

विकास | VIKAS

NEPAL'S POST EARTHQUAKE RECOVERY & RECONSTRUCTION



National Planning Commission
Singha Durbar, Kathmandu



National Reconstruction Authority
Singha Durbar, Kathmandu

NEPAL'S POST EARTHQUAKE RECOVERY & RECONSTRUCTION
SPECIAL ISSUE

विकास VIKAS

A JOURNAL OF DEVELOPMENT

VOL II • AUGUST 2021

NEPAL'S POST EARTHQUAKE RECOVERY & RECONSTRUCTION SPECIAL ISSUE

VOL II • AUGUST 2021



National Planning Commission
Singha Durbar, Kathmandu



National Reconstruction Authority
Singha Durbar, Kathmandu

विकास VIKAS

A JOURNAL OF DEVELOPMENT

VOL II • AUGUST 2021

NEPAL'S POST EARTHQUAKE RECOVERY & RECONSTRUCTION

SPECIAL ISSUE

Copyright © 2021

Published by:



National Reconstruction Authority
Singha Durbar, Kathmandu



National Planning Commission
Singha Durbar, Kathmandu

Websites:

<http://www.nra.gov.np> & www.npc.gov.np

This publication may be reproduced in part or in its entirety with due credit.

The contents of this special issue of the VIKAS Journal reflect the opinions of the authors. They do not necessarily represent the official opinion or position of the NRA.

Printed in Nepal

Price: NRs.



The Prime Minister



Message

I am pleased to learn that Volume II of *Vikas* is ready for publication. The successes and lessons from post-earthquake reconstruction will assist us to save resources and better respond to future disasters. The publication is both appropriate and timely as we are now in the concluding phase of reconstruction.

The earthquake killed over 8,000 people and damaged close to a million homes, many public offices, classrooms, health facilities and cultural heritage sites. The massive reconstruction effort was a grave challenge faced in Nepal's recent history. It also covered a vast area of rugged terrain. While Nepal may not be a financially wealthy country, the recovery process has proven, once again, our richness measured in terms of resourcefulness of our people and their determination to restore the country's economy, social fabric and unmatched cultural heritage.

Nepal is considered to be one of the most disaster-prone countries in the world. In this context, the pursuit of sustainable development, disaster risk management and post-disaster reconstruction is a continuous, complex and time-consuming process. Usually, after completing one initiative, we move on to the next without pausing to review and reflect on both the achievements and shortcomings of the task just completed. *Vikas-II* is a continuation of our effort to document evidence-based knowledge, on the basis of which we can take pride in our achievements and also, draw lessons from shortcomings.

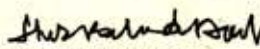
I look forward to seeing other publications of NRA debating the interrelated themes of sustainable development, disaster risk management and post-disaster reconstruction. Together, such multi-faceted analyses can provide valuable insights and feedback to national and local planning processes. I also believe that such a publication can assist in making public agencies at all levels in our federal republic both accountable and responsive.

I take this opportunity to thank all the people of Nepal for their patience and participation in our efforts to rebuild the nation. Likewise, I also thank the National Reconstruction Authority (NRA) for providing the leadership to the massive reconstruction effort and the many development partners who assisted in this huge national undertakings.

I congratulate the team involved in compiling and producing this publication and look forward to more efforts to research and reflect on the development efforts of the Government of Nepal and its partners as part of our commitment to sustainable, risk-informed development, national resilience, transparency and democratic governance.

Jay Nepal.

6th October, 2021


Sher Bahadur Deuba



National Reconstruction Authority



Foreword

I am delighted to share with you the second publication of the National Reconstruction Authority (NRA) and National Planning Commission (NPC) that recounts our experiences in reconstruction and rehabilitation after the 2015 Gorkha, Nepal earthquake. This and forthcoming publications of NRA will provide lessons for future generations and will also inform global efforts to cope with and rebuild after natural disasters.

In organizing the massive post-earthquake reconstruction programme, we internalized and delivered on the Build Back Better principle. Our alliance of many national actors, supported by international partners, has so far completed the reconstruction of about 800,000 houses, about 50,000 classrooms at 7500 schools, 1200 health institutions and over 1000 cultural and historical monuments, including archaeological monasteries. In addition, NRA-led efforts have also rebuilt 650 government offices, including buildings used by security agencies, over 1500 drinking water systems, and also constructed about 800 km of roads. We have developed new ways of communicating with affected Nepalis and of listening to their concerns. We have likewise supported the restoration of livelihoods, new roles and working opportunities for women and have developed special provisions to assist the most vulnerable members of our society.

Nepal's experience in reconstruction is a testament to international cooperation and goodwill towards Nepali citizens. Our achievements were made possible because of support of development partners who responded immediately to support rescue and relief operations and later joined hands with us in assisting in the enormous task of reconstruction.

The post-earthquake reconstruction and recovery efforts have laid a foundation for realizing our vision of building a Disaster Resilient Nepal and I hope these publications will be of use to people working in the identical situations. I congratulate all the contributors of articles and others who worked towards preparing this special edition of *Vikas*.

Sushil Gyawali
Chief Executive Officer
National Reconstruction Authority



National Planning Commission



Preface

The National Planning Commission (NPC) is glad to publish *Vikas II* – the second in the special publication series – in collaboration with the National Reconstruction Authority (NRA). In the immediate aftermath of the Gorkha earthquake, the NPC played a catalytic role in preparing the Post Disaster Needs Assessment (PDNA) and initiated preparatory recovery efforts prior to the establishment of the NRA. I am pleased to observe that the NRA has delivered on its mandate with flying colors. In the process of delivering results during an extremely difficult period, NRA has documented lessons that can provide guidance for future disaster management planning efforts.

The NPC is committed to working towards policy reforms based on the lessons learnt. NRA's work included five different but related thematic areas: private housing, heritage, public building and infrastructure, livelihood and governance. All interventions were made with attention to the needs of particular population groups and regions.

The core of NRA's learnings is related to promoting resilient housing and infrastructure for withstanding the impacts of future earthquakes and other natural disaster events. Another lesson is the need to reassess our land use system, the availability of technology at the end user level, access to finance, and the Government's delivery mechanisms at all levels. While the NRA's efforts on recovery are laudable, we have seen the need for continued and strengthened public sector engagement with all disaster-affected people, especially with the most vulnerable beneficiaries of reconstruction programs.

The NPC will promote discourse on capacitating national institutions for disaster response and management. The country has already begun work on reinvigorating the disaster management agenda requiring mandatory compliance with the existing building standards. We will also initiate a national debate on reinforcement of the existing housing stock through retrofitting, to facilitate increased resilience to future disasters. With the benefit of the NRA's experience and technological innovations, it will definitely be easier to extend retrofitting to municipalities beyond those covered by post-Gorkha earthquake reconstruction.

This joint publication is also a symbol of inter-institutional collaboration, of the achievements of NRA and also of our commitment to take the lessons learnt in the reconstruction effort and incorporate them in our development and disaster management processes.

Biswo Nath Poudel
Vice Chairman
National Planning Commission



Acknowledgements

There are a number of individuals and institutions whose guidance and contributions were vital for the preparation of this publication – and indeed for the extensive research, analysis and organization required for documenting lessons learned – which will culminate in the International Conference on Nepal's Reconstruction (ICNR-2021) to be held later this year. The Rt. Hon. Prime Minister Sher Bahadur Deuba, who chairs both NRA and the NPC, deserves our heartfelt appreciation for the leadership provided to the reconstruction and recovery activities. Mr. Sushil Gyewali, the NRA Chief Executive Officer, has led and guided the ICNR preparatory activities. The understanding of Dr. Biswo Nath Poudel, Vice Chairman, NPC, on the need to document learnings provided momentum to this publication. We also extend our gratitude to all members of the ICNR Organizing Committee for their contributions.

The Editorial Board members, Prof. Dr. Tara Nidhi Bhattarai (Editor in Chief), Mr. Basu Dev Sharma, Mr. Jitendra Bothara, Dr. Nigel Fisher and Prof. Dr. Ram Manohar Shrestha assisted us in reviewing the substance and structure of the research articles. Similarly, all peer reviewers worked to the highest academic and professional standards to assist the authors in completing their contributions. Mr. Binod Bhattarai and Mr. Chiran Ghimire edited the final texts to make this volume publication-ready. We thank you all.

We would also like to acknowledge the significant commitment, drive, and efficiency of the ICNR Secretariat, led by Dr. Chandra Bahadur Shrestha, Executive Committee Member, NRA. Mr. Manohar Ghimire, Under Secretary, contributed as Member Secretary of the Secretariat. Ms. Sulochana Nepali, the World Bank, represented the Development Partners at the Secretariat. The contribution of Mr. Sandeep Gurung and Mr. Janardan Nepal was also laudable.

The NRA and NPC task team bridged two different organizations, producing an output agreeable to both agencies, while meeting acceptable publication standards. This team comprised of Dr. Chandra Bahadur Shrestha (Coordinator), Mr. Basu Dev Sharma (Joint Secretary, NPC), Mr. Manohar Ghimire (Under Secretary, NRA), and Mr. Lok Bahadur Khatri (Under Secretary, NPC).

Finally, this volume would not have been possible without the contributions of authors and commentators. Once again, we thank you all!

Sushil Chandra Tiwari
Secretary
National Reconstruction Authority

Kewal Prasad Bhandari
Secretary
National Planning Commission



National Reconstruction Authority



About this publication

The National Reconstruction Authority (NRA) began documenting its work with a view to publishing the lessons and learnings through the scientific, corporate, institutional and open routes. Articles for international readership have been published in *Progress in Disaster Sciences*; an international journal published by Elsevier. The ICNR Secretariat organized a series of workshops, seminars and symposiums for reviewing and refining the articles.

This volume of *Vikas II* incorporates ten articles covering private housing, heritage and public buildings. Among them five discuss private housing, three take a close look at heritage and one on public buildings. Three others are project-based articles that bring experiences to the publication.

The first housing article has attempted to link housing survey to resilient housing construction. The article argues that the damage assessment-based housing database can play a catalytic role towards resilient housing. The second article draws conclusions based on a study of about 5000 earthquake-triggered landslides, which can be instrumental for formulating the settlement policies. The third article discusses how government grant policies influenced beneficiary behavior, arguing that the single-roomed houses were the outcomes of NRA's tranche deadlines. As mandated by the Sendai framework, all post disaster reconstruction efforts have followed the Build Back Better principle, which as this paper argues, has to be contextualized. The final housing article has looked at socio-technical assistance provided by a project and its outcomes.

This issue includes three heritage sector articles. The first heritage article deals with the seismic hazard for Dharahara. The second article compares the design outputs from two different seismic standards: IS1893:2016 and NBC105:2020. The third article has investigated the structural features of Kastamandap, demonstrating how historical monuments can be conserved with traditional construction materials. The last heritage paper has advocated urban renewal. Similarly, the article on the public building sector has argued that prefab technology was not appropriate for remotely located health facilities and that such technology can be used for emergency purposes in urban areas.

We are confident that this publication will contribute towards national and international discourse on post-disaster reconstruction and will contribute to build disaster resilient physical and social infrastructure.

Chandra Bahadur Shrestha
Executive Committee Member, NRA
Convener, ICNR

Editorial

This second special issue of *Vikas* has been published with the aim of sharing lessons learned from Nepal's experience in post-disaster reconstruction and recovery, following the 2015 Mw 7.8 Gorkha, Nepal earthquake. This volume has been compiled under the auspices of the National Reconstruction Authority (NRA), established by the Government of Nepal after the Gorkha earthquake to lead and coordinate post-earthquake reconstruction.

Almost six years after the establishment of the Authority, extensive achievements in reconstruction and recovery have been recorded. The intent of this second special issue of *Vikas*, as with the first, is to share the achievements, as a means of helping others to prepare for future earthquakes and other disaster events and to strengthen individual, community and societal resilience to mitigate and overcome their impacts.

As a first step in the information-sharing process, an international webinar, the National Seminar on Nepal's Reconstruction (NSNR-2020), was organized in Kathmandu on 24-27 August 2020. The NSNR-2020 provided a professional platform for national and international experts and researchers to share the lessons learned from Nepal's multi-dimensional reconstruction experience and to critically review the analyses presented.

In preparation for the NSNR-2020, 115 abstracts of papers were received. These were reviewed by an editorial board. The analysis and suggestions provided by the board facilitated the writing of full research papers, following the NSNR-2020 guidelines. In spite of the Covid 19 pandemic, 62 completed papers were submitted. All these papers went through a double-blind peer-review process. The papers were presented at the NSNR-2020, during which authors received additional suggestions and feedback from participants, panelists and facilitators.

The NRA made provision for the publication of manuscripts in two journals, namely *Vikas*, the journal of the National Planning Commission (NPC), Government of Nepal, and *Progress in Disaster Science (PDS)*, an international journal published by Elsevier. Authors of accepted papers were requested to indicate their preference for publication of their manuscripts in either journal.

This second special issue, like the first, comprises of papers submitted to *Vikas*. The articles cover a number of important areas of reconstruction, including private housing, cultural heritage, social sector reconstruction, population displacement, inclusive recovery strategies and multi-faceted approaches to addressing vulnerability.

We hope that these papers will be useful to researchers, policy makers, students and practitioners engaged in the fields of disaster management and disaster risk reduction, as well as to advocates and practitioners of disaster risk-informed development planning. Last but not least, these papers, along with those published in PDS, will serve both as an archival record and as a mirror reflecting how Nepal completed its reconstruction after the 2015 Mw 7.8 Gorkha, Nepal earthquake.

We are grateful to the Conference Organizing Committee for entrusting us with the responsibilities of the editorial board. We are also thankful to our distinguished reviewers for their comprehensive analysis and timely comments.

Editorial Board

Tara Nidhi Bhattarai, Editor-in-Chief

Basu Dev Sharma, Editor

Jitendra Bothara, Editor

Nigel Fisher, Editor

Ram Manohar Shrestha, Editor

Table of Contents

<i>Message</i>	iii
<i>Foreword</i>	iv
<i>Preface</i>	v
<i>Acknowledgements</i>	vi
<i>About this publication</i>	vii
<i>Editorial</i>	viii

SCIENTIFIC ARTICLES

1. Can Post-earthquake Housing Survey Contribute to the Resilient Housing Construction in Nepal? <i>Chandra Bahadur Shrestha, Manohar Ghimire</i>	3
2. A Site-specific Seismic Hazard Assessment for Sundhara, Kathmandu <i>Hari Ram Parajuli, Bikram Bhusal</i>	20
3. A Critical Review on Appropriateness of Use of Prefab in Construction of Health Post in Nepal After the 2015 Earthquake <i>Manjeet Raj Pandey, Siddhi Bhakta Maharjan, Nagma Mathema</i>	36
4. A Comparative Investigation of Seismic Standards Is1893:2016 and Nbc105:2020 in the Context of Seismic Design of Dharahara, a Historic Monument in Kathmandu Valley <i>Manohar Rajbhandari, Nima Sthapit, Srijana Sthapit</i>	46
5. Mass Movements in the Region of 2015 Gorkha Earthquake: Examples from Five Most Affected Districts in Central Nepal <i>Megh Raj Dhital, Tara Nidhi Bhattarai, Lekh Prasad Bhatta</i>	58
6. Structural Features of the Kasthamandap, and its Post-earthquake Reconstruction <i>Prem Nath Maskey, Minesh Ratna Tamrakar, Bipin Kumar Gautam</i>	95

PROJECT EXPERIENCES

7. Practical Approaches to Build Back Better with Inclusive Recovery from Earthquake Disasters: A Discussion Based on the 2015 Nepal Earthquake Recovery Project by JICA 107
Kozo Nagami, Tomoki Miyano, Naoki Nishimura, Yoji Toriumi, Nanako Tsukahara, Ayuko Nakamura
8. Effectiveness of Holistic Socio-technical and Financial Support to Enable Socio-economic Vulnerable Households to Build Earthquake Resistant Houses 127
Manindra Malla, Ajay Kumar KC
9. The Influence of Reconstruction Mandates and Affordability on Nepal's Post-earthquake Housing Reconstruction 142
Minar Thapa Magar, Uttam Paudel, Sneha Malani
10. Urban Regeneration of Dwalkha: Prospects and Challenges 165
Surya Bhakta Sangachhe, Aditi Dhakal
- Contributors* 179

SCIENTIFIC ARTICLES



Can Post-earthquake Housing Survey Contribute to the Resilient Housing Construction in Nepal?

