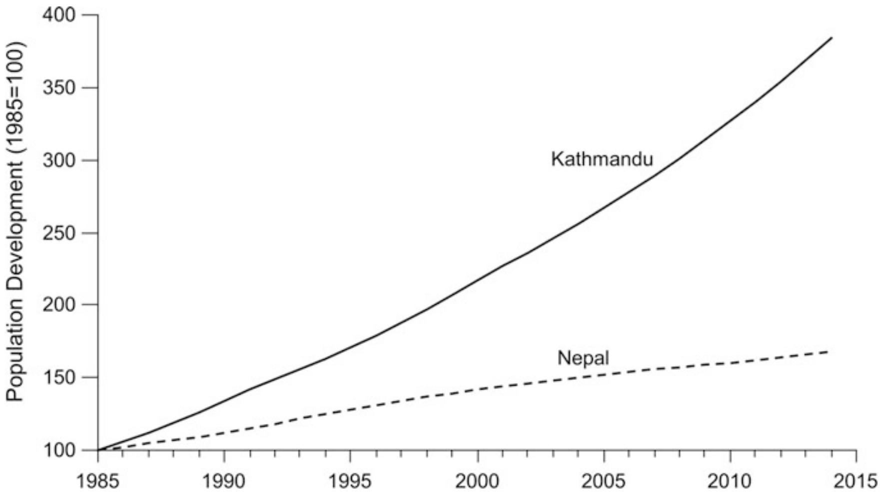


Fig. 2 Population development in Nepal. Comparison of total population growth with population increase in Kathmandu based on World Bank data (The World Bank 2017)

provided by the World Bank Development Indicator dataset (The World Bank 2017). The overall population in Nepal increased by around 70%, while the population in Kathmandu by almost 400%. Not only the fast-growing population in this geographic area, but also the agglomeration of economic activities increase earthquake risk, exposure and the vulnerability in a creeping manner, although the earthquake hazard as such remains constant and unchanged (Schneider et al. 2013; Liu et al. 2016).

In a preparedness policy perspective we have to ask, how this problem of increasing risk has been perceived and processed by the relevant Nepalese political institutions and policy subsystems. We want to know in which form the potentially disastrous impacts had been anticipated, and when these problems were publicly recognized and set on the governmental agenda. When and how does this lead to the formulation and implementation of political and administrative programs?

These questions only can be answered by a historical reconstruction of the various events and actors constellations that were related to this policy process. Since the greatest damage to human life is caused by collapsing buildings in earthquakes, we will particularly inquire, when and how specific regulation was promoted, to anticipate hazards by earthquake-resistant construction. For this we used press reports, governmental documents, and secondary literature to collect data on policy events at different levels of action in different areas of society that have shaped policy development in Nepal's earthquake preparedness in the last 30 years.

Figure 3 depicts the major policy events and their interrelatedness between the national and international level, and the governmental and non-governmental level. Explanations of the abbreviations and references are given in the annex of this article. The number of event relates to descriptions in Annex 1. At the top of the figure the three most important earthquakes in this period are indicated. The policy events at the lower levels include both policy measures such as laws, regulations and programs of action as well as the creation of institutions, networks and forums

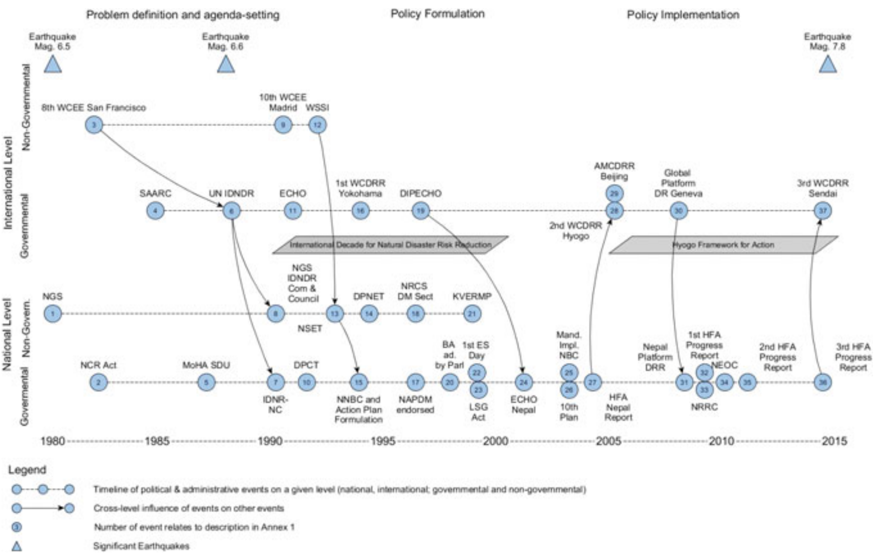


Fig. 3 Earthquake preparedness policy events at national and international level. Number of event relates to description in Annex 1. *Arrows* indicate cross-level influence of events on other events, emphasizing international policy diffusion

of information exchange. The events are taking place in governmental and non-governmental arenas.

From the perspective of the aforementioned policy cycle, it seems reasonable to divide preparedness policy into three phases: (1) problem perception and agenda-setting, (2) initiation and formulation of policy programs (in our case mainly focused on the national building code), and (3) the implementation of the various measures and regulations.

In the first phase, the development of policy corresponds to a well-known pattern of international policy diffusion. In this logic public policies are initiated by actors at the international level—such as the United Nations (UN) or European Union (EU), or even non-governmental organizations—which then migrate into national contexts (Stone 2004).

Initially, the policy issue was popularized by international academic circles and fed into the UN system. The declaration of the 1990s as the "International Decade for Natural Disaster Risk Reduction" by the General Assembly of the UN and the establishment of offices and conferences on this track influenced the national level in Nepal in a significant way. A supporting factor in this respect was the democratic transformation of the political system at the beginning of the 1990s in the context of the democratization wave, which at that time affected Eastern Europe and Asia, and also the increasing international openness.

In cooperation with the UN and international NGOs, the Nepalese government started to develop a national policy framework for Disaster Risk Reduction. The Ministry of Housing and Physical Planning and the Ministry of Home Affairs and the Department of Urban Development and Building Construction first raised the issue in late 1991. The considerable number of casualties caused by the collapse of public buildings in the 1988 earthquake is likely to have been a strong motivator for the ministries to enforce and monitor the development and implementation of a country-wide building code (Department of Urban Development and Building Construction 1994, 2003).