Chandra Bahadur Shrestha^a, Manohar Ghimire^b

Keywords: Damage survey, earthquake, beneficiary.

Abstract

The Government of Nepal provided housing grants to earthquake-affected households based on a Household Survey. However, its efficacy in terms of both time and money was questionable. The objective of this paper is to review the survey methods and to make recommendations for similar future interventions. The study was based on a review of literature on post-disaster surveys and on information collected from interaction programs and focus group discussions. Despite some weaknesses, the survey was helpful for creating a housing database at the local level to promote construction of disaster resilient houses. Such a survey can also assist in raising municipal revenue and facilitate rescue, relief and reconstruction.

1. Introduction

The 2015 Gorkha, Nepal earthquake of 25 April 2015 killed 8790 and injured over 22,300 people (NPC, 2015b). It also caused the economic loss valued at US\$ 7.6 billion. As it was extremely difficult to estimate the exact cost of the destruction, the Post Disaster Need Assessment (PDNA) had made estimates in terms of the monetary value except for the housing sector (NPC, 2015a). The private housing sector's requirement was estimated at US\$ 4077 million, which was nearly 61 percent of the total. The requirement in the health sector was estimated at US\$ 147 million, education US\$ 397 million, and that for the cultural heritage sector was US\$ 397 million. The PDNA had 21 other sectors

except housing. Overall, about a third of Nepal's population had been affected, and out of 31 impacted districts, 14 were categorized as severely affected and remaining 17 as moderately affected (NRA, 2016a).

In June 2015, the Government of Nepal (GoN) signed for a World Bank (WB) credit of US\$ 200 million for the reconstruction of 55,000 housing units. The agreement had a number of conditions, which included an owner-driven housing reconstruction approach and the mandatory requirement of constructing multi-hazard resistant standard housing units (WB, 2015). For implementing the project, it was mandatory for the National Reconstruction Authority (NRA) to identify beneficiary households through the Earthquake Household Damages and Characteristics (EHDC) survey. The

^a Executive Member, National Reconstruction Authority, email: cbshrestha1961@gmail.com

^b Under Secretary, Information Management Section, National Reconstruction Authority, email: mghimire@nra.gov.np

same methodology had been followed by the Japan International Cooperation Agency (JICA), that had provided US\$ 118 million for the Earthquake Housing Reconstruction Project (EHRP). Having committed to both of the major housing projects, it was imperative that the NRA generalized the covenants for the entire housing program (NRA, 2016b).

The Nepal Police collected data on housing destruction immediately after the earthquake on 25 April 2015 using the form shown in Annex 1. Based on the information, following additional validation, the District Disaster Relief Committee (DDRC) and the local governments had issued Earthquake Victim Household Identity Card (Annex 2), which was the basis for receiving relief packages. However, there was still a need for comprehensive assessment to ascertain the damage to the housing stock against uniformly applied engineering criteria, and to verify the eligibility of beneficiaries. The resulting surveys were considered instrumental for reassuring the public and ensuring public safety. It was also envisaged that the survey outputs would be instrumental for assisting both social and economic recovery, and promoting long-term risk reduction. The DDRC-led preliminary damage assessment and the National Planning Commission (NPC)-led EHDC were not congruent.

At the initial stage, it was estimated that there could be around 500,000 households with fully damaged houses, and an additional 250,000 households with partially damaged houses (NPC, 2015a). However, as it stood in end-August 2020, the number of beneficiaries who had suffered full damage was 834,911. (NRA, 2020b).

Also in the initial stages, almost all media, the general public and political parties had complained about the delay in reconstruction (Shrestha, 2016). The time taken for the beneficiary survey was one of the major factors contributing to the delay. This public perception caused the NRA to encounter enormous pressure to deliver, while also facing allegations of incompetence.

The NRA's Ninth Steering Committee (NRA, 2017a) meeting instructed the NRA Executive Committee to conduct a resurvey of those households that

had been declared as non-beneficiaries by NRA Grievance Handling Committee. The original result was based on the Household Registration for Housing Reconstruction Survey (HRHRS) and the decision pronounced the reservation of the Steering Committee on NRA's grievance redressal.

Two different survey methodologies were adopted in the 32 districts. Census surveys were carried out in 11 severely-affected districts and villages of Kathmandu Valley districts, whereas the verification model was adopted in the urban areas of the Kathmandu Valley districts and the moderately-impacted 17 districts. There was no verdict on which methodology was better suited, and under which circumstance.

How the NRA's housing database will be used in the post-NRA period had not been established when this article was written. The database includes house owner information, house information and demographic and socio-economic information. Such information is extremely important for settlement planning and enforcement of building codes by local governments. However, this potential remains underutilized owing to the lack of a direct link between the available databases at the NRA and the municipal decision-making process.

The objectives of this paper are: to examine concept and implementation of household registration for the Housing Reconstruction Survey; to collate the implemented method with practices in other countries; to establish links between the database and municipal settlement planning, and to secure a conducive environment for compliance with municipal building construction working procedures.

The rationale of this paper is to inform policy makers, academicians and users about the different methodologies used for conducting the housing survey. The purpose is to encourage policy makers to create housing inventories as a standard planning process to minimize need for a post-disaster survey to expedite post-disaster rescue, relief operations and the reconstruction process. Such interventions can minimize the socio-economic costs and maximize public welfare.

2. Methodology

This is an experience-based descriptive paper. All available household survey related literature was reviewed. Literature on Nepal's previous earthquakes, particularly those of 1988 and 1934 were studied. Practices of some countries such as New Zealand, China, India and Pakistan were also examined. Two officers from the Central Bureau of Statistics (CBS), two from the Ministry of Urban Development (MoUD), two from the Ministry of Federal Affairs and General Administration (MoFAGA) were interviewed. The interviews were open-ended. Similarly, field-level interviews were conducted with district administrators directly involved in household surveys in Dolakha, Sindhupalchowk, Gorkha and Nuwakot districts. A number of focus group discussions (FGDs) were conducted in Kathmandu Metropolitan City, Lalitpur Metropolitan City, and the Mahalaxmi Municipality, Konjyoson Rural Municipality and Mahankal Rural Municipality in Lalitpur District. Another FGD was carried out in the Gorkha Municipality. A comprehensive desk review of post-earthquake damage assessment surveys of China, India, Pakistan, and New Zealand were also carried out. Based on experiences in the 2015 Gorkha, Nepal earthquake and those in other countries, this paper has proposed an approach for linking the data with housing construction and settlement planning.

3. Findings

This section elaborates the elements in the questionnaire, preparation and the implementation of the survey. It also analyses the increases in the number of beneficiaries and the appropriateness of the Steering Committee's decision on the survey result. Both the positive and negative aspects of the adoption of different methodologies are also discussed.

3.1. Pre-survey enumeration

The Nepal Police had initiated a preliminary damage assessment survey (*Muchulka*) about a week after the

earthquake. The survey team comprised of one Sub Inspector and a Constable. The format used is shown in Annex 1. The form included a description of damage that was endorsed by three witnesses. The damage assessment was further endorsed by the municipality's Ward Secretary. Based on that survey and following further validation, the DDRC issued the Earthquake Victim Household Identity Card (Annex 2). It had categorized housing damage in two categories: full damage and partial damage. It also included information on the total number of casualties, number of injured people, house damage – full or partial, cattle shed damage – damage to reared animals and birds, food and others. Against this, the household of the deceased family was entitled to receive about US\$ 1400, the fully damaged houses received US\$ 50 and partially-damaged household, US\$ 30. An additional US\$ 20 was provided as food relief and US\$ 150 for warm clothing (MoHA, 2016).

3.2. Initiation of the Earthquake Household Damages and Characteristics (EHDC) survey

The World Bank (WB, 2015) in collaboration with the GoN formulated an earthquake reconstruction project, that had the EHDC survey as a major component. The WB emphasized the importance of building-level damage and a household survey for ascertaining the damage to the building against uniformly applied engineering criteria, and for verifying the eligibility of beneficiaries. Both GoN and the Bank expected that the survey would be instrumental for rebuilding earthquake-resilient houses and also in guiding social and economic recovery. The EHDC survey was planned to build on the Rapid Visual Damage Assessment work that was being carried out under the guidance of the Department of Urban Development and Building Construction (DUDBC). The objectives of the EHDC survey were to ascertain the damage to the housing stock, to prepare the list of beneficiaries eligible for housing grants, and to ensure site safety for reconstruction. The EHDC survey was renamed as HRHS later.

3.3. Designing of Earthquake Household Damages and Characteristics (EHDC) Survey

The GoN initiated preparatory activities for conducting a housing survey after signing the Financing Agreement with the International Development Association (IDA) on 14 August 2015 (GoN & IDA, 2015). The Ministry of Federal Affairs and Local Development (MoFALD) was the responsible agency for conducting the survey with technical support from the Central Bureau of Statistics (MoFALD, 2015). The objectives were to establish a household database and a list of potential beneficiaries based on uniformly applied engineering criteria, flag any site safety issues and recommend further evaluation; establish a comprehensive household database and a social security allowance beneficiary list; and collect baseline socioeconomic data to monitor the recovery from earthquake and evaluate the effectiveness of the program.

In addition to MoFALD and Central Bureau of Statistics (CBS), MoUD, the WB and the United Nations Office for Project Services (UNOPS) were the other directly-related stakeholders. After establishment, the NRA became the lead agency for the survey. In the first stage, 11 severely-affected districts, including 577 local governments were selected for the survey.

A two-member survey team was proposed: an engineer and a social mobiliser who was expected to have local knowledge. All engineers mobilized attended a training of seven-days in Kathmandu and the social mobilizers were oriented at the district level. Each engineer was provided with a tablet with software and was expected to collect and upload data that was accessible from the CBS-based processing unit. The team was monitored by the district and central-level monitoring and supervision teams. The entire operation was funded by the WB. UNOPS was contracted for implementing the survey (CBS, 2017b).

At the central level, the operation was steered by an NPC-led Steering Committee. Other members were the Ministry of Finance (MoF), MoFALD, MoUD and the CBS. The Technical Committee was chaired by the CBS Director General with five other members. The

UNOPS was designated to provide all procurement and logistics support, and Kathmandu Living Labs (KLL) was contracted by UNOPS to provide technical assistance to the CBS for developing the survey application, installing the application on tablets, providing training to surveyors on the use of the application, resolving any technical issues with the tablets during the survey, and supporting CBS to undertake data management and quality assurance until the data was transferred to MoFALD's MIS via the CBS platform.

3.4. Designing of HRHRS questionnaire

The questionnaire – for the HRHRS – had two sections (CBS, 2017b): Part 1: Detailed Information on Damage Assessment of Residential Buildings and Part 2: Demographic and Socio-Economic Information. Part I had information of owners and detail assessment of house, including information on legal ownership of land, condition of the house before and after earthquake, foundation of the building, damage grade of house, technical solution for damaged house, type of house, position of house, plan configuration of the house, building damage assessment, and geotechnical risk. Under Part II the survey included demographic and socioeconomic information including information on the income of the household head, age, sex, disability, educational status, size of family, social security allowance, facilities used by the household, etc.

3.5. First phase: Survey of highly-affected 11 districts

In the first phase, 11 most-affected districts were surveyed following the census method, starting with Dolakha District. The survey outcome is shown in Table 1.

More than 72 percent of the houses surveyed were declared as beneficiaries based on the damage grade. Households in the damage grades of 2 (major), 3, 4 and 5 were defined as beneficiaries. However, the households in these categories were disqualified if they had another house that was not damaged. Of the

Table 1: HRHRS outcome in 11 most-affected districts

S.N.	District	Surveyed		Beneficiaries		Total Beneficiaries
		Houses Nos.	HHs Nos.	Reconstruction	Retrofitting	
1	Okhaldhunga	39,352	36,114	19,819	1,643	21,462
2	Kavrepalanchok	98,019	91,906	67,731	2,415	70,146
3	Gorkha	78,074	75,911	58,503	2,019	60,522
4	Dolakha	60,639	70,496	51,940	637	52,577
5	Dhading	89,122	86,381	70,581	1,494	72,075
6	Nuwakot	77,148	75,454	65,773	936	66,709
7	Makwanpur	90,994	88,461	30,238	4,150	34,388
8	Rasuwa	12,644	12,384	11,236	117	11,353
9	Ramechhap	58,623	55,262	43,609	2,149	45,758
10	Sindhupalchok	88,741	90,083	78,537	376	78,913
11	Sindhuli	68,750	64,913	34,269	2,408	36,677
Total		762,106	747,365	532,236	18,344	550,580

Source: (CBS, 2017b)

total beneficiaries, nearly 97 percent were categorized as full beneficiaries and three percent houses were identified as retrofittable.

Further, nearly 15,000 households had more than one house. The data also showed that the magnitude of destruction was overwhelming, and that very few of the buildings were earthquake-resilient.

3.6. Second Phase: Survey in Kathmandu Valley

In the second stage, the CBS conducted a beneficiary survey in Kathmandu Valley covering 22 municipalities and 19 Village Development Committees (VDCs). The census method was applied in 19 VDCs and the verification model was used in the municipalities – meaning that the survey would cover only households who had received the DRCC’s relief identity card and those who considered themselves victims of the 2015 Gorkha earthquake. Other institutional arrangements were similar to the first beneficiary survey in 11 districts. The only difference was that the NRA’s role became prominent in this phase. This survey was funded by the WB but was undertaken directly by government agencies rather than the UNOPS.

Of the total beneficiaries, more than 98 percent were full beneficiaries, and two percent were declared as partial beneficiaries. The criteria used earlier for defining beneficiaries was the basis. The summary of the survey and the beneficiaries identified in the first step are listed in Table 2.

3.7. Third phase of survey in 17 districts

The HRHRS was rolled out in 17 moderately-affected districts in January 2017. The verification model, previously used in Kathmandu Valley municipalities, was used. The NRA led the survey and mobilized 364 engineers and 364 social mobilisers. This survey was funded by the Department for International Development (DFID) and UNOPS was mobilized for surveying. The budget estimate was US\$ 2.31 million. The summary of the survey and the beneficiaries identified in the first step are listed in Table 3.

There were 17 districts covered in the third phase, which after the process of federalization resulted in 18 owing to the split of the erstwhile Nawalparasi district into two districts.

The estimated number of the survey households

Table 2: Outcomes of the second phase HRHS

S.N.	District	Surveyed		Beneficiaries		Total Beneficiaries
		No. of Houses	No. of households	Reconstruction	Retrofitting	
1	Kathmandu	51,124	52,991	42,500	575	43,075
2	Bhaktapur	30,197	31,819	26,066	280	26,346
3	Lalitpur	33,093	33,162	25,893	667	26,560
Total		114,414	117,972	94,459	1522	95,981

Source: (CBS, 2017b)

Table 3: Outcomes of the HRHS in 17 moderately-affected districts

S.N.	District	Surveyed		Beneficiaries		Total Beneficiaries
		No. of Houses	No. of households	Reconstruction	Retrofitting	
1	Arghakhanchi	1,648	1,587	1,036	67	1,103
2	Kaski	11,074	10,410	6,026	242	6,268
3	Khotang	12,899	12,642	8,443	253	8,696
4	Gulmi	7,050	6,883	4,144	195	4,339
5	Chitwan	15,269	15,038	7,335	593	7,928
6	Tanahu	25,536	24,475	13,821	466	14,287
7	Dhankuta	4,561	4,448	2,796	70	2,866
8	Nawalparasi	984	992	872	8	880
9	Parbat	10,940	10,947	5,269	417	5,686
10	Palpa	10,727	10,172	4,652	384	5,036
11	Baglung	3,847	3,701	2,375	82	2,457
12	Bhojpur	9,379	9,159	5,749	453	6,202
13	Myagdi	1,413	1,346	868	7	875
14	Lamjung	22,361	21,791	13,959	539	14,498
15	Solukhumbu	17,460	16,852	11,979	456	12,435
16	Syangja	16,111	15,910	8,766	567	9,333
17	Sankhuwasabha	5,169	4,878	1,953	326	2,279
Total		176,428	171,231	100,043	5125	105,168

Source: (CBS, 2017b)

was 98,248 (CBS, 2016), which later rose to 176,428. This suggested that either the beneficiary list of the DDRC was too conservative or more people came forward to seek the housing grant through the survey.

However, the actual number of beneficiaries reported was 105,168, suggesting that the DDRC number was close to the final count.