With the technical assistance of the United Nations Development Program (UNDP) a three-year program entitled "Policy and Technical Support to the Urban Sector" was established within the ministry. As part of this program, the "National Building Code Development" project was launched in 1992 within the Department of Urban Development and Building Construction. The project focused on seismic hazard mapping and risk assessment, the preparation of a building code and the development of alternative building materials and technologies. It sub-contracted a number of international consultants, such as Beca Consultants from New Zealand, Golder Associates from Canada and Urban Regional Research from the USA (Department of Urban Development and Building Construction 1994, 2003). Ties to international consultants and sponsors that have had experiences with managing seismic hazards in the region were the nucleus of a network incorporating not only governmental but also non-governmental actors at different levels, which later became more and more important. The review of the policy framework suggests that the strongest players on the non-governmental level were the National Society for Earthquake Technology (NSET) and the UNDP as well as Oxfam and the Red

Cross in Nepal. These independent observers sponsored or conducted studies that promoted policy change, in particular after Nepal's deep political crisis ending with 2006 Accord between the Civil War parties (see for example: National Society for Earthquake Technology Nepal 2008; Nepal Red Cross Society and International Federation of Red Cross and Red Cross Crescent Societies 2011; Oxfam 2015).

In order to understand the abilities and limitations of the various actors, we must also take into account changes in the environment and institutional contexts. In this respect, the transformation of the political regime was an important factor. A big problem in Nepal's democratization process was, as will be shown later on in more detail, the change of the old aristocratic regime towards democracy. This created not consolidation but rather instability. So it was astonishing that despite various political crises, the beginning of a Civil War and several governmental changes, six years later the Nepalese Government succeeded in passing the national *Building* Act (#2055) in 1998. It specified the requirements for the regulation of building construction in order to make buildings more earthquake resistant.

Because of the Civil War and other political instability, it took another 8 years until implementation of the building regulation was put into practice. In 2007 and 2010, the activities were resumed. In cooperation with UNDP, the Ministry of Home Affairs and the Department of Urban Development and Building launched the Earthquake Risk Reduction and Recovery Preparedness program. After the 2006 Accord, the National Society for Earthquake Technology and the UNDP as well as Oxfam and the Red Cross moved the issue back onto the public and political agenda and finally to the administrative arena.

The 1998 Building Act together with the 2009 Building Regulation then provided a legal framework for earthquake resistant construction. This framework authorized municipalities to implement the National Building Code, but did not specify a particular organization that was authorized to follow up and monitor the compliance. As such, no party was accountable or felt responsible. Despite the National Building Code under the Building Act and the Nepal Standard (an adaptation of various International Standards—i.e. British and Indian Standards) being published in 1994 and updated and formally approved in 2003 (now including 23 Volumes), only a small fraction of Nepal's municipalities (a bit more than 10%) had implemented it by 2015 [26 of 217] (Prasad 2015).

The implementation process was slow. The Earthquake Risk Reduction and Recovery Program with UNDP support and as part of the Hyogo Framework for Action (HFA) disseminated the National Building Code in five municipalities between 2007 and 2010 and published a report in 2011 which stated: Mandatory Rules of Thumb within the National Building Code (NBC 201–205) are in place to guide owner-builders of small-builds (typically non-engineered construction) to build earthquake and fire safe small-builds. This was a pragmatic answer to a lack of resources to enforce the more comprehensive building regulations, but now in some way hinders the code's implementation. Another factor that impairs the effective implementation is the provision included in the 1994 code to not only comply with the building code but also the Nepal Standard or other approved Standards (i.e. Indian Standard) that are not necessarily complementary. This situation has created legal uncertainty confusing those applying for building permits and thus opting to find and exploit loopholes in the system. Civil servants on the ground are lacking who can assist in preparing a permit, and follow up to ensure that their advice is carried out. The prior situation has shown that the actors struggled to implement the code not only at community but also at municipal level. There is evidence that this centralized organization of the political system hinders implementation in lower-ranking jurisdiction (Government of Nepal et al. 2009; Government of Nepal 2015; Oxfam 2015).

In contrast, with the National Action Plan on Disaster Management in Nepal (agreed in 1996) and its National Strategy for Disaster Risk Management (agreed in 2009) the Nepalese government has gone some way to comply with international recommendations and given more emphasis to Disaster Risk Reduction (NSET 2008). The latter is designed to dovetail the Disaster Management Act (prepared in 2008 and coordinated by the Nepal Centre for Disaster Management with assistance by Oxfam) and provides a broad framework for Disaster Risk Reduction management. It also provides a coherent model for district and local levels integrating all disaster managements into single committees at each level. It appears to be strongly supported by some district governments, which are already adopting its disaster management strategies. The Ministry of Local Development and the National Authority for Disaster Risk Management are responsible for providing overall guidance and support to the above (Nepal Red Cross Society and International Federation of Red Cross and Red Cross Crescent Societies 2011; Oxfam 2015).

Another strong advocate for the implementation of the National Disaster Management Strategy is the Nepal Risk Reduction Consortium established in this context. It is an international body (incl. Asian Development Bank; UN's Office for the Coordination of Humanitarian Affairs and UNDP; World Bank etc.) cooperating with the Government of Nepal. It is chaired by the Ministry of Home Affairs and is grounded onto the UN's (International Strategy for Disaster Reduction) Hyogo Framework for Action (HFA) 2005–2015, an international program aiming at increasing disaster preparedness, which was issued as a part of the World Conference on Disaster Reduction in January 2005, in Kobe, Japan. In 2005 at the second World Conference on Disaster Reduction in Hyogo, Japan, a national delegation from Nepal took part and reported on disaster reduction policy and particularly the implementation of the building code and other policy measures (Nepal Red Cross Society and International Federation of Red Cross and Red Cross Crescent Societies 2011; Ministry of Home Affairs 2015a).

By this conference, the HFA process was institutionalized which exerted international pressure on national implementation processes. In this process, the Ministry of Home Affairs reported periodically about its implementation activities. The first national HFA progress report was submitted in 2009 and was remarkable critical. It described a situation in which institutional commitment was attained, but further achievements were neither comprehensive nor substantial. A serious problem was seen in the decentralized administration following the Local Self-Governance Act (1999), which however was lacking a "systematic and assured mechanism of resource allocation and distribution to the local authorities from the central government" (Ministry of Home Affairs 2009). In this sense, also the HFA reports in 2011 and 2015 pointed to major implementation gaps. Interestingly, the 2015 report was submitted few days before the Gorkha Earthquake. The earthquake was a reality check, which unfortunately showed that Nepal's Earthquake Preparedness was insufficient (Ministry of Home Affairs 2011a, 2015a, b).

Following the earthquake in 2015, the government endorsed Fundamental Construction Bylaws on Settlement Development, Urban Planning and Building Construction, prepared by the Ministry of Federal Affairs and Local Development in the same year. It is to state that the authorities would face legal action when they approve designs or the construction of buildings owned by public entity and local authority without adopting the existing building code. Besides, the municipalities and the Village Development Committees (VDC) with more than 1000 households are required to follow the code to allow new construction (as cited by Kathmandu Post, November 11th, 2015). The revised legal framework now gives actors the authority to enforce the building code under specific circumstances also beyond the municipal level. As such, it has slightly improved its capacity to enforce the code and thus control building activities at the VDC level.

To get a rough impression of the actor constellation that was involved in the design and implementation of Nepal's land use policies (here in particular the National Building code) in the domain of earthquake preparedness, we conducted a qualitative content analysis of English language newspapers in Nepal. Our research focused on articles in the LexisNexis database selecting articles between 1980 and 2015 with the search operators "earthquake AND [prediction OR preparedness OR building code OR retrofit OR land use) AND LAND (Nepal)]". Manual coding (involving two independent coders) followed the criteria: actors engaged in the administrative planning; coordination; organization; monitoring (transparency, accountability, stakeholder involvement, corruption) with regards to agreeing and enforcing building codes/land use plans for housing developments/critical infrastructures. In the time frame from 2005 to March 2015 until the earthquake, we found 212 articles of relevance and counted the mentioning of various actors. Table 1 reports the results for the Top 10 of the most mentioned actors and also the categorization of the various actor types (governmental and non-governmental; local, national and international).

While it is no surprise that the Nepalese government is at the top, the prominent position of NSET, a national nongovernmental actor is astonishing. International organizations such as UNDP and the UN have been highly visible in the media.

Table 1 Prominent policy actors on earthquake preparedness policy mentioned in English language newspapers in Nepal

Actors	Type	Mentions
Nepal Government	GO	45
National Society for Earthquake Technology	NGO	27
Department of Urban Development and Building Construction	GO	15
Kathmandu Metropolitan City Office	LGO	13
United Nations Development Program	INGO	10
United Nations	INGO	9
Municipalities	LGO	9
USAID	INGO	8
Ministry of Urban Development	GO	5
Department of Education	GO	4

3 Flaws and Impairments in Preparedness Policy

Against the background of this policy development, we have to ask why these risks and the need for preventive policies had been acknowledged so late. Why the political system needed a full decade to enforce mandatory building regulations? Why particularly the implementation of preparedness measures in towns and in the countryside was faltering? In summary, we have to ask which were the major impairments and complicating factors, which have weakened the capacity of Nepal to effectively reduce the fatalities of earthquake by effective preparedness policies.

While there have been some factors that have fostered a preventive, forward-looking and sustainable policy, such as the democratic and international opening up of the political system and Nepalese society as a whole. It is interesting, that Nepal's membership in Intergovernmental Organizations grew from 22 in 1985 to 55 in 2015. However, there were also many events, processes and conditions, which impeded an effective preparedness policy. In the following sections, we will focus on four factors, which in our perspective have hindered or at least impaired the formulation and, above all, the implementation of an effective earthquake preparedness policy.

3.1 Over-Crowded by Social and Economic Problems and a Whole Array of Natural Disasters

Despite all the criticism of bad government in the last 30 years, it is important to remember that Nepal is not only one of the poorest countries in the world, but also a country that is exposed—based on its geographic location—to far greater risk of natural disasters than most of the other countries in the world. A network of international organizations led by the EU Commission has compiled a global

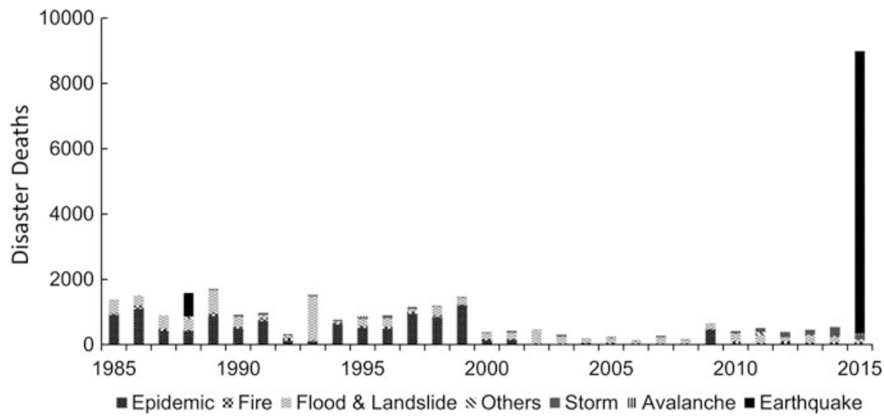


Fig. 4 Fatalities in Natural Disasters in Nepal 1985–2015. Historical and recent data are provided by the Nepal's Disaster Report 2015 (Ministry of Home Affairs 2015b)

database of disaster risks. This database provides an index for risk management classifying 191 countries in terms of risk, vulnerability and coping capacity. In this ranking, Nepal ranks within the group of countries exposed to high and very high risks and vulnerabilities (INFORM 2017). This category includes countries in the Middle East, South Asia and a large part of Africa.

Much of the problems of Nepal are also linked to its social and economic situation. UNDP ranks this country still in the lowest category of his most recent Human Development Index (HDI) statistics, close to countries such as Pakistan and Myanmar (UNDP 2015a). The poverty in Nepal results in a permanent lack of sufficient resources. Such immediate economic pressures usually prevent long-term and sustainable political planning.

A similar problem-displacing effect stems from the fact that earthquakes are not the only natural hazards with which Nepal is struggling (Pokhrel et al. 2009). It experiences frequent floods and landslides, particularly in the middle and western regions. Continuous and frequent natural disasters displace or superimpose sporadic disasters, even if the destructive potential of the sporadic disasters is much greater. Figure 4 shows the multitude of disaster fatalities that Nepal experienced within the last 30 years. Historical and recent data are provided by the Nepal's Disaster Report 2015 (Ministry of Home Affairs 2015b).

3.2 Social Unrest and Instabilities of the Political System

For centuries Nepal has been culturally and politically linked to an absolute monarchy as a traditional form of political power (Whelpton 2005). Political but also ethnical and religious components are here connected in a highly complex way (Bhandari 2014). Accelerated modernization in the second half of the twentieth century and the democratization wave at its end—the Euro-Asian Spring—unleashed centrifugal forces that ultimately culminated in the Civil War between 1996 and 2006. The political violence peaked in 2001 with the assassination of the king and nine other members of the royal family. Between 1996 and 2006 fractions of the communist party initiated a rebellion against the government by exploiting social grievances, economic deprivation, and political marginalization in rural areas. The warfare lasted a decade, and a comprehensive peace accord was only reached in 2006. In the following year the monarchy was abolished and Nepal became a Federal Republic (Bhandari 2014). Figure 5 indicates these regime transformations by dotted lines, based on the well-known POLITY IV data set (Marshall and Gurr 2014).

These conflicts too were ultimately detrimental to sustainable policy, since they absorbed the government to a large degree and impaired its action capacity. But it is surprising that during this time particularly civil society organizations such as the NSET succeeded, against all odds, to keep the issue of earthquake preparedness on the political agenda.