3.8. Grievance handling

The NRA's "Grievance Management related to Reconstruction and Rehabilitation Guidelines, 2016" (NRA, 2017b) was the guiding document for addressing grievances. The total number of grievances received was 635,973 or almost 100 percent of the declared beneficiaries (NRA, 2020c). This could have resulted from some issue in the HRHS, including some questions that were inappropriate. For example, the questionnaire included all damage features but the final damage grade was ascertained by the engineer. Another contributing factor was human error. NRA had deployed freshly graduated engineers as surveyors as it was not possible to enlist 3000 experienced engineers at one time. The judgment of the fresh graduates was therefore questionable. This was also – perhaps – because rubble stone masonry, an ubiquitous construction approach in rural Nepal, is not included in the Civil Engineering curriculum. Anecdotal evidences suggested that the third contributing factor was the greed of individual households supported by politicians.

3.9. Beneficiary survey in Nepal and other countries

Nepal experienced two major earthquakes in 81 years. The first, in 1934 had a magnitude of 8.4. According to Earthquake Nepal (EH, 2020), around 4,300 people had been killed and roughly 20 percent of all buildings had been destroyed, and another 40 percent were damaged. In Kathmandu Valley around 25 percent of all houses were destroyed, similar to the temples in the old town of Bhaktapur (EH, 2020). The beneficiary survey was conducted by a team of an officer and a soldier and it had final authority to decide and distribute money to beneficiaries on the spot. Any fraudulent activity was subject to the death penalty (Sumsher, 1935). In 1988, another 6.9 magnitude earthquake occurred near the Indian border and affected much of northern Bihar and eastern Nepal killing at least 709 persons and injuring thousands. The earthquake had affected 50,000 buildings. According to interviews with the government officers involved in the reconstruction, at the time the beneficiaries were identified based on the recommendation of the Village Panchayats, the then local governments.

Table 4: NRA's grievance handling stages

Stages	Original registration (a)	Resurvey 2017 (b)	Registration Mid Dec. 2017 (c)	Resurvey 2020 (d)
Total registered grievances	216,285	129,410	101,278	189,000
Beneficiaries	40,967	84,408	9,368	25,315
Reconstruction beneficiaries	40,967	44,104	4,242	17,014
Retrofitting beneficiaries	13,925	40,304	5,126	8,301
Non-beneficiaries	72,613	45,000	–	146,707
Cases for reexamination	13,189	–	265	–
New cases	54,943	–	68,396	–
Others	20,625	–	–	–

Source: (NRA, 2020a)

Each column of Table 4 is further elaborated below:

Col. 1 - grievances from 14 severely affected districts until the end of mid-July 2017;

Resurvey – mid-July to mid-Nov. 2017 of non-beneficiaries and new grievances as directed by NRA Steering Committee;

Resurvey for new grievance and existing grievance: deadline mid-Nov. 2017; and

Resurvey conducted during Mid-March 2020 to Mid Aug. 2020 of 189,000 households.

The 2005 Pakistan earthquake of 7.6 magnitude had killed 73,000 people and rendered 2.8 million people homeless. The door-to-door survey teams comprised 3-5 members including, a federal government technical representative – army personnel, province or state representative – local school teachers or district representative – Patwari (revenue officials), community representative – elected local union council official, village representative – community notable or facilitator (Arshad, 2013). The team visited all households and filled up a very simplified questionnaire (NDMA, 2007). If the team found that the household was eligible for housing grant, it concluded a memorandum of understanding and submitted it to the central office for record.

The 2001 Gujarat earthquake, also known as the Bhuj earthquake, had a magnitude of 7.7 on the moment magnitude scale. It killed more than 20,000 people, injured 167,000 and destroyed nearly 340,000 buildings (Johnson and Olshansky, 2016). The Disaster Authority there had adopted slightly different methodologies in urban and rural areas. In urban areas, a senior structural engineer, a junior engineer, a cameraperson, and a representative from the local authority were mobilized. This team's damage assessment was reviewed by a senior team of experts. The methodology for the rural areas was simpler. The beneficiary survey team consisted of one engineer, one revenue or Panchayat representative, and an NGO representative or social worker. Altogether 2051 teams were mobilized with 2932 technicians, 1794 revenue officers and 2798 other individuals (Mishra, 2004).

The 2008 Wenchuan earthquake had a magnitude of 7.9 and killed 69,226 people, and another 17,923 people were missing (Xinhua News Agency, 2008). In China, as all property belongs to the national government, it was not necessary to undertake damage assessment of individual households. The Government of the People's Republic of China (PRC) assessed the damage in totality and planned reconstruction for the whole region.

The 2010 Canterbury earthquakes, magnitude 7.1, had no human casualty but caused extensive

damage to property. In February 2011, another tremor with a magnitude 6.3 struck just 6 km away from the Christchurch Central Business District (CBD) and killed 185 people (CERA, 2012). Over 100,000 of the region's 160,000 homes also suffered significant damages. New Zealand instituted powerful legal mechanisms for commissioning various organizations. The damage assessment was of the responsibility of the Earthquake Commission (EQC), an insurance company, but it was also granted the responsibility for repairing or rebuilding of insured homes rather than simply paying cash settlements to homeowners. The EQC also conducted land damage assessments as part of its claims process using remote sensing and subsurface investigations to characterize the regional issues while hundreds of engineers also conducted detailed land-damage assessments.

The analysis presented above shows that Nepal, India and Pakistan had similar damage assessment methodologies whereas China and New Zealand had adopted different methods. The methodologies in India and Pakistan were much simpler, as the survey team was authorized to take decisions on the spot.

In order to avoid the public pressure as witnessed in India, Nepal retained that authority at the central level and this allowed it to address field level problems. But this also meant adding huge technological responsibility at the central level. The Chinese methodology of comprehensive planning was not replicable in Nepal based on financial and institutional capacity. The New Zealand experience required the insurance regime to be extremely strong, which was possible there because its disaster preparedness began in 1935 when it had enacted the first building bylaw (Tipler, 2019). There were a number of similarities among Nepal, India and Pakistan. All countries had an engineer and other persons with local knowledge involved. As there is a positive correlation between insurance coverage and economic development (Cristea, Marcu and Cârstina, 2014), Nepal could consider adopting the New Zealand model after it makes further progress in economic development.

3.10. Planning of housing construction at the local level

How the housing database can contribute to effective settlement development and resilient housing construction requires further study. For local level planning, there is a National Planning Commission (NPC) directive requiring that to be based on the Constitution of Nepal, Local Governance Act – 2074 and National Natural Resources and Financial Act – 2074 (NPC, 2018). The directive requires the local governments to prepare short, medium and long-term plans that also need to incorporate the disaster prevention and reconstruction activities. For disaster risk purposes, there is a separate guideline issued by the Ministry of Home Affairs (MoHA, 2019). After experiencing unprecedented destruction during the 2015 Gorkha earthquake, the Ministry of Urban Development (MoUD) and the Ministry of Federal Affairs and Local Development (MoFALD) also jointly issued a Basic Standard for Settlement Development, Urban Planning and Building Construction – 2072 (MoUD & MoFAGA, 2015).

Nepal's federal structure provides for three levels of government. The municipalities and rural municipalities are the local governments, and they need to prepare their development plans according to their financial capacities. The local plans have to be synchronized with the provincial and national periodic plans. Three types of plans need to be formulated: long, medium and annual. Problem analysis is the point of departure for local level planning; the plans also require a vision, concept and targets. An accurate estimation of revenue is also essential. There have to be separate sectoral plans, which have to be assessed with respect to effectiveness, equity, cost effectiveness, acceptability, timeline, uncertainty and sustainability. The plans also require implementation plans, including provisions for monitoring and evaluation.

Settlement and housing construction comprise a significant sector in the municipal planning process. The housing plan has to incorporate land use-based zoning of the municipality, which includes residential and commercial zones. The vulnerable areas have to

be delineated and there are areas where no housing construction is allowed (KMC, 2018).

The MoUD and the MoFALD's Basic Standard for Settlement Development, Urban Planning and Building Construction - 2072 (MoUD & MoFAGA, 2015) requires municipalities to further elaborate the provisions in the periodic plan. The basic standards are intended to ensure compliance to the building codes. The basic standard also regulates the land plotting businesses and has defined a minimum standard for all building purposes – for both residential, commercial and social – which includes open space, road width and other infrastructure. The most important provision is the requirement to demolish vulnerable houses and other infrastructure. The building database can serve as an important resource for such demolition. The building also has to be used for the defined purpose. For example, the buildings which were constructed for residential purposes have been used for schools and hospitals, which must be prohibited. There is a provision for mandatory geo-technical investigations for all buildings above the height of 15 m. The standard also prohibits housing construction on a slope exceeding 300 and restricts building shopping complexes in residential areas. The minimum road width defined is four meters in all locations except heritage sites. The basic standard has also stipulated the floor area ratio which is 70 percent for buildings below 250 sq. m and 60 percent for those above 250 sq. m.

In addition to the basic standard, the DUDBC has issued the Nepal National Building Code: NBC 206: 2015 (DUDBC, 2015). The Building Code classifies buildings in eight groups: residential, assembly, educational, hospital & clinic, commercial, office, industries and storage. The Building Code also classifies buildings based on their height: general, medium rise, high rise, and skyscrapers. The code has also defined dimensions of exits, corridors, staircases, plinth height, minimum number of rooms, ventilation, fire safety requirements, etc. Further, there are more specific requirements for multi-story buildings.

The HRHRS housing database can be used in the municipalities for developing appropriate policies and

strategies. The municipal plans can be developed based on spatial characteristics of housing. The implementation of Basic Standard for Settlement Development, Urban Planning and Building Construction - 2072 can also be much easier with the housing database. How to handle the houses that do not comply with building codes can be determined using the housing database. The building database can be used for settlement planning and to avoid risk during natural disasters, and also for the purpose of generating revenue and for ensuring compliance with standards. Finally, the database can also be extremely useful for strengthening houses and for making demolition decisions for risky houses.

4. Discussion

This paper intended to examine the beneficiary survey methods used after the 2015 Gorkha earthquake and to compare that with practices in other countries. This paper also aimed to recommend the appropriate model for the future by establishing a link of the database to municipal housing construction and settlement planning for mitigating disaster risks. All steps that were adopted for the HRHS were described and analyzed starting with the pre-survey preparation to conclusion. The findings section also described the building construction permit system.

4.1. Survey organizations

The survey organizations lacked clarity with regard to the owner. MoFALD was the de jure owner of the survey. However, the Steering Committee was headed by the NPC instead of MoFALD, which was a contradictory arrangement. The reason for the NPC leadership could have been the engagement of the CBS, an agency under the NPC that was to conduct the survey. The NPC's leadership in other preparatory activities could have been another reason why it had chaired the Steering Committee. The problem was further aggravated as the CBS had no institutional experience in the collection of engineering related data. The HRHS was planned to build on the ongoing Rapid Visual

Damage Assessment work being carried out under the DUDBC's guidance. A considered decision could have been taken whether to assign the DUDBC as the lead agency. The Senior Divisional Engineer who was supposed to play a crucial role in quality control was under the DUDBC's command; the CBS thus could make requests and not order cooperation. The problem was further compounded due to absence of elected local governments immediately after the earthquake. The Village Secretary was the only authority at the local level but many of these officials had abandoned their village posts after the start of the Maoist insurgency (Lawoti, 2009). The survey team was therefore unable to obtain local support which constrained its capacity to deliver. Therefore, the survey approach was not robust enough for responding to the challenge.

4.2. Recruitment of survey staff

The UNOPS selected the Health Research and Social Development Forum (HERD) for mobilizing human resources for the survey. HERD was an NGO with institutional experience in dealing with health-related issues as its vision is to promote health and wellbeing of people (HERD Nepal, 2020). Or, its institutional focus was directed towards health rather than building construction. HERD faced a herculean task of recruiting 5029 engineers, social mobilisers and other professionals within a very short period of time. It was almost impossible to get as many professionals in the market. Consequently, it recruited mostly fresh graduates who were provided with a short training. Nepal's civil engineering curriculum does not include rubble stone masonry in mud mortar, a building type of most target houses, which meant that the engineers had very little knowledge of the questionnaire and the understanding of all engaged was not identical. Moreover, the questionnaire allowed them to use discretionary judgment on the damage category. Under these circumstances, it was fairly difficult to receive a uniform, well considered outcome. Consequently, it is believed that the households who should have been entitled to receive grants did not receive them and

those who should not have received, were included in the eligibility list.

4.3. Appropriateness of the questionnaire

The questionnaire was divided into two sections. Part I included the detailed assessment of residential building. All information included in Part I was relevant as it attempted to clarify legal ownership issues, which is instrumental for providing grants. Secondly the characteristics of the house and characteristics of damage were also assessed. However, there was no direct link between damage characteristics and the damage grade that the enumerator would assign. The general assumption seemed to have been that the enumerator should reach the appropriate conclusion after filling out the questions dealing with the damage characteristics. Ultimately the enumerator's subjective judgment was used for ascertaining the damage grade. There should have been a direct connection between the damage characteristics and damage grade, which was a visible weakness in the questionnaire.

two questions: family members' details with physical disability if any. The grant amount was flat for all types of households: US\$ 2000 at the initial stage which was increased to US\$ 3000 later. Based on the expert opinion of the NRA executives, it was confirmed that if those two questions had been embedded under section I, the interview time would have shortened by at least one third and that would have had a profound impact on survey time.

4.4. Timing and quality of the household survey

The duration and number of beneficiary surveys is presented in Table 5.

Table 5 shows that the surveys were completed within a year. The survey of this magnitude was the first of its type in Nepal. It was also done during the period when Nepal had no elected local governments. Recruitment and mobilization of over 5000 people at a time was the major task. The general public had perceived this as a delayed operation because the survey was started eight months after the earthquake (Sharma,

Table 5: Timing and Output of CBS Led Beneficiary Survey in Three Phases

Phase	Duration	Surveyed Beneficiaries (Nos)	Human Resource
First	2016.01.15 to 2016.06.20 (5 months)	679,919	5,029
Second	2016-07-11 to 2016-09-15 (2 months)	107,631	1,050
Third	2017-04-14 (5 months) 2016-11-21	114,308	364

Source: (CBS, 2017a)

In the absence of the direct link, the enumerator's discretion prevailed and that could have been biased. The second requirement in the questionnaire was the assessment of geo-technical risk. It was not wrong to have this requirement but the NRA did not take any decision based on the geo-technical risks reported in the questionnaire. The DDRC collected landslide information of 475 locations, which was the basis for further investigation by a team of geologists, engineers and surveyors. Hence, the questions included in the questionnaire were redundant. Similarly, Part II that dealt with demographic and socio-economic information also became largely irrelevant except for

2016). One question that was often asked was whether or not such a comprehensive survey should have been carried out after such a huge disaster.

The NRA Steering Committee doubted the outcome of the survey and later asked the NRA Executive Committee to do a second survey of the households that had been declared as non-beneficiaries (NRA, 2017a) by the NRA's Grievance Redressal Committee. The submission of grievances had also continued despite the fact that the number of beneficiaries exceeded the total number of households. For example, in Dolakha, the number of households was 45,688 in 2011, and the population in the Mountain districts

had been decreasing. However, the number of beneficiaries had reached 72,859 which was 1.59 times more than the number of households considering that the number of households had remained constant after 2011. Similarly, the household to beneficiary ratio in Ramechhap, Sindhupalchowk, Kavrepalanchowk, Nuwakot, Dhading, Rasuwa and Gorkha was: 1.29, 1.36, 1.04, 1.32, 1.08 times, respectively. The number of beneficiaries exceeded the number of households and that meant that there had been an artificial increase in the number of beneficiaries.

The inaccurate survey may have also contributed to inflated number of beneficiaries. Based on the FGDs and opinions of the district authorities, ineligible households may have been included in the first list of beneficiaries, which could have instigated others to also make attempts to be listed. The inappropriate survey may have also caused some of the households that should have been included from being excluded from the beneficiary list. This situation could have also created social injustice and prompted grudges. The inclusion of non-beneficiaries increased the State's liability significantly but this did not do away with the discontent among some households.

4.5. Assessment of different methodologies adopted in different survey phases

Although the survey was conducted in three phases, there were basically two different methodologies used. The first was the census and second was the verification model. Comparison has to be undertaken based on the objectives which were set earlier. The principal objectives of the survey were to ascertain the complete scope of damages to the housing stock, to ascertain the list of beneficiaries to receive housing recovery assistance, to ascertain site safety to ensure that rebuilding at a specific site was safe, and to promote public confidence on recovery efforts underway.