However, political violence was not the only barrier for problem recognition, policy formulation and consistent implementation. During this whole period, Nepal not only faced two profound regime transformations, but also a vast number of governmental changes. Particularly the fragmented party system made it extremely difficult to organize stable majorities. If one takes the official change of heads of governments as a proxy variable, the average lifetime of a government in the last 30 years was a bit more than one year. Figure 5 depicts these changes by a line chart on the basis of a list of prime ministers and heads of governments published in Wikipedia (https://en.wikipedia.org/wiki/List_of_Prime_Ministers_of_Nepal#References).

Frequent votes of no-confidence thus created low policy continuity (Hagen 2012: 90–91). New governments often set new priorities, and sometimes recognized problems were even completely removed from the policy agenda, initiated

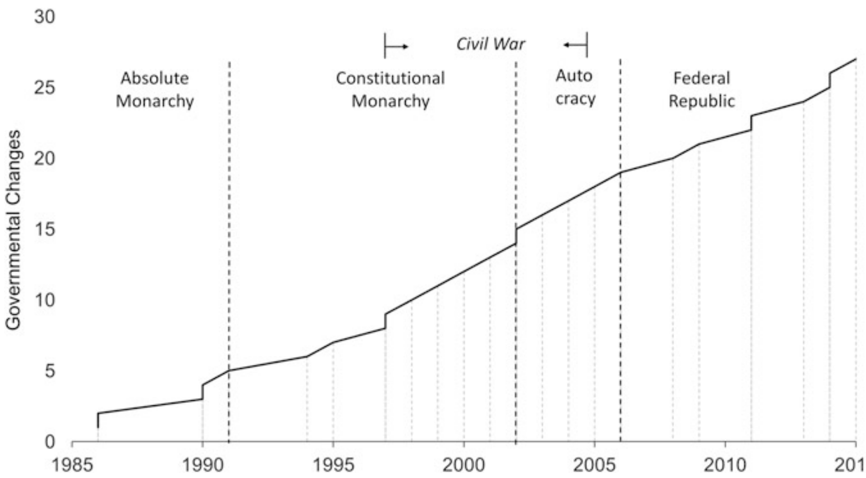


Fig. 5 Regime transformations and governmental changes. *Line chart* indicates cumulative number of government changes between 1985 and 2015

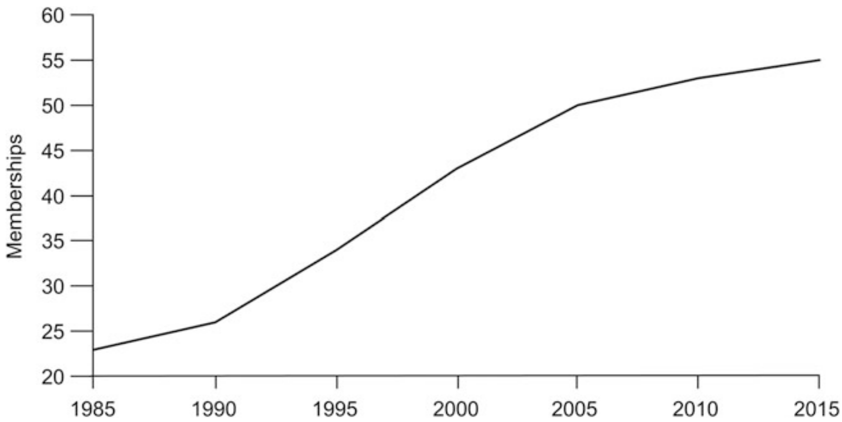


Fig. 6 The political globalization of Nepal. Development of Nepal's memberships in intergovernmental organizations

programs were suspended, and sometimes the laws passed by the old government were not implemented. Due to many votes of no-confidence this was an endemic problem in Nepal during the last decades. A consistent and sustainable processing of policy problems was thus difficult in such an unstable political context.

Political instability thus absorbed the Nepalese government to a large degree, and hindered efforts to address the issue of disaster preparedness in a consistent and sustainable manner. This is crystallized particularly in the failure to implement the National Strategy for Disaster Risk Reduction or ratify the Disaster Management Act. The legislation that is currently in place is open to interpretation, with no specific targets given. Also, it does not assign clear authority to specific actors, making them accountable for failing to introduce the necessary policies.

In this context, the increasingly close embedding of Nepal in the network of international organizations and stakeholders was an important force, which counteracted the restraining national forces. As shown in Fig. 6, Nepal was particularly involved in the process of political globalization during the 1990s, for which membership relationships in intergovernmental organizations can be taken as an indicator. Data for this relationships are collected from CIA world fact books from 1985 to 2015 (CIA 2015).

3.3 Civil Society and Societal Knowledge Infrastructure

Although with NSET, the Nepalese civil society possessed an important actor that kept the preparedness policy issue on the political agenda, few other national civil society actors could exert pressure on the government to drive effective Disaster

Risk Reduction. National science, too, did not play the role that it usually occupies in policy advocacy in highly developed countries. Scholars at the few autonomous universities that exist in Nepal lack sufficient resources to fulfill such a brokerage role between state and society (Bhatta 2012).

We must remember, however, that social and political liberty, particularly the freedom of speech and press was severely restricted during many periods of the past thirty years (Fig. 7). Prior to the 2006 the Freedom of Speech Publications Act of 1980 hindered the publication of materials with potential to undermine the interests of sovereignty of the nation; the principles of the constitution or encourage, abet or propagate party politics. Although the constitution at the time guaranteed freedom of speech, in practice journalists treated a fine line to avoid imprisonment. Although the Act was repealed in the context of the pro-democracy movement, social and political struggles continued to undermine the raise and the credibility until today. Given these circumstances, media outlets and independent journalists still failed to implement the 1993 Working Journalist Act (revised in 2007) or the 2003 Nepal Press Council and Federation of Nepalese Journalists' Code of Conduct (revised 2008) (Gurung 2011). Ownership issues and self-censorship in light of continuous harassment further undermined the credibility of the media system up until the 2015 earthquake. This weakened its role as an independent observer that can act as a credible and trustful broker between state and society with regards to disaster risk reduction planning and implementation. Journalists reported threats to well-being if they publish stories on the criminal or misconduct of the politically or economically powerful (Gurung 2011). The Federation of Nepalese Journalists' monthly media monitor shows that the administrative system repeatedly failed to address the situation and protect journalists appropriately. It is important to note in this context that improvements have been observed in this context. An indication of the overall improvement of the situation of journalistic reporting is Nepal's position at the global impunity index (GII). This indicator is compiled by the Committee on Protect Journalists (CPJ) and measures unsolved journalist murders per 1 million inhabitants. Between 2002 and 2011 a whole series of murders of journalists had been registered in Nepal, so Nepal ranked relatively high at the index in 2012 (i.e. at position 6 just below Colombia and above Afghanistan). However, in 2013 Nepal has completely disappeared from this list and has never returned (Committee to Protect Journalists 2012).