Against the first objective, both the census and verification model served the purpose. In the verification model, the municipality or the Village Development Committee prepared a list of victims on the basis of

the DDRC's Earthquake Victim Card. Additional aspirant households were also added if they felt excluded for some reason. Based on this, the local government prepared a consolidated list which was the basis for surveying. The verification model intended to save time and cost. The complete scope of damage to the housing stock was revealed by both methods, and in this respect, there was no need for having the census. The second objective was to prepare the beneficiary list, which was also possible with both survey models. The third objective of assessing site safety was not adequate in the questionnaire as it required more intensive investigations. Therefore, both survey methodologies did not deliver the third objective.

The HRHS objectives were limited to the reconstruction period. A census would have been justified had there been a long-term objective of settlement planning and converting weaker structures (though not damaged) into earthquake resilient ones. It would have also been justified if the database created had been planned for handover to the local governments for planning purposes. From all these perspectives, the verification model was more appropriate for reconstruction purposes.

4.6. Linking beneficiary survey to long-term planning

The survey required further clarity in terms of the stated objectives of ascertaining damages to the housing stock, finalizing the list of beneficiaries and ensuring site safety for rebuilding at specific sites. For such a situation, the census survey would not have been required and the verification model would have been adequate. Similarly, the content of the questionnaire could have been more focused on the housing damage. In retrospect, the scope of survey was widened unnecessarily and that contributed to wastage of financial resources and the resulting delays. However, if the objective had been to create a database for long-term planning of settlements with earthquake resilient housing stock and to support the creation of a production-oriented society, then the census survey

would have been appropriate. However, in both cases the content of the questionnaire would have required adjustments to match the objectives. For the future, it would be important to ensure that all local governments have a comprehensive database of housing stock with land characteristics and also basic socio-economic information of the household. The local governments could outsource both the surveys and the establishment of a database system. With such information available, they would only need to conduct light surveys after natural disasters, which can be completed in a short time. Such an arrangement can facilitate the State to plan settlements and evacuate houses from vulnerable to safe areas. Such a database can also be instrumental for extending appropriate credit facilities and other extension services.

4.7. Beneficiary survey methodology in Nepal and other countries

Nepal's methodology was compared with other four countries: India, Pakistan, China and New Zealand. The methodologies of three South Asian countries were similar. There could be a number of reasons to explain this including similar socio-economic conditions, identical level of development, and people's psychology. In all three earthquake projects, the design was influenced by the World Bank. Drawing lessons from the 2001 Bhuj Earthquake, the Bank may have replicated the methodology in Pakistan, and continued the same in Nepal. However, the methodology did not appreciate the subtle differences among the three countries. India had a stable democratic system with functioning and thriving local governments whereas Pakistan had a tumultuous history where the military and civilian rulers had taken turns at ruling. The Pakistan army had played the central role in Pakistan's beneficiary survey.

When tremors struck Nepal in 2015, the monarchy had been abolished but the first Constituent Assembly had not been able to promulgate a constitution (IDEA, 2015). The second Constitutional Assembly was elected in 2013 but the Assembly had not finalized the constitution when the earthquake occurred in 2015. The

disaster may have expedited the political agreements and the Constitution was promulgated on 20 September 2015. There were, however, no local governments because elections were held only in 2017/18. The Village Secretary was the only government representative at the village level but the person operated from the district headquarters as many local government offices had been damaged during the 1996-2006 Government-Maoist conflict. In retrospect, therefore the adopted methodology was not appropriate in the circumstance when it was designed and the DDRC would have been an appropriate agency for the identification of beneficiaries.

With the vast differences in socio-economic circumstances, the highly successful methodologies used in China and New Zealand were difficult to replicate in Nepal.

The socio-political environment in Nepal changed as reconstruction progressed. Nepal now has elected local governments in the federal structure. Therefore, in future these local governments have to be made accountable for beneficiary identification. However, there are certain limitations, the local leaders are elected based on partisan contest and aspire to be reelected, which could create situations of bias in identification. This could also lead to tendencies to maximize the number of beneficiaries for the sake of local popularity. In the nutshell, even though the future beneficiary identification responsibility should be shifted to the local governments there would also be need for adequate safeguards to prevent bias.

4.8. Way forward

As suggested by key experts, the outcome of the FGDs and based on the comprehensive review of the national and international experiences, the household database generated during reconstruction was deemed to be an essential input for effective planning, management and reconstruction after a disaster. It also facilitated the social security system. Towards this, Nepal has made some headway. The CBS has included housing information in the census (CBS, 2012). The CBS housing data

includes type of foundation, type of outer wall, roof of the house, source of drinking water, fuel for cooking, source of lighting, toilet in the house, and other household facilities. Other socio-economic information is also included. This statistical overview can serve as a good resource for developing macro-level policies. However, it does not include the data on individual households, which is indispensable for disaster preparedness, rescue relief and reconstruction.

Some municipalities such as the Kathmandu Metropolitan City have introduced an electronic Building Permit System (KMC E-BPS Project, 2020). The building permit is essential before constructing a house and compliance to the Building Code is mandatory. The owner is also required to secure a building completion certificate. For approval, the owner needs to submit information on house characteristics, land use zone and subzone, high tension line, Right of Way of river, description of land, road width and Right of Way (RoW). This information is adequate for maintaining a housing record. However, this information does not sufficiently include land characteristics and lacks socio-economic information.

Against this background, it will be sensible for municipalities to maintain a database similar to that built by the NRA. Some adjustment may be required in the questionnaire as the purpose of NRA was to assess damage caused by the earthquake whereas the purpose of the housing database would be to use the data for land use planning, vulnerability assessment, evacuation, and for delivering services. The database will be also useful to strengthen the weak houses and to demolish un-retrofitable houses. Such a database can also facilitate speedy rescue operation and reconstruction following disasters.

However, the present laws, rules and policies do not include provisions for enforcing such housing

information systems. Hence, the MoUD and MoFAGA would need to issue guidelines that can then be enforced at the local level.

5. Conclusions

The objective of the household registration for the HRHRS was justified. Having no local governments, an inexperienced agency (CBS) to carry out housing surveys, and anomalies in the survey leadership resulted some limitations in the survey outcomes. Unavailability of the required number of human resources with professional experience to tackle the technical complexities resulted in a large number of grievances. Despite these, the NRA's housing database facilitated and has led towards creating and maintaining municipal-level housing databases. This information will be instrumental for land use planning, for ensuring robust housing structures based on the ground characteristics, and for collecting housing revenue.

In addition, municipalities can intervene for strengthening houses or even issue demolition orders for managing vulnerable structures. Such databases can also be extremely valuable for house or land pooling initiatives for urban renewal. For this, the MoUD in conjunction with the MoFAGA will need to either amend the Basic Construction Standards for Settlement Development, Urban Planning and Building Construction - 2072 (MoUD & MoFALD, 2015) and Nepal National Building Code NBC 206:2015 (DUDBC, 2015), or issue another guideline for requiring local governments to maintain housing databases. The new guidelines, can enable Nepal's municipalities to develop disaster resilient settlements, furnish better amenities and deliver effective services, and also make post disaster relief and rescue and reconstruction simpler and more effective.

References

- [1] Arshad, S., & Athar, S., 2013. Rural Housing Reconstruction Program Post-2005 Earthquake Learning from the Pakistan Experience A Manual for Post-Disaster Housing Program Managers. Washington D.C.
- [2] CBS, 2012. National Population and Housing Census 2011. Central Bureau of Statistics, National Planning Commission, Government of Nepal, Kathmandu. <https://cbs.gov.np/publications>.
- [3] CBS, 2016. Conceptual Plan of Household Registration Program in Earthquake Affected 17 Districts. Central Bureau of Statistics, Kathmandu.
- [4] CBS, 2017a. Nepal – Household Registration for Housing Reconstruction Survey 2016-2017. Kathmandu. <http://cbs.gov.np/nada/index.php>.
- [5] CBS, 2017b. Nepal – Household Registration for Housing Reconstruction Survey 2016-2017 – Overview, Central Bureau of Statistics. <https://nada.cbs.gov.np/index.php/catalog/69/study-description> (accessed 2 September 2020).
- [6] CERA, 2012. Recovery Strategy for Greater Christchurch – Mahere Haumanutanga o Waitaha. Christchurch.
- [7] Cristea, M. et al., 2014. The Relationship between Insurance and Economic Growth in Romania Compared to the Main Results in Europe – A Theoretical and Empirical Analysis. *Procedia Economics and Finance*. Elsevier BV, 8, pp. 226–235. doi: 10.1016/s2212-5671(14)00085-9.
- [8] DUDBC, 2015. Nepal National Building Code: NBC 206:2015. Department of Urban Development & Building Construction, Ministry of Urban Development, Government of Nepal, Kathmandu. http://www.moud.gov.np/images/category/NBC_206_2015_ARCHITECTURAL_DESIGN_REQUIREMENTS1.pdf.
- [9] EH, 2020. Earthquake Nepal. <http://www.earthquake-nepal.com/> (accessed 2 September 2020).
- [10] GoN & IDA, 2015. Financing Agreement: Earthquake Reconstruction Project. Government of Nepal, Kathmandu.
- [11] HERD Nepal, 2020. HERD at a glance. <https://www.herd.org.np/page/20> (accessed 13 June 2020).
- [12] IDEA, 2015. Nepal's Constitution Building Progress, Challenges, and Contributions of International Community. Stockholm. International Institute for Democracy and Electoral Assistance, Sweden.
- [13] Johnson, L. A., & Olshansky, R. B., 2016. After Great Disasters: How Six Countries Managed Community Recovery, Lincoln Institute of Land Policy. https://www.lincolnst.edu/pubs/dl/3679_3031_after-great-disasters-full.pdf.
- [14] KMC, 2018. Building Construction Working Procedure, Kathmandu Metropolitan City. https://www.kathmandu.gov.np/sites/kathmandu.gov.np/files/documents/bhawan_nirman_karyabidhi.pdf (accessed 3 September 2020).
- [15] KMC E-BPS Project, 2020. Building Permit Process Information, Kathmandu Metropolitan City. <http://www.kmcebps.gov.np/Home/BuildingPermit> (accessed 13 June 2020).
- [16] Lawoti, M., 2009. The Maoist Insurgency in Nepal. *The Maoist Insurgency in Nepal*. 1013 (October), pp. 1–31. doi: 10.4324/9780203869390.
- [17] Mishra, P., 2004. The Kutch Earthquake 2001: Recollections, Lessons and Insights, National Institute of Disaster Management. https://nidm.gov.in/PDF/pubs/KUTCH_2001.pdf (accessed 2 September 2020).
- [18] MoFALD, 2015. Conceptual Notes and Workplan of Household Registration Program for Housing Reconstruction in Earthquake Affected Districts. Kathmandu.
- [19] MoHA, 2016. Gorkha Earthquake 2072: Experience and Learning. Government of Nepal, Kathmandu.
- [20] MoHA, 2019. Guidelines for Formulating Disaster Preparedness and Reconstruction Plan. Kathmandu. <https://mail.google.com/mail/u/0/#search/Santosh.Bisht%40mottmac.com/FMfcgxwDsFlPzLlLhVVDTQzRFGXhgKlh?projector=1&messagePartId=0.1> (accessed 16 June 2020).
- [21] MoUD & MoFAGA, 2015. Standard for Settlement Development, Urban Planning and Housing Construction, 2072. Nepal. <http://www.moud.gov.np/images/category/Basti-Bikash-Mapdanda-2072-Final1.pdf>.

- [22] NDMA, 2007. Earthquake 8/10: Learning from Pakistan Experience. Islamabad. <http://www.ndma.gov.pk>.
- [23] NPC, 2015a. Post Disaster Need Assessment. Kathmandu. www.npc.gov.np.
- [24] NPC, 2015b. Post Disaster Needs Assessment – Sector Reports, pp. 3–20, 67–78, 287–294. <http://www.gfdr.org/gfdr/node/118>.
- [25] NPC, 2018. Guidelines for the Preparation of Local Level Planning – 2075. Kathmandu. <https://www.npc.gov.np/en>.
- [26] NRA, 2016a. NRA Steering Committee Decision on 25.08.2016. <http://www.nra.gov.np/np/content/steeringcomdes/0> (accessed 1 September 2020).
- [27] NRA, 2016b. Working Procedure for Earthquake Affected Private Housing Grant Distribution, 2073. National Reconstruction Authority, Nepal. www.nra.gov.np.
- [28] NRA, 2017a. Decisions of Ninth Meeting of the NRA Steering Committee. National Reconstruction Authority, Nepal. www.nra.gov.np.
- [29] NRA, 2017b. Working Procedure for Reconstruction Grievance Management, National Reconstruction Authority. <http://www.nra.gov.np/np/resources/details/bYI1dNmmAfcggmU2atIc8fiZ02PODtOvb-Cw1Sq4k8WY> (accessed 16 June 2020).
- [30] NRA, 2020a. EHRP Nepal: Inspection Dashboard, National Reconstruction Authority. <https://ehrpinspection.nra.gov.np/> (accessed 16 June 2020).
- [31] NRA, 2020b. NRA Housing Data Visualization. <http://www.nra.gov.np/np/mapdistrict/datavisualization> (accessed 2 September 2020).
- [32] NRA, 2020c. Settlement of Grievances, National Reconstruction A. http://www.nra.gov.np/np/news/details/P4M4D8SnX7CXgD-y-7uXzAQK6z4Z-qcFCm2pAD_y-iM (accessed 2 September 2020).
- [33] Sharma, B., 2016. Talk of quick survey for aid hollow. The Kathmandu Post. <https://kathmandupost.com/national/2016/03/10/talk-of-quick-survey-for-aid-hollow> (accessed 3 September 2020).
- [34] Shrestha, M., 2016. Many earthquake victims will spend another harsh winter in temporary shelters. Himalayan Times. <https://thehimalayantimes.com/business/perspectives/reconstruction-delay/>.
- [35] Sumsher, B., 1935. Nepal's Mega Earthquake – 1990 BS. Jorganesh Chhapakhana, Kathmandu.
- [36] Tipler, J., 2019. Earthquake Preparedness in New Zealand. Wellington.
- [37] WB, 2015. Project Appraisal Document for an Earthquake Housing Reconstruction Project. Kathmandu.
- [38] Xinhua News Agency, 2008. China View: China Quake Death Toll Remains Unchanged at 69,226. 25 August.



A Site-specific Seismic Hazard Assessment for Sundhara, Kathmandu

Hari Ram Parajuli^a, Bikram Bhusal^b

Keywords: *Gorkha earthquake, Kernel density, soil amplification, time history analysis.*

Abstract

A study was carried out to obtain seismic hazard for the monument called Dharahara located at Sundhara, Kathmandu by considering smooth gridded sources and subduction zone attenuation models with logic trees. The seismicity parameters were evaluated by dividing the whole region into four zones. Uncertainties associated with the estimation of seismic intensities were addressed by using uniform and kernel density function methods together. Probabilistic response spectra were developed for 39 percent, 10 percent and 5 percent probabilities of exceedances in 50-year period, and peak ground acceleration found was 0.305g, 0.571g and 0.728g, respectively, at the site with soil amplification factor to 1.4.

1. Introduction

Dharahara, the tallest tower in Kathmandu, was built by Bhimsen Thapa, the first prime minister of Nepal in 1824 B.S.¹ It is located at Sundhara, in central Kathmandu, Nepal. The original height of the tower was 72.96 m. The tower was significantly damaged by the Nepal-Bihar earthquake ($M_w=8.1$) in 1934 B.S (Ambraseys and Douglas 2004). After 1934 earthquake, the historical lime masonry monument was raised to 61.88 m by Juddha Shamsher Jang Bahadur Rana, the then prime minister. Dharahara comprised of a central core column with diameter of 900 mm and outer wall with varying thickness of 1.8288 m at the bottom and 0.7366 m at the top. The nine story tower had a height of 61.88 m from the base and 54.102 m

from the top of the exterior stone footing steps. Also, the slab of cantilever verandah projected at the top had a width of 900 mm and thickness of 75 mm. Since the tower was built using brick masonry and traditional technology, the tower has historical value. The tower completely crumbled and collapsed in the 2015 Gorkha, Nepal earthquake killing 183 people inside. The Dharahara has been rebuilt and even though it resembles the original tower the new structure is equipped with modern facilities. The reconstruction plan said the new Dharahara would be 72.96 m tall with 11-storeys above the ground, while it was to have 21-storeys from the inside.

The new structure has a mini exhibition theatre on the 18th floor and a mini museum with some history of past earthquakes. The original tower was a

^a Executive Member, National Reconstruction Authority, Nepal, hariparajuli@ioe.edu.np

^b Lecturer, National College of Engineering, bikramrijal103@gmail.com

¹ Bikram Sambat, or the Nepali year, is 57 years ahead of the Gregorian calendar.

brick masonry structure and the new one was built using modern technology, while retaining the traditional appearance. Such reconstruction efforts involve site-specific seismic hazard assessments.

1.1 Faulting and seismic sources

Nepal is narrow and elongated country in Greater Himalayas, lying towards the southern collisional boundary of the Indian and the Eurasian Plates. Within the narrow width of Nepal three fault systems – Main Central Thrust (MCT), Main Boundary Thrust (MBT) and Himalayan Frontal Thrust (HFT) – pass from the east to the west throughout the length of the country, including many other smaller (92) faults (BECA,

1993). The geological map including major faults with MFT, MBT, MCT and several small faults is provided in Figure 1. The information on the faults were collected based on existing literature (Pandey et al., 2002, Stevens et al., 2018, Rahman and Bai, 2018, Bothara et al., 2002). As a result of sliding of seismically active zones, world records of earthquake occurrences is about 17 percent in the trans-Himalayan belt (Ulak, 2016). Alongside the many faults in the country, Nepal also has a complex geography. The higher Himalayas –altitude 5000 m and above -- consists of mainly vertical and steep rocky slopes with excessive amounts of quartzite, gneisse, marble and schist. The lesser Himalayan zone also consists of similar rocks and is also a zone that is very active and uplifting at high

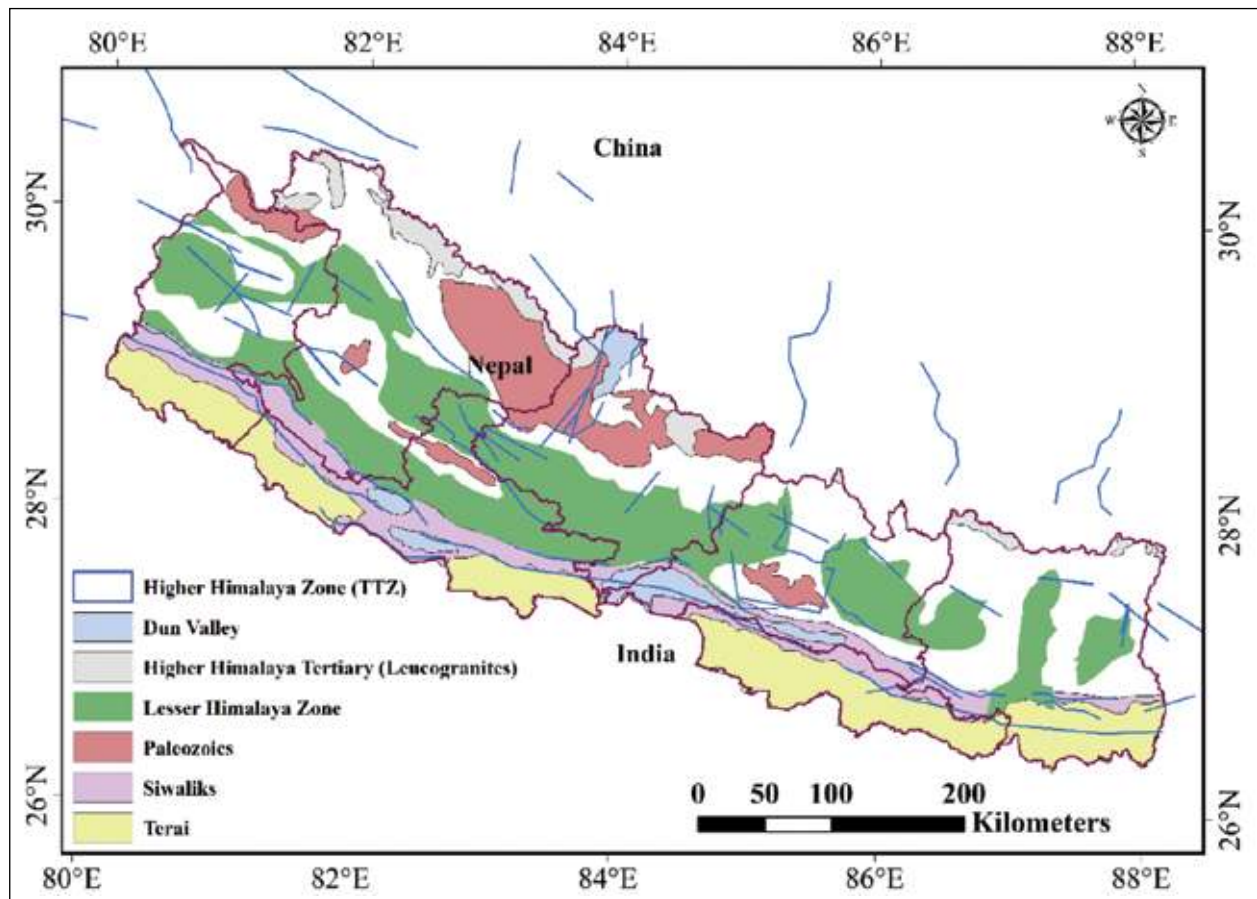


Figure 1: Location of major faults in Nepal (after Amatya and Jnawali, 1994)

rate. In midlands or Mahabharat range the soil formation consists of deeply weathered rocks and limestone, dolomite marble and granites. The Siwaliks which lies in lowermost part of Nepal (Terai or plains) comprise of river deposits and coarse sediment in the north, near to the base of Siwalik range (Amatya and Jnawali, 1994, Dahal, 2010). The Terai also comprises of several Dun valleys like Trijuga in the east, Dang in the west, and Chitwan in the central part of the country. These are filled with coarse to fine alluvium soil.

The non-uniformity in soil type and the complex geology causes the different level of shaking and destruction during earthquakes. In case of Kathmandu Valley, the soil beneath the city is mainly formed of young soft fluvio-lacustrine sediments; the southern part is dominated by silty-clayey soil whereas the northern part is dominated by sand and fluvial gravel and sand deposit around Bagmati river. This alludes to the possibility of amplification of ground motion and result maximum destruction in structures (Kumahara et al., 2016). In addition there are several faults -- Jhiku Khola, Chitlang, Kulekhani, Malagiri and Kolphu Khola faults -- around the Kathmandu Valley with the potential of producing earthquakes (Ulak, 2016). Though many closely spaced faults have been identified around Kathmandu, it is hard to justify the sources individually for lack sufficient earthquake records associated with each fault. Generally, all earthquake data are collected and magnitude-frequency relationship is developed and considered as a single source. However, density of earthquake occurrences at various location are considered from two methods -- uniform hazard density and kernel density function method (Woo, 1996) which is explained in following sections.

1.2 Earthquake sources modeling

To study seismic hazard analysis of a region identification and delineation of earthquake sources are required. Several approaches are used for identification including fault activity, geologic evidence, historical seismicity, tectonic evidence and instrumental seismicity (Kramer S.L, 1996). Earthquake sources can be

modeled as point, linear, areal or volumetric depending on the information on the tectonics of the region. Also, identification of the source is very complex and in the absence of clear identification, the smooth gridded source method can be used. Since MCT, MBT, HFT are situated in a narrow width and there is no clear evidence of where the past earthquake falls under the faulting system, this study has considered the areal source model. The seismicity within the study area is not uniform throughout historically higher seismicity observed in the northern parts. Also, higher seismicity can be observed in the range between the higher Himalayas and the Mahabharat range, and lower seismicity in southern part of study area (Terai region) including some parts of India. For defining the boundaries of area source regional crustal geology, historical earthquake distribution and faulting system has been considered. Four areal sources were adopted for hazard analysis and recurrence relationship based on historical seismicity and it is assumed that a source zone is considered with region of uniform seismicity. The study area was further divided into grids and seismic activity rate was obtained for each cell considering center of cell as a site. Areas of 200 km radius around the site were divided into small cells and each cell was considered as a source. Earthquake densities in each cell were calculated by kernel density and uniform density function method (Parajuli et al. 2010). The earthquake data and delineation of seismic sources are plotted in the Figure 2.

1.3 Attenuation of ground motion

Transmission of seismic waves basically depends on the geological formation beneath the soil surface. So, proper selection of Ground Motion Prediction Equations (GMPEs) should be done, which for the Himalayan region have been developed based on the past earthquake accelerations. However, this is also an area where very few studies have been done compared to other sub-duction zones in the world. Due to unavailability of attenuation laws developed for this region we need to look for suitable equations developed from

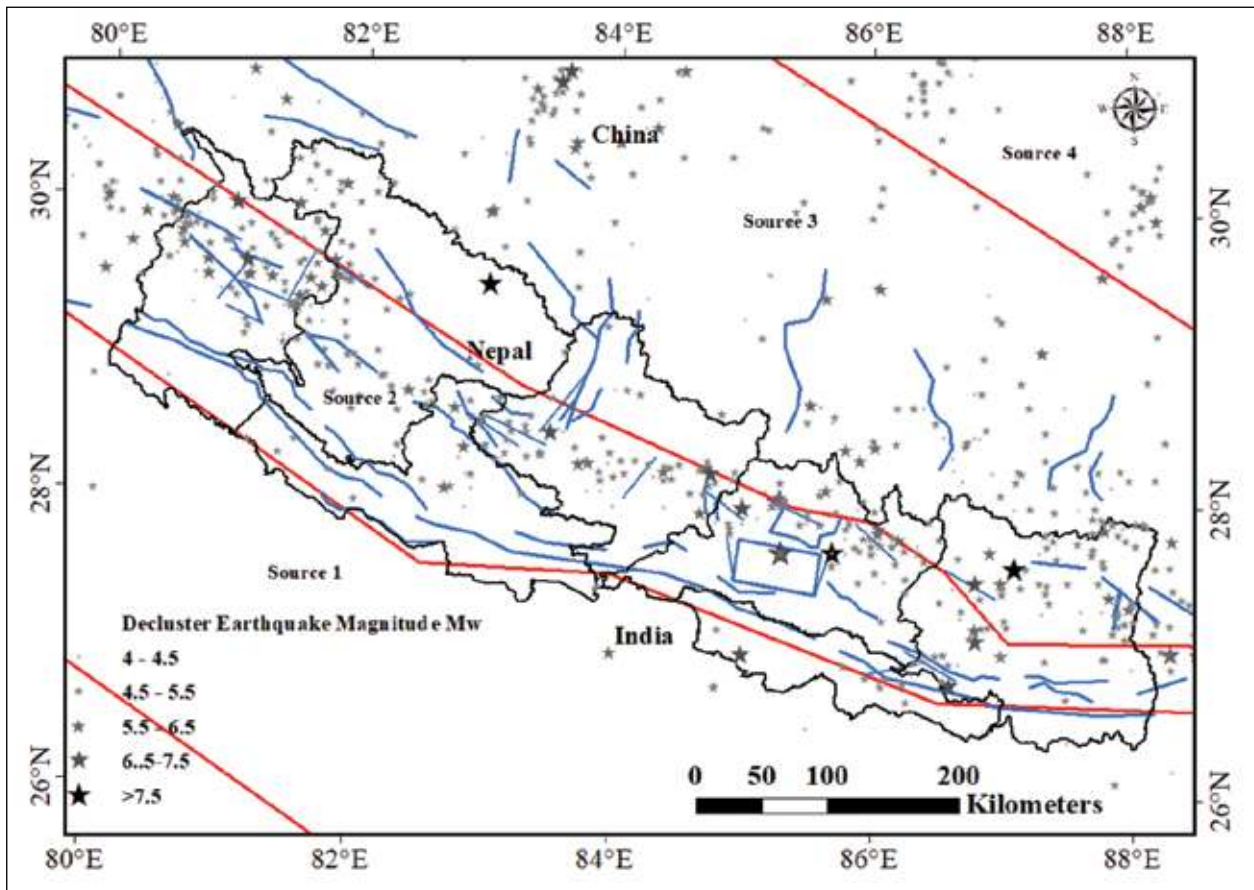


Figure 2: Earthquake data and delineation of seismic sources (after Parajuli et al 2010)

other similar tectonic environments from the global database. There are several attenuation relationships developed for subduction zones, which are also suitable to use in the Himalayan region. Youngs et al. (1997) developed attenuation relationship based on Cascadia, Japan, Mexico, Peru and Solomon Islands with magnitude ranging from 5.0 to 8.2 moment magnitude (M_w), however, its acceleration has been dominated by amplified accelerogram of the Mexican earthquake. Gregor et al. (2002) developed the same from the Cascadia mega thrust earthquakes considering three different rupture geometries to model the M 8.0, 8.5, and 9.0 events. Atkinson and Boore (2003) primarily developed an attenuation relation for the Cascadia region using limited, strong ground motion records of subduction

and bulk of the datasets were added from Japanese earthquakes through 2001. They proposed the coefficients for the only one site, not as specific sites as rock and soil. Kanno et al. (2006) considered a database of all Japanese strong ground motion records between 1963 and 2003 in order to identify a new standard attenuation relation for Japan, for response acceleration as well as peak value. Zhao et al. (2006) have presented a spectral acceleration attenuation model for Japan using a very large number of strong ground motion databases up to 2003.

Comparative study about suitability of the seismological and a geological condition for Nepal was done by two Nepali researchers. Maskey and Mishra (2004) have investigated the suitability of attenuation relation

for this region. They said that the relation can be used for estimation and comparison purposes without doubt and concluded that the attenuation laws proposed by Youngs et al. (1997), Donovan (1973), Cornell (1979) and Crouse (1991) were the most suitable for the Nepal region unless a better alternative was found. As Nepal lies in the subduction zone, the attenuation laws developed for the subduction zone explained earlier is used to develop the peak ground acceleration (PGA) and spectral acceleration (SA). Considering the suggestion of past studies and suitability of the tectonic environment of the Himalayan region, Young's et al 1997, Kanno et al (2006), Zhao et al (2006) have been used in this study.

2. Probabilistic Seismic Hazard Assessment

Probabilistic Seismic Hazard Assessment (PSHA) first initiated by Cornell (1968), thereafter has become widely accepted method of estimating earthquake intensity for future damages. It has been further advanced following the development of attenuation laws after the 1990s.

2.1 Regional seismic hazard analysis

In Nepal, the Basic Exchange and Cooperation Agreement for Geo-spatial Cooperation [BECA (1993)] had conducted probabilistic seismic hazard analysis of Nepal and risk assessment of Nepal, which was the basic for the Nepal Building Code (NBC) 105:1994. Pandey et al. (2002) had conducted a seismic hazard analysis and prepared seismic hazard map of Nepal. They had prepared a seismo-tectonic model proposing the mechanism of great earthquakes of Himalaya to be consistent with stick slipping of the Indian basement along a sub horizontal detachment interface. The seismic sources were characterized keeping in view the seismo-tectonic model and by adopting the characteristic fault model PSHA. They had collected a micro seismic database of more than 5000 local earthquakes of magnitude greater than two occurring within the country and near the vicinity between March 1994

to 2002. The frequency magnitude relationship was derived for the eastern and western seismic belts of the higher Himalaya and the attenuation relationship, given by Young's et al (1997), was used to obtain peak ground acceleration. They considered M8.2 earthquake with a return period of 500 years in the assumption that it represented the matured seismic gap in the central Himalaya. The contour of PGA for bedrock condition was compiled for this return period with the significant moment magnitude greater than M5 for all sources, but contribution of the northern sources in the PSHA was ignored.

Gupta et al. (2006) had prepared seismic hazard maps of Northeast India based on the uniform hazard response spectra for absolute acceleration at stiff sites. A new attenuation model for pseudo-spectral velocity scaling was developed using 261 recorded accelerograms in Northeast India. The entire area of Northeast India was divided into 0.1° grid size, and the hazard level was assessed for each node of the grid by considering the seismicity within a 300-km radius around the node. To consider the spatial distribution of seismicity around each node, a spatially smoothed probability distribution function of the observed epicentral distances was used. Uniform hazard contours for pseudo-spectral acceleration as the hazard parameter was obtained for an exposure time of 100 years and for 50 percent confidence level at different natural periods for both horizontal and vertical components of ground motion. The trends reflected by these contours shown are consistent with the major seismo-tectonic features in the region. Parajuli et al (2010) had done the PSHA based on the past earthquake and slip rate of the region.