The changing development of civil liberties and freedom of speech in Nepal is presented in Fig. 7 on the basis of the well-known Freedom House indicators (Freedom House 2017). The US based Freedom House publishes an annual report in which the current state of civil and political rights in most of the countries in the world is rated on a scale from 1 (most free) to 7 (least free).

An even greater obstacle to the spread of information, however, has long been the general socio-economic situation of the population. At the beginning of the 21st century, only a small part of the population was literate and had access to mass media. Only few could afford a daily newspaper let alone have access to a computer or own a mobile phone. Important in this context is the gap between the urban and rural population. Modern forms of communication were significantly less common

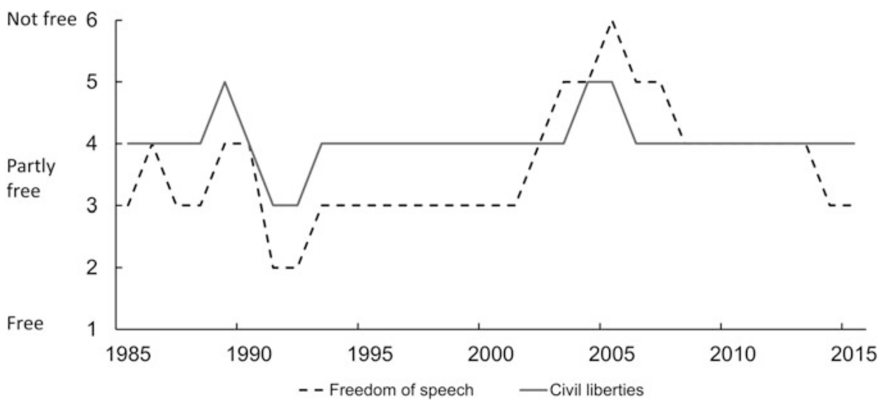


Fig. 7 Freedom and civil liberties. Nepal's ranking in the Freedom House reports with regards to civil and political rights. The scale ranges from 1 (most free) to 7 (least free) (Freedom House 2017)

in rural areas, in which—according to the last census in 2011—still four fifths of the Nepalese households lived (see Table 2).

Poor transportation and ICT infrastructure made access to information for the rural population more difficult. Here messages of public importance are still transmitted via radio or still carried by traditional means (Gurung 2011). However, a promising development is that the penetration of the country with mobile radio has reached an approximate full supply in the last 10 years.

Table 2 Nepal's communication infrastructure in 2011 (CBS 2014)

	Nepal total	Urban	Rural	Nepal total	Urban	Rural
	Million households			In percent		
Households	4.6	1.0	3.6	100	22	78
Households with means of communication						
Radio	2.8	0.6	2.2	60	57	61
TV	2.0	0.6	1.3	43	64	37
Cable TV	1.0	0.6	0.5	23	57	14
PC	0.4	0.2	0.1	9	25	4
Internet	0.2	0.1	0.1	4	13	2
Telephone	0.4	0.2	0.2	9	24	5
Mobile Phone	3.5	0.9	2.6	76	89	73

3.4 Weak Public Administration and Infrastructural Implementation Power

In light of the 2015 earthquake, in which the majority of people was killed from collapsing building, the implementation problems of the national building code are a further impairment for effective policy-making. The current framework lacks effective mechanisms to ensure the implementation of the code particularly in the rural areas that are managed by VDCs. Due to this rural structure and based on the Local Self-Governance Act (1999), Nepal's public administration has a skewed structure. The "infrastructural power of the state" (Mann 2008) in terms of systematic administrative penetration of the scattered territory is rather weak. In a country where most of the population still lives in the countryside, the government depends in policy implementation at the local level on the active monitoring and support by the local administration.

The administrative penetration of rural areas by centrally administrated policies is highly problematic. For instance, in the 2015 national progress report on the implementation of the HFA it was reported that only one quarter of the Nepal's VDCs and municipalities had been reached with the Disaster Risk Reduction program. While many district, local and national actors work effectively with communities, the lack of legally mandated coordination limits the scope and capacity of Community Based Disaster Risk Reduction Management projects and challenges integration of Disaster Risk Reduction across all levels. At their best, these projects work with local and district authorities closely, entrenching Disaster Risk Reduction projects and committees into local government. The projects provide training and risk awareness, and build capacities for related sustainable planning processes in the future. However, the lack of current electives at local level (relying instead upon civil servants until local elections are held) and relative geographical isolation can result in incoherence between Community Based Disaster Risk Reduction Management and Disaster Risk Reduction at the national level.

The lack of a Disaster Management Act, the challenges of political transition and the on-going push to engage full community participation in Disaster Risk Reduction, are all factors to overcome before reaching a sustainable approach to Disaster Risk Reduction. The Disaster Management Act is hoped to address these challenges by providing an implementation authority and coordinating mechanisms at all levels. Though not yet decided, it is hoped that this act will establish integrated multi-tasked and multi-skilled Disaster Risk Management Committees at the district and local levels to further promote coherence, community engagement and coordination. However, the current lack of legal mandated coordination across national, district and local levels regarding Disaster Risk Reduction implementation and policy still remains a challenge.

Administrative agencies and resources are concentrated in the center, i.e. the Kathmandu area, and the distribution of resources from central government down to local authorities is unbalanced and does not correspond to the growing tasks at the

Table 3 Revenue sharing among the levels of government in selected countries (Lamichhane 2012)

Countries	Share of Central Government in percent	Share of Provinces in percent	Share of Local Government in percent	Total revenue in percent of GDP
Nepal (2009)	95	–	5	12
India (1995)	64	33	3	15
Brazil (2001)	58	26	16	24
Switzerland (2009)	59	25	16	18
Germany (2009)	70	22	8	26

local level. Toni Hagen, a profound expert on Nepal, compares the situation there with federal Switzerland and writes: "In Switzerland, the money of taxpayers flows, on every level, mainly from the center to the periphery. In Nepal the flow of tax money goes the other direction, namely from the periphery to the center" (Hagen 2012: 88). The skewness of the distribution becomes particularly clear when comparing Nepal with other countries. Table 3 compares the sharing of governmental revenue between different levels of government between a selected set of countries. In Nepal the distribution is highly unbalanced, where 95% are concentrated on central government (Lamichhane 2012).

Although administrative weaknesses in Nepal undoubtedly also have cultural causes (e.g. fatalism and Brahmanism), the main weakness undoubtedly lies—particularly in the policy areas that are relevant in our case—in this unbalanced sharing of resources between the center and the decentralized administrative units. The organizational integration and financial equipment of Nepal's public administration does not keep up with its political federalization. As decentralization at the political level was difficult to achieve in a lengthy political process leading to the new constitution (Lecours and Arban 2015), decentralization is even more challenging at the administrative level. The federalization envisaged by the new constitution presupposes a whole background structure of functioning political-administrative institutions, and is therefore, as Bhandari, rightly expressed, "not a one-day job" (Bhandari 2014).