Thapa & Wang, (2013) carried out the seismic hazard analysis of Nepal based on pattern recognition method, by considering the distribution of earthquakes, fault information, and tectonic features dividing whole region into a 23 areal sources, mainly central Nepal, Southern Tibet, Northern India, Northern Bangladesh and Western Bhutan. In the research maximum magnitude was determined based on the largest historical and instrumental earthquakes. The minimum magnitude

was set at 4 and hypocenter depth 10 km was set for the whole region. The whole area was divided into a 0.20x 0.20 kilometer grid and had used the attenuation relationship developed for western China. The maximum PGA was estimated between 0.21g to 0.62g for 10 percent probability of exceedance. Also, it was observed that the highest and lowest ground motion was observed in far western and Eastern parts and the southern part of Nepal, respectively. Bai and Rahman, (2018) studied the probabilistic seismic hazard of Nepal using three different seismic sources. The study area was divided into 0.10 x 0.10 and radial distance of 300 km from the center of each grid was taken into account. Different seismic hazard maps for PGA value and Spectral Acceleration (SA) value at 0.2 sec and 1 sec natural period at 5 percent critical damping factor for 10 percent and 2 percent probability in 50 years was calculated for various locations of Nepal. However, the maximum PGA obtained in this study were 0.45g at bedrock with 10 percent probability in 50 years. Stevens et al, (2018) Nepal, earthquake (hereafter the Gorkha earthquake carried out the PSHA of Nepal using mix of faults and area source models to describe six seismic sources in Nepal. Modified GR model parameters was calculated using maximum likelihood estimator method. Four GMPEs related to subduction interfaces were used with V_{s30} (US Geological Survey Global V_s 30 map) for considering the site effect. Logic based open-quake model was prepared with 0.15° spacing for both latitude and longitude, minimum magnitude of M_w 5 up-to designated M_{max} with standard deviation 0.275 and mean weight of 0.45. The maximum ground shaking including site effect was 0.4g to 0.6g at 10 percent probability of exceedance. Bhusal and Parajuli, (2019) had carried out the probabilistic seismic hazard analysis of Nepal by collecting data on earthquakes of magnitude greater than 4 M_w occurred in the region by dividing the whole area into 9842 sites using global earthquake model open quake. Logic tree approach was used for seismic source considering area and linear source with various attenuation relationship, which reduced the spatial and epistemic uncertainty. Different seismic hazard map was plotted for different

returns period. The maximum PGA obtained in this study area was 0.52g at bed rock for 10 percent probability in 50 years.

From existing literature review, Pandey et al (2002) considered earthquake data between March 1994 to 2002 i.e., eight years and with minimum magnitude M_2 using single attenuation relationship. Hence, the research showed the result was not sufficient to depict the seismicity of entire region so an enlarged database of seismic events was deemed necessary with the use of several attenuations (more specifically logic tree approach for region where single attenuation relationship is not derived) to perform hazard analysis. Moreover, research by Thapa and Wang (2013) considered single value of 'b' which represented relative likelihood of large and smaller earthquakes and the single attenuation law which was developed for western China for all the considered sources. However, the assumption of single uniform value of b and single attenuation law does not represent actual scenario of hazard analysis. Bai and Rahman (2018) and Steven et al (2018) both considered several earthquake sources and calculated seismic parameters for each source. The historical and instrumental seismic database is inadequate and therefore completeness for several sources are difficult and consideration of a single value as in Thapa and Wang (2013) is inadequate to represent the entire seismicity. The current study was performed with adoption of seismic sources from the research of Parajuli et al (2010) with recent catalogue of seismic events and attenuation relationship, using the logic tree approach.

2.2 Earthquake catalogue

Historical earthquake data were gathered within the rectangular coordinates bounded by coordinates (78° 30' 00" E, 25° 30' 00" N) and (89° 30' 00" E, 31° 30' 00" N) around the site. The area source to be studied was divided into smaller areas by making a grid of size 0.5° along longitude and 0.25° along latitude. The input data for the analysis was obtained from the recorded previous earthquakes. In case of Nepal, the data is available

since 1255. The source of such earthquake data was the website of United State Geological Survey (USGS) archive, literature (Rana., 1935) and National Earthquake Monitoring and Research Center (NEMRC), etc. A total of 1228 records of magnitude greater than 4.5M in the area was obtained with (year, month, day), location (latitude and longitude), magnitude (body wave magnitude, surface wave magnitude, moment magnitude, Richter magnitude etc.), and focal depth.

These earthquakes may or may not occur at the previously identified faults. The past data show a good correlation with all known tectonic features, and average trend of past seismicity can be considered to represent the future trend with good confidence. The recorded earthquake was in the local scale like body wave magnitude, surface magnitude, Richter scale, etc. For the homogeneity in magnitudes, it was necessary to convert the different units of magnitude as well as the record in intensity scale (for earthquakes since ancient times) to the derive the moment magnitude. All magnitudes and intensities were converted to the moment magnitude using different empirical relations. The catalogue was also modified based on Ambraseys and Douglas (2004), Scordilis (2006), Hanks and Kanamori (1979).

$$M_w = 0.69 \times M_L + 1.7738 \quad (1)$$

$$M_w = 1.2765 \times M_s - 1.0825 \quad (2)$$

The body waves (m_b) were converted using Scordilis (2006) relationships which are given in equations

$$M_w = 0.85 \times m_b + 1.03 \text{ For } m_b \leq 6.2 \quad (3)$$

$$M_w = 0.99 \times m_b + 0.08 \text{ For } m_b > 6.2 \quad (4)$$

For intensity scale Hanks and Kanamori (Mcquire 2004) and McGuire (2004) was used as shown in the equations

$$\log M_0 = 19.36 + 0.481 \times t_i + 0.0244 \times t_i^2 \quad (5)$$

$$M_w = \frac{2}{3} \times \log M_0 - 10.7 \quad (6)$$

The earthquake record contained a large number of aftershocks which required to be removed to make

the database Poissonian. Aftershocks were filtered based on the space and time (Gardner and Knopoff, 1974), which is near the main or parent shocks. For this the aftershocks were identified based on its distance from epicenter of main shock and time difference in occurrence with main shock. All the data around the sources were converted into moment magnitude and passed through Gardner and Knopoff (1974) window and presented in table 1.

2.3 Recurrence relationship and completeness

Earthquake recurrence relationship was developed to access the seismicity of four source zones as mentioned in the Figure 2. The data was dispersed as per time interval and magnitude interval as shown in Table 1. The recorded earthquake events are not uniform due to the difficulty in obtaining old data. The recorded earthquakes are usually biased with the recent earthquakes due to the seismograph density. So, a de-clustering of the earthquake catalogue had to be done based on Gardner and Knopoff to reduce serious underestimation of mean rate of occurrence of lower magnitude and higher magnitude earthquakes. After de-clustering of earthquake catalogue, completeness of each source was performed. Moreover, it is necessary to do completeness analysis for the best fit of frequency formula and it was done as per (Stepp, 1992). For this, earthquake events were grouped into small intervals of time and each magnitude range (0.5M) was judged separately for all four seismic zones.

Recurrence coefficients obtained from regression analysis was plotted (Figure 3) following Stepp's (1992) procedure tabulated in Table 2., coefficients for this relation and maximum magnitude ever occurred in these source zones. The flattest slope in area 2 indicated there were a large number of biggest magnitude earthquakes, among them highest magnitude was 8.1. Similarly, the steepest slope in area 1 indicated that there were fewer larger magnitude earthquakes in this area. The largest known magnitude ever occurred in area 1 was 6.6 Mw.

Table 1: Arrangement of earthquake data

Year		Nos. of earthquakes exceeding the magnitude							
Start	end	4.5	5	5.5	6	6.5	7	7.5	8
1255	1910	41	32	27	22	17	12	5	2
1910	1920	2	2	2	2	2	1	0	0
1920	1930	0	0	0	0	0	0	0	0
1930	1935	4	4	4	4	4	3	1	1
1935	1940	1	1	1	1	1	0	0	0
1940	1945	1	1	1	1	1	0	0	0
1945	1950	1	1	1	1	0	0	0	0
1950	1955	7	7	7	2	1	0	0	0
1955	1960	3	3	3	2	0	0	0	0
1960	1965	2	2	2	0	0	0	0	0
1965	1970	6	6	6	3	0	0	0	0
1970	1975	18	14	6	0	0	0	0	0
1975	1980	38	27	3	1	0	0	0	0
1980	1985	59	31	10	6	2	0	0	0
1985	1990	56	26	5	3	1	0	0	0
1990	1995	76	35	5	3	1	0	0	0
1995	2000	120	44	12	4	2	0	0	0
2000	2005	106	33	10	4	2	0	0	0
2005	2010	106	40	9	4	2	0	0	0
2010	2015	180	78	11	7	5	1	1	0

Table 2: Earthquake recurrence parameters

Area	a	b	M _{max}
1	5.18	1.27	6.6 in 1833
2	5.04	0.91	8.1 in 1934
3	6.3	1.16	8.2 in 1505
4	5.86	1.18	7.2 in 1934

2.4 Magnitude uncertainty

After delineating sources and calculation of recurrence parameters the next step was to obtain the size of the earthquake that the source zone was expected to produce. Maximum size of the earthquake was taken from

past earthquake data. However, there is no certainty of future earthquake of being less than or equal to past ones in terms of magnitude. Also, chances of occurrence of smaller earthquakes is more frequent than larger ones. To address the uncertainty in magnitude (M) produced by each source zone, various recurrence

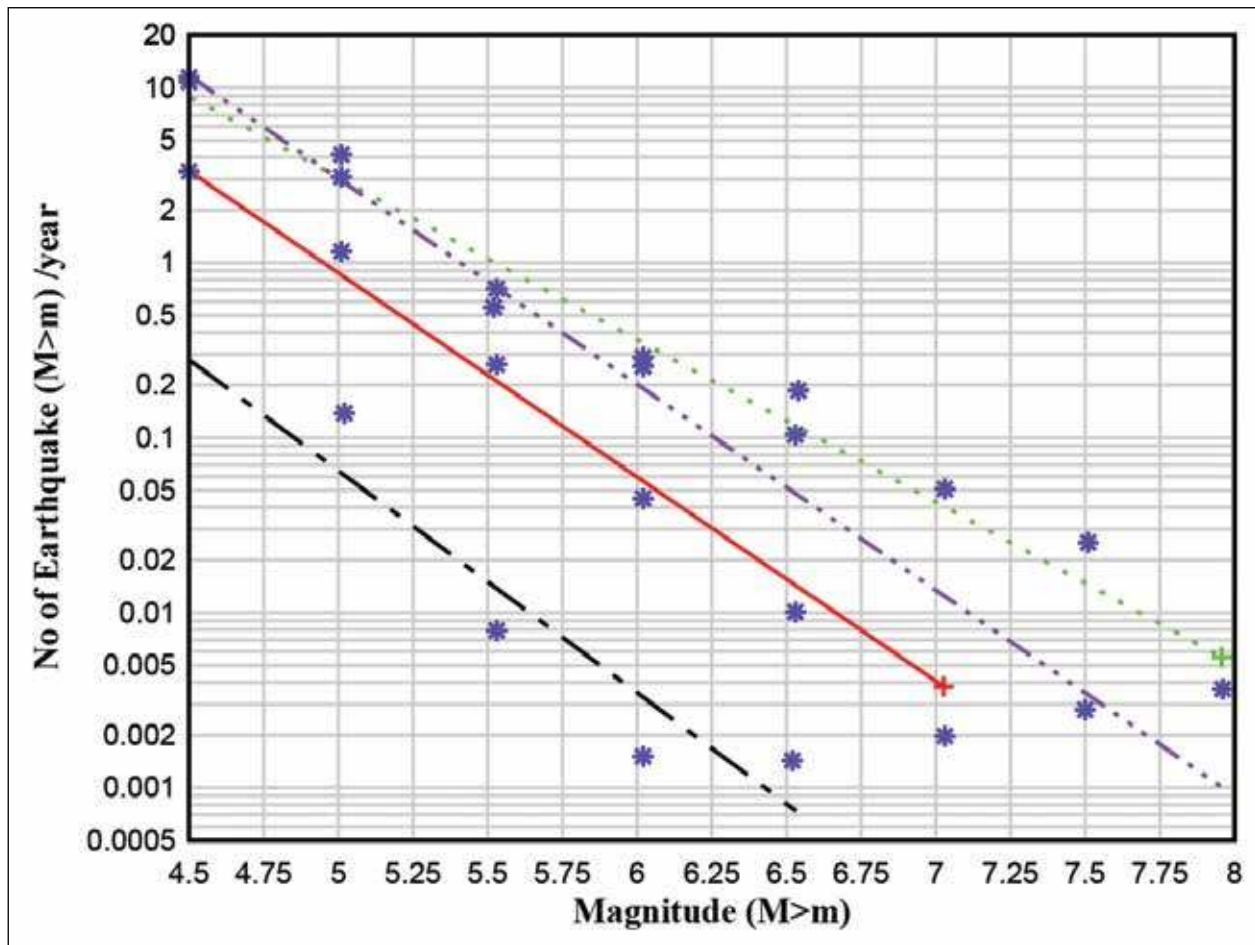


Figure 3: Recurrence relationship of earthquake

relationships specifying the average rate at which an earthquake of some size M will be exceeded was developed. The basic assumption of the recurrence law is that the future earthquake can also be predicted based on past ones (Kramer 1996).

The analysis was done by discretizing the area of Nepal in small zones and by taking the available past records of earthquakes, it was also necessary to characterize the seismicity of each zone. The magnitude frequency relationship thus obtained should accommodate the maximum size earthquake. The recurrence relation as per Gutenberg and Richter (1944) is,

$$\log \lambda_m = a - bM \quad (7)$$

Where,

λ_m = mean annual rate of exceedance of magnitude M

a = mean yearly number of earthquakes of magnitude greater than or equal to zero

b = relative likelihood of large and small earthquakes

As b value increases the number of larger magnitude earthquake decrease compared to those of smaller magnitude earthquakes.

The standard Gutenberg-Richter law predicts the non-zero mean rate of exceedances for magnitudes up to infinity. We were concerned with the earthquake greater than magnitude $M_{4.5}$ since greater size earthquakes produce maximum level of shaking, generally. So bounded recurrence relation law was

used to express the certain maximum magnitude $M_{\max}$ associated with each source zone (Table 2) the value of which was greater than minimum magnitude $M_{\min}$. The probability density function for Gutenberg Richter law with lower and upper bound magnitude is given by

$$f_M(m) = \frac{\beta \exp[-\beta(m - m_{\min})]}{1 - \exp[-\beta(m_{\max} - m_{\min})]}$$

2.5 Temporal uncertainty

The temporal uncertainty of an earthquake is suitably modeled by Poisson's model. Considering an earthquake event follows Poisson's process, the mean rate of exceedances over a fixed interval of time span is estimated (Kramer 1996). Mean rate of exceedances for various probability of exceedance in 50 years were estimated. For this study, probability of exceedances 5 percent, 10 percent and 39 percent in 50 years were considered.

2.6 Uniform Density Model and Kernel Density

Because the low availability of data of only a few earthquakes and uncertainty of locating the earthquake, hazard has been estimated using three different methods, namely Uniform density and Kernel density (Woo 1996) and relative density methods, which were compared and combined to yield single result (Parajuli et al (2010)). Instead of giving higher weights near the areas of earthquake occurrence as in the Kernel density method, the Uniform density method distributes earthquake densities equally irrespective of whether there are earthquakes or not. If there is the lack of recognizable earthquake faults and seismically active geologic structure in any area then the uniform density model is adopted. In such a model the earthquake densities are equally distributed in all areas whether or not there is an earthquake. Maximum magnitudes for these area sources are typically assessed from an extrapolation of historical seismicity of the region, from compelling worldwide analogs of the regional tectonic setting from regional paleo seismologic data and interpretations, or

simply from the judgment of experts. Uniform density model forgets faulting and assumes uniform geology and gives the equal weightage to the whole area capable of producing an earthquake.