We can summarize that Nepal's core problem was that its governance capacity was declining over a long period. Multiple factors such as centralization of power resources but also corruption, ethnical fragmentation, and bias towards urban development undermined the effective formulation and implementation of collective decisions (Sharma 2012).

For several years, the World Bank has been trying to describe the development of state control and regulation power by means of governance indicators (Kaufmann et al. 2011). On the basis on these data (The World Bank 2016) Fig. 8 depicts the evolution of Nepal's capacity of governance during the last three

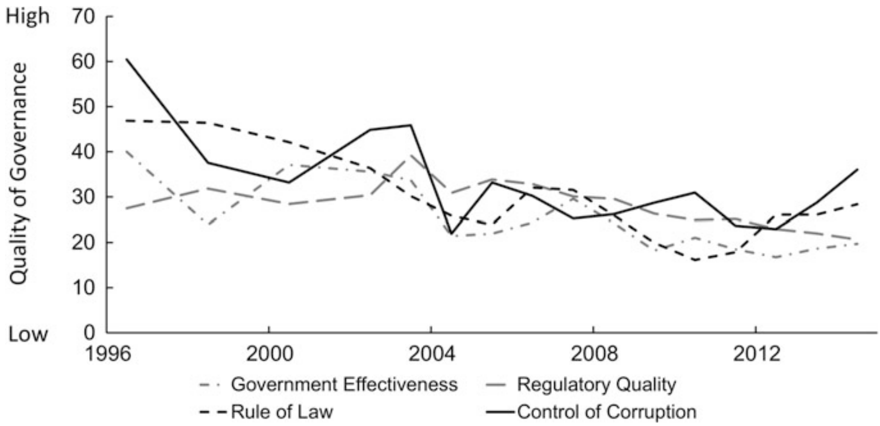


Fig. 8 Quality of governance. The evolution of indicators of governance quality in Nepal based on World Bank data (The World Bank 2016)

decades. The indicators show that quality declined since the 1990s and only slightly improved during the past years.

An important dimension of governance capacity is accountability and the absence of corruption. Interestingly, these were factors which in a larger comparative study were identified to significantly explain effective earthquake prevention through building regulation (Keefer et al. 2011). Even in metropolitan areas, where binding rules could be more easily observed and implemented than in rural settings, parts of the administration are either incapable or corrupt to penalize even blatant architectural crimes. Three days after the 2015 earthquake the newspaper Nepali Times told the story of a striking example: A building in KMC-6 was called 'Saat Talle' because it was the only seven-story house in the neighborhood. Its owner had obtained KMC approval to build a five-story house. However, he added illegally two floors. When it collapsed on 25 April, this building alone killed 30 people. The central challenge for earthquake preparedness in Nepal is therefore not so much the mobilization of sophisticated knowledge and advanced technologies in the implementation of earthquake-proof construction projects, but more in the effective administrative allocation of resources in a highly decentralized context and a consistent implementation and enforcement of existing basic rules. As could be observed in other contexts (Karki and Lu 2015), government and public administration must not be a silent observer of violations of rules that can have lethal effects during the next earthquake.

4 Conclusion

In earthquakes, the greatest damage to human life is caused by collapsing buildings. The most important strategy to anticipate such risks is effective regulation for earthquake-resistant construction. The riddle to be solved in this analysis was the faltering and sluggish process of formulation and enforcement of building rules. By reconstructing the policy process, which included not only events at the national but also the international level, we were able to show that relevant policy knowledge by international networks was already available in the early 1990s, and also had been used for policy initiation at the national level. Our research identified an extensive network of state and non-state actors with access to science-based knowledge necessary to inform policy formulation and implementation.

The faltering policy process is explained by several political and non-political factors: in a cultural context, in which allegiance to a given fate is promoted (fatalism), and in the developmental context of a poor country where government is always under pressure by multiple clashing problems, rather slow-moving and looming problem such as earthquake risks are displaced and repressed. Also detrimental for effective policy-making where frequent governmental changes contributing to low policy continuity and consistency.

A further important factor was the weak infrastructural power of Nepal's government in a shattered landscape where it is particularly difficult to implement policy choices on the ground. Although the new constitution provides for a federal political order, administrative and fiscal federalization is only slightly developed. The administrative resources were and are still highly concentrated on the political center in Kathmandu. Local governments are still lacking legitimacy, authority and finances. Last but not least, the still rampant corruption is a major problem for effective and consistent policy enforcement.

Keeping people save from disaster has been a comparatively smaller topic on the public agenda during the last years. Hopes are that in the wake of the 2015 earthquake, the ideas and objectives of the 2015 Sendai Framework for Disaster Risk Reduction (2015–2013) about community involvement will now be implemented much more vigorously (UNDP 2015b). Still, to guarantee better disaster preparedness in the future, it will have no choice but to give the administrative units that are designated for these functions, more institutional power, and financial autonomy to ensure greater policy consistency and effectiveness.

Annex 1

List of Policy-Events Visualized in Fig. 3.

No.	Abbr. of policy-event	Explanation	References
1	NGS	Nepal Geological Society	https://en.wikipedia.org/wiki/Nepal_Geological_Society
2	NCR Act	Promulgation of Natural Calamity (Relief) Act	Ministry of Home Affairs (2011a)

(continued)

(continued)

No.	Abbr. of policy-event	Explanation	References
3	8th WCCE, San Francisco	8th World Conference on Earthquake Engineering	Shah et al. (1993)
4	SAARC	South Asian Association for Regional Cooperation	Dash (1996)
5	MoHA SDU	Establishment of Special Disaster Unit (SDU) in Ministry of Home Affairs	Ministry of Home Affairs (2011a)
6	UN IDNDR	International Decade for Natural Disaster Reduction (UN)	Aitsi-Selmi et al. (2015), Tozier de la Poterie and Baudoin (2015)
7	IDNR-NC	Formation of IDNDR National Committee; Formation of NGS-IDNDR Council	Ministry of Home Affairs (2011a)
8	IDNDR-Comm. & Council	IDNDR-Committee and Council	Ministry of Home Affairs (2011a)
9	10th WCCE, Madrid	8th World Conference on Earthquake Engineering	Shah et al. (1993)
10	DPCT	Establishment of Disaster Prevention Technical Center (DPTC) in Nepal	Ministry of Home Affairs (2011a)
11	ECHO	European Commission Office for Humanitarian Aid	Versluys (2009)
12	WSSI	1st World Seismic Safety Initiative in Bangkok	Shah et al. (1993)
13	NSET	National Society for Earthquake Technology	http://www.nset.org.np
14	DPNET	Disaster Preparedness Network Nepal	http://www.dpnet.org.np/
15	NNBC and Action Plan Formulation	Formulation of Nepal National Building Code and National Action Plan on Disaster Management	Ministry of Home Affairs (2011a)
16	WCDRR Yokohama	World Conference on Disaster Reduction, Yokohama, Japan	Aitsi-Selmi et al. (2015), Tozier de la Poterie and Baudoin (2015)
17	NAPDM endorsement	National Action Plan on Disaster Management endorsed by government	Ministry of Home Affairs (2011a)
18	NRCS DM Sect	Disaster Management section was setup at Nepal Red Cross Society (NRCS)	Ministry of Home Affairs (2011a)
19	DIPECHO	ECHO's Disaster Preparedness Programme (DIPECO)	Hollis (2014)

(continued)

(continued)

No.	Abbr. of policy-event	Explanation	References
20	BA ad. By Parl.	Building Act adopted by Parliament	Ministry of Home Affairs (2011a)
21	KVERMP	Kathmandu Valley Earthquake Risk Management Project launched	Dixit et al. (2000)
22	ES Day, 1st.	First Earthquake Safety Day (ESD) celebrated	Ministry of Home Affairs (2011a)
23	LSG Act	Local Self Governance Act promulgated	Ministry of Home Affairs (2011a)
24	DIPECHO Nepal	First DIPECHO project launched in Nepal	Ministry of Home Affairs (2011a), Harat et al. (2015)
25	Mandatory Impl. NBC	GON decides mandatory implementation of Building Code	Ministry of Home Affairs (2011a)
26	10th Plan	The Tenth Plan (2002–2007), providing overall strategic framework for government policy and planning	Ministry of Home Affairs (2011a)
27	Nepal Report	Nepal Report within Hyogo Framework for Action	Disaster Management Section, Ministry of Home Affairs; Aitsi-Selmi et al. (2015)
28	WCDRR Hyogo	World Conference on Disaster Reduction, Hyogo, Japan	Aitsi-Selmi et al. (2015), Tozier de la Poterie and Baudoin (2015)
29	AMCDR Beijing	First Asian Ministerial Conference on Disaster Risk Reduction in Beijing, China	Aitsi-Selmi et al. (2015)
30	Global Platform DR Geneva	Global Platform for Disaster Risk Reduction established in Geneva, Switzerland	Ministry of Home Affairs (2011a), Djalante (2012)
31	Nepal Platform DRR	National Platform for Disaster Risk Reduction (NPDRR) established	Ministry of Home Affairs (2011a)
32	HFA Progress Report	Nepal Report within Hyogo Framework for Action	Ministry of Home Affairs (2011b), Aitsi-Selmi et al. (2015)
33	NRRC	Nepal Risk Reduction Consortium Launched	Ministry of Home Affairs (2011a)
34	NEOC	National Emergency Operation Center established at the national level	Ministry of Home Affairs (2011a)

(continued)

(continued)

No.	Abbr. of policy-event	Explanation	References
35	HFA Progress Report	Nepal Report within Hyogo Framework for Action	Ministry of Home Affairs (2011b), Aitsi-Selmi et al. (2015)
36	HFA Progress Report	Nepal Report within Hyogo Framework for Action	Ministry of Home Affairs (2015a)
37	WCDRR Sendai	World Conference on Disaster Reduction, Sendai, Japan	Aisi-Selmi et al. (2015), Tozier de la Poterie and Baudoin (2015)

References

Aitsi-Selmi A, Egawa S, Sasaki H, Wannous C, Murray V (2015) The Sendai framework for disaster risk reduction: renewing the global commitment to people's resilience, health, and well-being. Int J Disaster Risk Sci 6:164–176. doi:10.1007/s13753-015-0050-9

Bhandari S (2014) Self-determination and constitution making in Nepal: constituent assembly, inclusion, and ethnic federalism. Springer, Singapore

Bhatta P (2012) Global ranking a dream too far for Nepal's long-degraded universities. http://www.universityworldnews.com/article.php?story=20120328082036102. Accessed 1 Jul 2016

CBS (2014) Statistical pocket book of Nepal. Government of Nepal, Central Bureau of Statistics

CIA (2015) World fact books 1985–2015. http://www.theodora.com/wfb/abc_world_fact_book.html. Accessed 3 Jun 2017

Committee to Protect Journalists (2012) Getting away with murder. https://www.cpj.org/reports/2012/04/impunity-index-2012.php. Accessed 15 Mar 2017

Dash K (1996) The political economy of regional cooperation in South Asia. Pac Aff 69:185–209

Department of Urban Development and Building Construction (1994) National building codes. http://www.dudbc.gov.np/buildingcode. Accessed 20 Jun 2006

Department of Urban Development and Building Construction (2003) National building codes. http://www.dudbc.gov.np/buildingcode. Accessed 20 Jun 2016

Dixit A, Dwelley-Samant L, Nakarmi M, Pradhanang S (2000) The Kathmandu Valley earthquake risk management project: an evaluation. In: 12WCEE2000. New Zealand Society for Earthquake Engineering, Upper Hutt, New Zealand

Djalante R (2012) Review article: adaptive governance and resilience: the role of multi-stakeholder platforms in disaster risk reduction. Nat Hazards Earth Syst Sci 12:2923–2942. doi:10.5194/nhess-12-2923-2012

Freedom House (2017) About freedom in the world. Freedom House Data. Country and Territory Ratings and Statuses, 1972–2016. https://freedomhouse.org/report-types/freedom-world. Accessed 6 Mar 2017

Government of Nepal (2015) Post disaster needs assessment—Volume B. http://un.org.np/sites/default/files/PDNA-volume-B.pdf. Accessed 1 Feb 2016

Government of Nepal, Ministry of Physical Planning and Works, Earthquake Risk Reduction and Recovery Preparedness Programme for Nepal (2009) Recommendation for update of Nepal national building code. http://errrp.org.np/document/study_report/NBC Update-Final Report-Building Code July 15 09.pdf. Accessed 15 Aug 2016