2.7 Probabilistic spectra

The plot of mean annual rate of exceedance versus peak ground acceleration gives the seismic hazard curve. The probability of exceedance of certain ground motion is estimated by assuming probability distribution of ground motion. The probability of exceedance of certain ground motion of parameter Y rather than the particular value y^* is calculated for one possible earthquake at one possible source location and is multiplied by the probability that the particular magnitude earthquake will occur at the particular location. This process is repeated for all possible magnitudes and locations with the probabilities of each summed (Kramer 1996). For a given earthquake occurrence, the probability that a ground motion parameter Y will exceed particular value y^* can be computed by using total probability mean rate of exceedance from equation 9. This is equivalent to assuming that each source is capable of generating only N_M different earthquakes of magnitude, m_p at only N_R different source to site distances, r_k , mean rate of exceedances can be represented by equation 9.

$$\lambda_{y^*} = \sum_{i=1}^N \sum_{j=1}^{N_M} \sum_{k=1}^{N_R} v_i P[Y > y^* | m_j, r_k] p[M = m_j] p[R = r_k] \quad (9)$$

All the calculation steps were adopted as described in (Kramer 1996) by using MATLAB programming.

2.8 Logic tree

Due to unavailability of GMEs for Himalayan subduction zone, GMPEs developed for worldwide seismicity are used. In order to address epistemic uncertainties allocated in the GMPEs the logic tree with equal weights was used as shown in the Figure 4. The results have been presented in following sections.

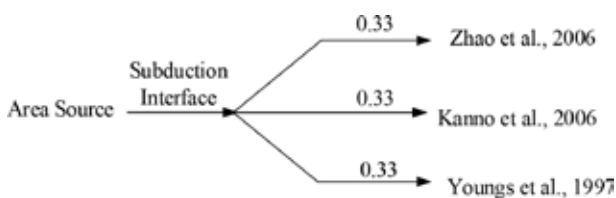


Figure-4: Logic tree for attenuation relationship

3. Result and discussion

After accessing the seismicity of source zones probabilistic seismic hazard analysis was conducted using three attenuation laws developed by Young's et al (1997), Zhao et al (2006) and Kanno et al (2006) using the logic tree approach for calculation of PGA and spectral accelerations for both hard and site (soft) soil condition. The borehole logs of studied site were plotted in Figure 5(b) and it was observed that the studied

site consists predominantly clay with alternative layer of clay and sand while the lower depth below 200 m consists of gravel. It indicated presence of soft soil so average shear wave velocity from surface to 30 m depth ($V_s 30$) was adopted to be 180m/sec (Ganapathy, 2011) for hazard analysis. The plot between mean rate of exceedance and PGA has been depicted in Figure 5(a). From Figure 5(a) PGA for 10 percent probability in 50 years (0.00211 mean rate of exceedance) was obtained to be 0.571g and that for 39 percent probability in 50 years (0.00989 mean rate of exceedance) was obtained to be 0.306g for soft soil condition. Finally, response spectra for 5 percent, 10 percent and 39 percent probability in 50 years was plotted for soft soil condition in Figure 5(b). Also, the PGA was evaluated at the site for bed rock using shear wave velocity 1000 m/sec.

The PGA value for all three-percentage probability for 50 years was tabulated in Table 3. Soil amplification

Table 3: Soil amplification factors for different return periods

SN	Probability or exceedance	PGA (g) at Rock	PGA (g) at Site (soft soil)	Amplification
1	39% in 50 years	0.214	0.306	1.43
2	10% in 50 years	0.403	0.571	1.41
3	5% in 50 years	0.520	0.729	1.4

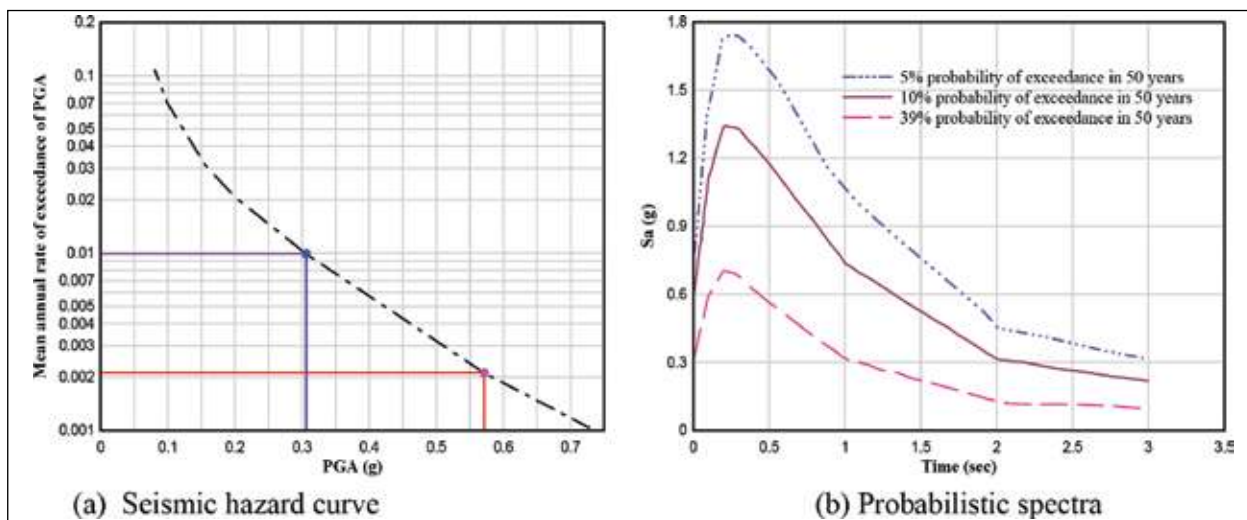


Figure 5: Probabilistic spectra at Sundhara, Kathmandu

factor was calculated for the site and found to be 1.4.

The value of spectral acceleration in current study was observed to be higher than the similar studies performed in the research database. It may be because of the consideration of larger magnitudes and a greater number of earthquakes in the vicinity of studied region.

Usually, non-linear analysis is widely adopted for seismic analysis of structures to evaluate the actual performance of the structure. Also, non-linear analysis depicts different damage states of the structures and helps to provide an actual scenario of damage on the structure when subjected to seismic loading. Non-linear dynamic analysis attempts to represent the actual performance of structure when subjected to actual time history of ground motion. Further, a particular time history is not sufficient to analyze the structure since the ground motion parameter of every earthquake is different. Moreover, for non-linear analysis a target response spectrum is required. Time history of the selected ground motion is then matched with target response spectrum.

The site-specific response spectra developed for Sundhara site was compared with the codal provision

existing during the period as shown in Figure 6(a). Both codal response spectra seemed to be lower than the obtained site-specific response spectra for Sundhara and it also shows that the existing code recommended value predicts lower seismic demand. Hence, the obtained hazard was adopted as the target response spectra in this study.

For the time history analysis, we need a cluster of historic seismic events and the selection of the time history depends on the target response spectrum. In this study we used the ground motion having 475 years return period, which was estimated and plotted in Figure 5(b). By providing the target response spectrum in ngawest2.berkeley.edu. (peer ground motion database) suitable ground motions as shown in Figure 7 was obtained. The selection of input was performed based on source to site distance, type of faults, site characterizations, seismic region and so on.

As already mentioned in various literature, the Gorkha, Nepal earthquake had a longer period of vibration, so it affected high rise structures. Since the studied structure also resembles a typical high-rise structure having a natural period of vibration of

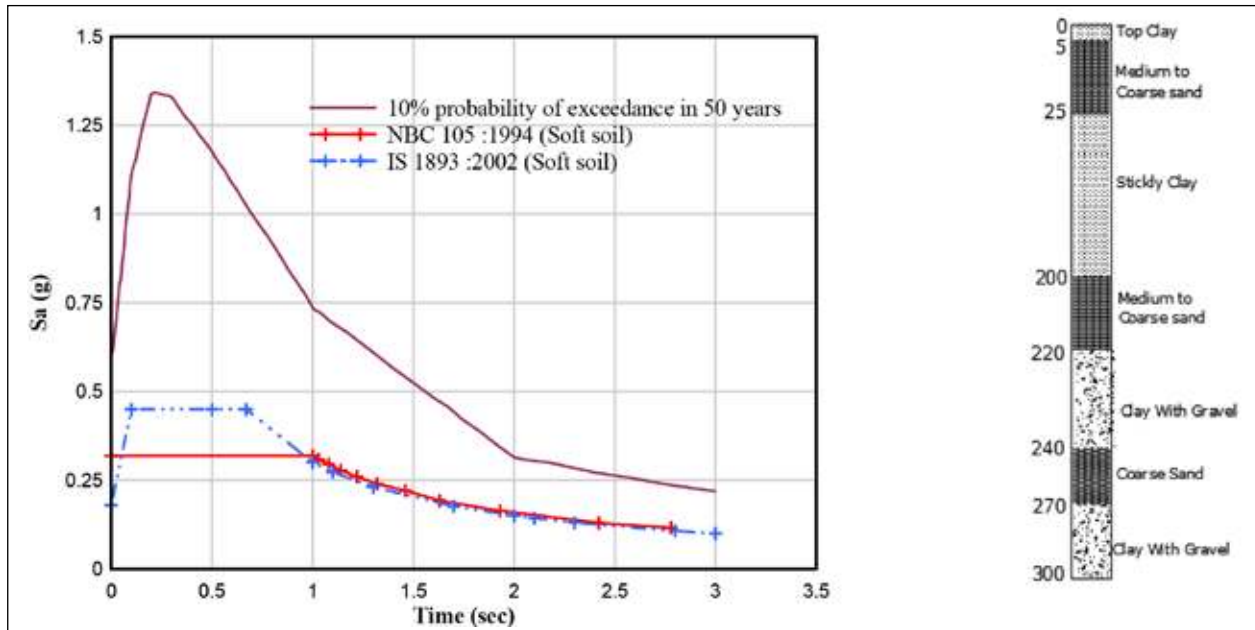


Figure 6: (a) Comparison of site specific and codal response spectra (b) Borehole logs(m) for site

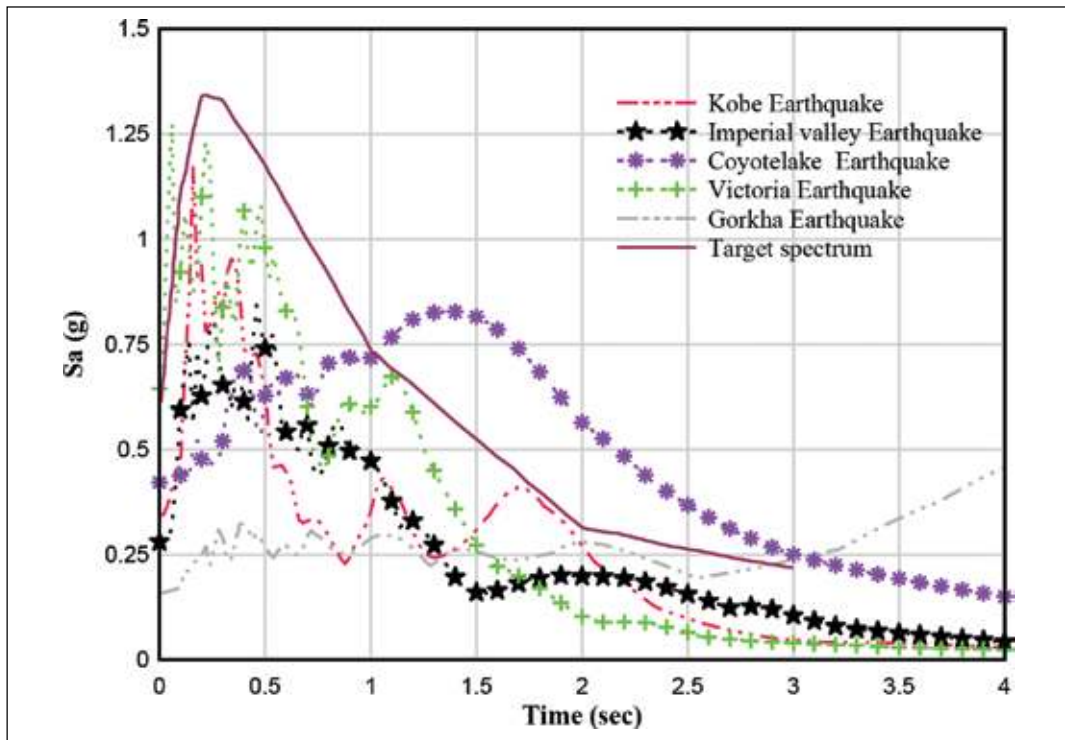


Figure 7: Original response spectra for different scenarios

around 2 sec (Thumb rule - number of stories 10) the time history and comparison of the response spectrum has been plotted in Figure 8(a) and 8(b), respectively.

As observed in Figure 8(b) the response spectrum of

Gorkha, Nepal earthquake seemed to be higher than the spectrum of codal provision.

Seismomatch, which was developed by seismosoft using wavelets algorithm proposed by Abrahamson

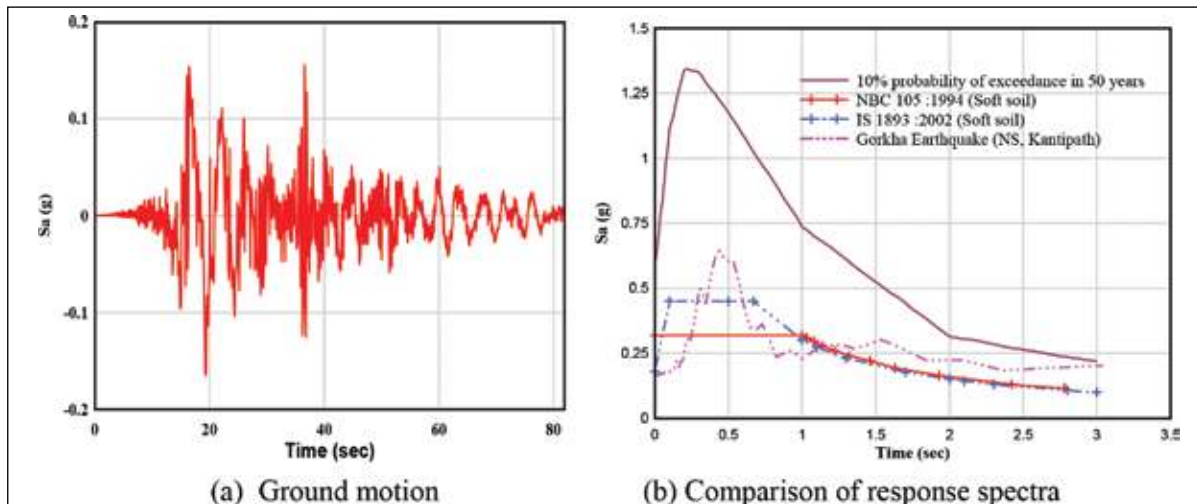


Figure 8: Time history of Gorkha, Nepal earthquake

(91992) and Hancock et al. (2006) or the algorithm proposed by Al Atik and Abrahamson (2010) were then matched with specified response spectrum. Using Seismomatch, the target response spectrum was matched with the available ground motions, which consisted of Kobe, Imperial valley (ElCentro), Coyotelake, Vactoria Mexico, Gorkha earthquake based on matching minimum and maximum time period of 0.2 and 1.5 times natural time period of building, respectively and is shown in Figure 9.