Gurung R (2011) Journalism in transition. http://www.ifp-ew.eu/pdf/201110IfPEWJournTransMediaInfoConflict.Nepal.pdf. Accessed 1 Feb 2016
Hagen T (2012) Decentralization and development: the role of democratic principles. Ratna Pustak Bhandar, Kathmandu
Harat A, Chojnacki M, Leksowski K (2015) Humanitarian aid of the European Union and United Nations: actions, responsibilities, and finances. Bull Geogr Socio 65–73. doi:10.1515/bog-2015-0025
Hollis S (2014) The global construction of EU development policy. J Eur Integr 36:567–583. doi:10.1080/07036337.2014.902943
Howlett M, Ramesh M (1995) Studying public policy: policy cycles and policy subsystems. Oxford University Press, Toronto [u.a.]
INFORM (2017) Index for risk management—Results 2017. http://www.inform-index.org/.. Accessed 6 Mar 2017
Karki TK, Lu B (2015) What makes a big and difficult policy enforcement possible? A success story from Kathmandu Metropolitan City. Habitat Int 49:386–392. doi:10.1016/j.habitatint.2015.06.011
Kaufmann D, Kraay A, Mastruzzi M (2011) The worldwide governance indicators: methodology and analytical issues. Hague J Rule Law 3:220–246. doi:10.1017/S1876404511200046
Keefer P, Neumayer E, Plümper T (2011) Earthquake propensity and the politics of mortality prevention. World Dev 39:1530–1541. doi:10.1016/j.worlddev.2011.02.010
Kenis P, Schneider V (1991) Policy networks and policy analysis: scrutinizing a new analytical toolbox. In: Mayntz R, Marin B (eds) Policy networks. Empirical evidence and theoretical considerations. Campus-Verlag, Frankfurt/M., pp 25–59
Kumasaki M, King M, Arai M, Yang L (2016) Anatomy of cascading natural disasters in Japan: main modes and linkages. Nat Hazards 80:1425–1441. doi:10.1007/s11069-015-2028-8
Lamichhane HR (2012) Fiscal federalism and local government finance in Nepal. Master's Thesis. Tribhuvan University, Nepal
Lecours A, Arban E (2015) Why federalism does not always take shape: the cases of Italy and Nepal. Reg Fed Stud 25:183–201. doi:10.1080/13597566.2015.1011138
Liu B, Siu YL, Mitchell G, Xu W (2016) The danger of mapping risk from multiple natural hazards. Nat Hazards 82:139–153. doi:10.1007/s11069-016-2184-5
Malla RB, Kayastha K, Sharma S, Ojha SP (2015) Earthquake preparedness and disaster relief in Nepal. American Society of Nepalese Engineers
Mann M (2008) Infrastructural power revisited. Stud Comp Int Dev 43:355–365. doi:10.1007/s12116-008-9027-7
Marshall MG, Gurr TR (2014) Polity IV project: political regime characteristics and transitions. Polity IV annual time-series, 1800–2015. http://www.systemicpeace.org/inscr/p4ch2015.xls. Accessed 8 Mar 2017
Mayntz R (2003) New challenges to governance theory. In: Bang HP (ed) Governance as social and political communication. Manchester University Press, Manchester, pp 27–40
Ministry of Home Affairs (2009) National progress report on the implementation of the Hyogo Framework for Action (2007–2009). http://www.preventionweb.net/english/countries/asia/npl/. Accessed 3 Feb 2016
Ministry of Home Affairs (2011a) Nepal disaster report: policies, practices and lessons. http://www.moha.gov.np/uploads/document/file/Nepal_Disaster_Report_2011_20130904031242.pdf. Accessed 1 Feb 2016
Ministry of Home Affairs (2011b) National progress report on the implementation of the Hyogo Framework for action (2009–2011). http://www.preventionweb.net/english/professional/policies/v.php?id=15615. Accessed 3 Feb 2016
Ministry of Home Affairs (2015a) National progress report on the implementation of the Hyogo Framework for Action (2013–2015). http://www.preventionweb.net/english/professional/policies/v.php?id=41755. Accessed 3 Feb 2016
Ministry of Home Affairs (2015b) Disaster Report 2015. Kathmandu

National Society for Earthquake Technology Nepal (2008) National Strategy for Disaster Risk Management (NSDRM). http://www.nrcs.org/sites/default/files/pro-doc/NSDRMNepal.pdf. Accessed 1 Feb 2016

Nepal Red Cross Society, International Federation of Red Cross and Red Cross Crescent Societies (2011) Nepal—laws, policies, planning and practices on international disaster response. http://www.ifrc.org/PageFiles/134443/idrl-nepal.pdf. Accessed 1 Feb 2016

Oxfam (2015) Efforts of Nepal towards building a disaster resilient country. https://www.sheltercluster.org/sites/default/files/docs/b.gadal-_efforts_of_nepal_towards_building_a_disaster_resilient_country.pdf. Accessed 1 Feb 2016

Pokhrel D, Bhandari BS, Viraraghavan T (2009) Natural hazards and environmental implications in Nepal. Disaster Prev Manag 18:478–489. doi:10.1108/09653560911003679

Prasad SR (2015) Urbanization, earthquake vulnerabilities & national building code. IJSRR 4:47–63

Rinscheid A (2015) Crisis, policy discourse, and major policy change: exploring the role of subsystem polarization in nuclear energy policymaking. Eur Policy Anal 1:34–70

Schneider V (2012) Governance and complexity. In: Levi-Faur David (ed) The Oxford handbook of governance. Oxford University Press, Oxford, pp 129–142

Schneider V (2015) Relationalism in political theory and research: the challenge of networked politics and policy-making. Przegląd Politol 3:191–206

Schneider V, Leifeld P, Malang T (2013) Coping with creeping catastrophes: national political systems and the challenge of slow-moving policy problems. In: Siebenhüner B, Arnold M, Eisenack K, Jacob K (eds) Long-term governance for social-ecological change. Routledge, New York, pp 221–238

Shah H, Katayama T, Rynn J (1993) An international connection—WSSI: "World Seismic Safety Initiative". Bull New Zeal Natl Soc Earthq Eng 26:445–450

Sharma K (2012) Politics and governance in Nepal. Asia Pacific J Public Adm 34:57–69. doi:10.1080/23276665.2012.10779387

Stone D (2004) Transfer agents and global networks in the "transnationalization" of policy. J Eur Public Policy 11:545–566. doi:10.1080/13501760410001694291

The World Bank (2016) Worldwide governance indicators|databank. www.govindicators.org. Accessed 6 Mar 2017

The World Bank (2017) World development indicators|data. http://data.worldbank.org/data-catalog/world-development-indicators. Accessed 6 Mar 2017

Tozier de la Poterie A, Baudoin M-A (2015) From Yokohama to Sendai: approaches to participation in international disaster risk reduction frameworks. Int J Disaster Risk Sci 6:128–139. doi:10.1007/s13753-015-0053-6

UNDP (2015a) World development report 2015. Work for human development. http://www.undp.org/content/undp/en/home/librarypage/hdr/2015-human-development-report/. Accessed 1 Oct 2016

UNDP (2015b) Annual report 2015. UNDP in Nepal. http://www.np.undp.org/content/dam/nepal/docs/reports/annual_reports/UNDP Annual Report 2015 March 30 2016 Final.pdf. Accessed 1 Oct 2016

USGS (2017) United States geological survey data on earthquakes. Largest earthquakes, significant events, lists and maps by magnitude/year/location. https://earthquake.usgs.gov/earthquakes/. Accessed 6 Mar 2017

Versluys H (2009) Europe's global role: external policies of the european union—Google books. In: Orbie J (ed) Europe's global role: external policies of the European Union. Ashgate, Surrey

Whelpton J (2005) A history of Nepal. Cambridge University Press, Cambridge