Finally, the response spectra for the site was compared with the response spectra of two soil types (Type C and D) soft and very soft soil in the latest provisions

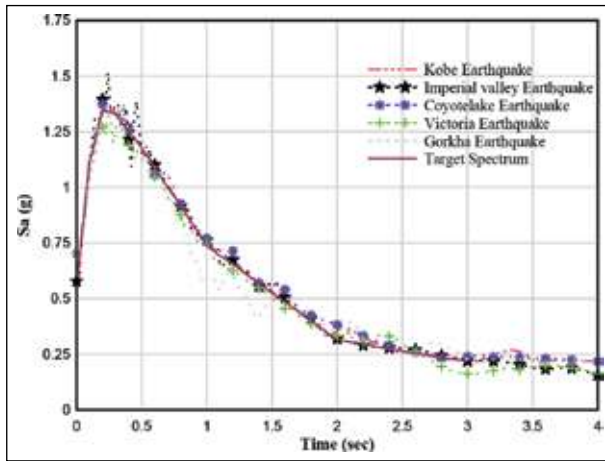


Figure 9: Matched response spectra curves

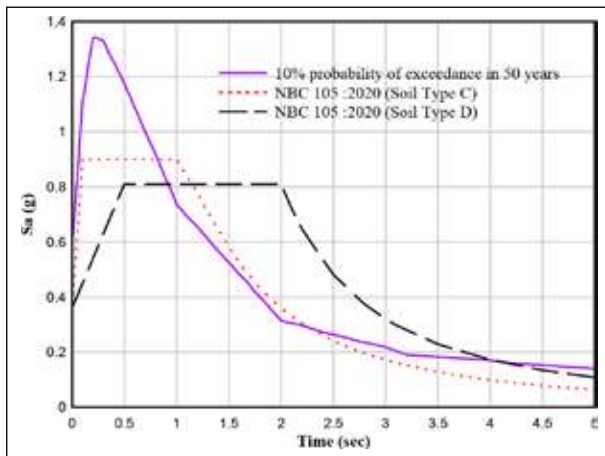


Figure 10: Comparison of spectrum spectra for site with NBC 105:2020

of the Nepal Building code (NBC) 105:2020. The revised standard for seismic provision has provided response spectrum corresponding to very soft soil (Type D) for Kathmandu Valley. As observed in Figure 10, the response spectra for the site predicts higher spectral value for low time period as compared to both soil types. However, the code recommended value, especially for soil type D seemed to be higher for higher time period.

4. Conclusions

A study was performed to obtain the site-specific hazard for a particular site considering all of the governing parameters. This methodology is believed to be useful as the available code provision always considers for the overall seismic hazard scenario for a region. Moreover, with consideration of local site-specific hazard, the estimation of hazard within that areas has been well depicted. It can further help in designing important historic structures, for example Dharahara, with site specific hazard within the area. Hence, with the adopted methodology, the peak ground acceleration for 39%, 10% and 5% probabilities of exceedances in 50 years were found to be 0.305g, 0.571g and 0.728g, respectively, at the site for soft soil condition from the PSHA. Soil amplification found was 1.4. These can be useful designing structures around the Sundhara area. Also, the obtained site-specific response spectra developed for the Sundhara site was compared with the codal provision existing during that period. Both the codal response spectra seemed to be lower than the obtained site-specific response spectra for Sundhara. Also, it was observed that response spectrum of Gorkha, Nepal earthquake was higher than the codal values. Finally, the target response spectrum was matched with the available ground motions database and importance of time history analysis in analyzing high rise structures was highlighted.

References

- Abrahamson, N.A., 1992. Non-stationary spectral matching. *Seismological Research Letters* 63(1), 30
- Amatya, K.M., & Jnawali, B.M., 1994. Geological map of Nepal, scale 1:1,000,000. Dep. of Mines and Geol., Gov. of Nepal, Kathmandu.
- Ambraseys, N.N., & Douglas, J., 2004. Magnitude calibration of north Indian earthquakes. *Geophysics. J. Int.*, Volume 159, pp. 165-206.
- Atik, L.A. et al., 2010. The variability of ground-motion prediction models and its components. *Seismological Research Letters*, 81(5), pp.794-801.
- Bai, L., & Moklesur Rahman, M., 2018. Probabilistic seismic hazard assessment of Nepal using multiple seismic source models. *Earth and Planetary Physics*, 2(4), 327-341. <https://doi.org/10.26464/epp2018030>.
- Baker, J.W., 2013. An introduction to Probabilistic seismic hazard analysis. White paper version 2.01, p. 79.
- BECA WORLEY INTERNATIONAL, 1993. Seismic Hazard Mapping and Risk Assessment for Nepal, New Zealand: s.n.
- Bhusal, B., & Parajuli, H.R., 2019. Probabilistic Seismic Hazard Analysis for Nepal Using Areal and Longitudinal Faults Source, Proceedings of IOE Graduate Conference, ISSN 2350-8914.
- Bothara, J.K. et al., 2002. Protection of Educational Buildings Against Earthquakes: A manual for designers and builders. National Society for Earthquake Technology-Nepal (NSET).
- Cornel, I.C., 1968. Engineering Seismic Risk Analysis. *Bulletin of Seismological Society of America*, Volume 58, pp. 1583-1606.
- Crouse, C.B., 1991. Ground-motion attenuation equations for earthquakes on the Cascadia subduction zone. *Earthquake spectra*, 7(2), pp.201-236.
- Dahal, R.K., 2010. Engineering Geology of Nepal. Published in personal home page www.ranjan.net.np.
- Das S., Gupta et al., 2006. A probabilistic seismic hazard analysis of northeast India. *Earthquake spectra*, 22(1), pp. 1-27.
- Ganapathy, G.P., 2011. First level seismic microzonation map of Chennai city—a GIS approach. *Natural Hazards and Earth System Sciences*, 11(2), pp.549-559.
- Gardner J.K. & Knopoff L., 1974. Sequence of earthquake in southern California with aftershock removal. *Bulletin of the seismological society of America*, 16(5).
- Gregor, J.N. et al., 2002. Ground Motion Attenuation Relationship for Cascadia Subduction Zone Megathrust Earthquakes based on Stochastic Finite-Fault Model. *Bulletin of Seismological Society of America*, 92(5), pp. 1923-1932.
- Gutenberg, B. & Richter, C.F., 1944. Frequency of Earthquakes in California. *Bulletin of Seismological Society of America*, 34(4), pp. 1985-1988.
- Hancock, J. et al., 2006. An improved method of matching response spectra of recorded earthquake ground motion using wavelets. *Journal of earthquake engineering*, 10(spec01), pp.67-89.
- Indian Standard Code (IS 1893), 2002. Part I: Criteria for earthquake resistant design of structures: General provisions and buildings. Bureau of Indian Standards, New Delhi, India
- Jain, S.K. & Murthy, C.V.R, 2005. Proposed draft provisions and commentary on Indian Seismic code IS 1893 (Part 1). Department of Civil Engineering, Institute of Engineering, Kanpur.
- Japanese International Cooperation Agency (JICA), 2002. The study on earthquake disaster mitigation in the Kathmandu valley, Kingdom of Nepal, s.l.: s.n.
- Kanno, T. et al., 2006. ANew Attenuation Relation for Strong Ground Motion in Japan based on Recorded Data. *Bulletin of Seismological Society of America*, 96(3), pp. 879-897.
- Kawashima, K. et al., 1984. Acceleration of peak ground motion and absolute acceleration response spectra. *Proc., Eight World Conference on Earthquake engineering*, San Francisco, Volume 2, pp. 257-264.
- Kramer, S., 1996. Geotechnical earthquake engineering. Prentice-Hall International series in Civil Engineering and Engineering Mechanics.
- Kumahara, Y. et al., 2016. Geomorphic features of active faults around the Kathmandu Valley, Nepal, and no evidence of surface rupture associated with the 2015 Gorkha earthquake along the faults. *Earth Planets Space* 68, 53. <https://doi.org/10.1186/s40623-016-0429-x>.

- Maskey, P.N. et al., 2004. Risk consistent response spectrum and hazard curve for a typical location of Kathmandu Valley, 13th world conference on earthquake engineering, Vancouver, B.C., Canada, Aug.1-6, p. 3124.
- Maskey, P.N., & Mishra, H.K., 2005. Selection of Attenuation Laws for Estimation of Seismic Input in Nepal. Journal of the Institute of Engineering, 5(1), pp. 75-85.
- Mcguire, R.K., 2004. Seismic hazard and risk analysis. Earthquake Engineering Research Institute, MNO-10.
- Mishra, H.K., 2004. Attenuation of ground motion for the region, Master's thesis, s.l.: s.n.
- Molnar, P., 1984. Structures and tectonics of Himalaya: Constraints and implication of geophysical data. Ann. Rev. Earth Planet Sci. 12 , 489-518.
- Nepal Building Code (NBC-105),1994. Seismic design of buildings in Nepal. Department of Building, Ministry of Physical Planning and Works, Government of Nepal.
- Pandey, M.R. et al., 2002. Seismic Hazard Map of Nepal, Kathmandu, Nepal: s.n.
- Parajuli, H.R. et al., 2010. Probabilistic seismic hazard assessment for Nepal. WIT Transactions on Information and Communication Technologies, 43, pp. 405-416.
- Parajuli, H.R. & Bhusal B., 2018. Site Specific Probabilistic Seismic Hazard Assessment of Nepal, Heritage Publishers, Kathmandu, Nepal
- Rana B.S. & J.R., 1935. Nepal's Great Earthquake 1934 (in Nepali). s.l.:Sahayogi Press, Tripureshwor, Kathmandu.
- Schwart, D., 1988. Geology and Seismic Hazards: Moving into the 1990's. In: Proceedings,Earthquake Engineering and Soil Dynamics II: Recent Advances in Ground Motion Evaluation. ASCE, Newyork: Geotechnical Special Publication (20), pp. 1-42.
- Schwartz, D.P. and Coppersmith, K.J., 1984. Fault Behaviour and Characteristics Earthquakes: Exmples from the Wasatch and Sa Andreas fault zones. Journal of geophysical research, 89(B7), pp. 5681-5698.
- Stepp, J., 1992. Analysis of completeness of the earthquake sample in the Pudet Sound area and its effect on statistical estimates of earthquake hazard. Seattle, WA, s.n., pp. 897-909.
- Stevens, V.L., Shrestha, S.N. and Maharjan, D.K., 2018. Probabilistic seismic hazard assessment of Nepal. Bulletin of the Seismological Society of America, 108(6), pp.3488-3510.
- Thapa, D. R., & Guoxin, .and W. (2013). Probabilistic Seismic Hazard Analysis. Probabilistic Seismic Hazard Analysis in Nepal, 12(4), 577-586. <https://doi.org/10.1007/s11803-013-0191-z>
- USGS, n.d. <http://pubs.usgs.gov/gip/dynamic/understanding.html>,http://earthquake.usgs.gov/regional/world/world_deaths.php. s.l., s.n.
- Ulak, N. (2016). Nepal's Earthquake-2015: Its Impact on Various Sectors. The Gaze: Journal of Tourism and Hospitality, 7, 58-86. <https://doi.org/10.3126/gaze.v7i0.15120>
- Wesnousky, S.G., Scholz, C.H. Shimazaki, K. and Matsude, T. , 1984. Integration of geological and seismological data for the analysis of seismic hazard: A case study of Japan. Bulletin of the Seismological society of America, Volume 74, pp. 687-708.
- Woo, W., 1996. Kernel estimation methods for seismic hazard area source modeling. Bull. Seismol. Soc. Am., 86(2), pp. 353-362.
- Wu, S.C., Cornell, C.A. and Winterstein, S.R., 1995. A hybrid recurrence model and its implication on seismic hazard results. Bulletin of Seismological society of America, 85(1), pp. 1-16.
- Youngs, R.R., Chiou S.J., Silva, W.J. and Humphrey, J.R., 1997. Strong ground motion attenuation relationships for subduction zone earthquakes. Seismological Research Letters, 68(1), pp. 59-73.
- Youngs, R.R., Day, S.M. and Coppersmith, K.J., 1985. Implication of fault slip rates and earthquake recurrence models to probabilistic seismic hazard assessments. Bulletin of the Seismological Society of the America, 75(4), pp. 939-964.
- Zhao, J. X., Zhang, J., Asano, A., Ohno, Y., Oouchi, Takahashi, T., Ogawa, H., Irikura, K., Thino, H. K., Somerville, P. G., Fukushima, Y., and Fukushima, Y., 2006. Bulletin of Seismological Society of America, 96(3), pp. 898-913.



A Critical Review on Appropriateness of Use of Prefab in Construction of Health Post in Nepal after the 2015 Earthquake

Manjeet Raj Pandey^a, Siddhi Bhakta Maharjan^b, Nagma Mathema^c

Key Words: *Prefabricated-technology, health-facilities, reconstruction, Gorkha earthquake, policy, sustainability.*

Abstract

As a result of the devastating 2015 earthquake, more than 600 health institutions in the 14 hard-hit districts suffered severe infrastructural damages. Damage to the physical infrastructure substantially disrupted health service delivery and created challenges in restoring health services. With the intention to ensure long-term infrastructure solutions, the Ministry of Health and Population made a policy decision to reconstruct health facilities using prefabricated (prefab) technology and developed a concise type design and specifications for the construction. This study aims to explore the pros and cons of using prefabricated technology in the reconstruction of health facilities. The effectiveness of constructing health facilities using prefabricated technology were assessed taking into consideration the challenges faced by implementing agencies during construction and those faced by beneficiaries while using the building. Primary data was collected through stakeholder interviews and field-research and secondary data was obtained from reviews of existing literature. Health officials, project managers, and contractors involved in the construction of health facilities were interviewed. The prefab health posts constructed after the earthquake were visited during field data collection. Results indicate that the use of prefab technology was not appropriate for the construction of health-facilities located in remote areas around Nepal. However, since the construction could be carried out quickly, prefab buildings can be of use for constructing hospitals and quarantine centers in cities and urban areas during emergencies.

1. Introduction

The 7.6-magnitude earthquake rattled Nepal on 25 April 2015 killing more than 8700 people and leaving more than 22,000 severely injured [1]. The epicenter

of the earthquake was Barpak, which is 80 kilometers North-West of Kathmandu (aerial distance). The damage was further intensified by the hundreds of aftershocks that followed the major earthquake.

According to the Post Disaster Needs Assessment

^a Construction and Strategy Director, United World Schools Nepal, email: manjeetrp@gmail.com

^b Cofounder & Engineer, SERD Consultant, email: cdsiddhi002@gmail.com

^c Health Data Analyst, ToggleCorp Solutions, email: nagmamathema7@gmail.com

published by the National Planning Commission, 31 districts were affected by the earthquake among which 14 were severely affected. More than 498,852 houses and 2,656 government buildings had completely collapsed. The financial loss was estimated to be US\$ 7 billion [2]. In the Post Disaster Recovery Framework published by the National Reconstruction Authority, estimated that more than US\$ 8.3 billion would be required for reconstruction and recovery.[5]

According to the Department of Health Services (DoHS) annual report, a total of 793 health facilities in the 14 hard-hit districts were damaged. This included 26 hospitals, 44 Primary Health Care Centers (PHCCs) and 723 health posts [6]. In the months following the earthquake, the Ministry of Health and Population (MoHP) with the technical support of National Health Sector Support Program (NHSSP), conducted a detailed engineering assessment of the health facilities. The assessment said more than 84 percent health facilities suffered extensive damages: 375 public health facilities were completely damaged [2] while 310 health facilities were partially damaged. The total economic loss due to infrastructure damage in the health sector was calculated to be US\$ 64.22 million [2]. The economic loss due to infrastructural damages in hospitals was US\$ 23.18 million, in PHCC was US\$ 2.01 million and in health post was US\$ 22.81 million [2].

With many health infrastructures affected, health services were provided from tents and makeshift structures after the earthquake. These structures could only function for a few months and faced significant difficulties when the monsoon season started. To address the urgent need of quality health services, the MoHP decided to build health posts and primary health care centers using prefab technology that would allow quicker construction compared to the conventional methods.

To facilitate the smooth reconstruction, quality control and inclusion of basic requirements in the building, MoHP published a “Standard Guidelines for the Post-disaster Reconstruction of Health Buildings” in July 2015. The comprehensive document contained all information related to the reconstruction of PHCC and

health posts including site selection, implementation and coordination mechanism, choice of building materials and technology, waste management, accessibility, Water, Sanitation and Hygiene (WASH) requirements, and more importantly, it included complete engineering drawings and quantity estimates for each design [3]. Different government and non-government agencies involved in the reconstruction of health facilities damaged by the earthquake adopted the standard guideline in reconstruction. The guidelines had one type design for PHCC and two type designs for health posts, which the agencies had to follow while constructing the health facilities using prefab.

The Standard Guidelines published by the MoHP recommended that implementing agencies should choose from three prefab options that were readily available in the market: Insulated Fiber Cement Board, Sandwich Panel, and Solid Walls. Some agencies also utilized 3-D panels to construct health facilities.

As per the latest report regarding the status of construction of health facilities damaged in 2015, 367 of 394 health centers that required reconstruction had been constructed. Among these, 273 were constructed using the prefabricated technology.[7]

This paper examines the benefits and drawbacks of using prefabricated technology for the construction of health facilities in different earthquake affected areas. As this relatively new construction technology dominated most construction projects in the post-2015 context, a detailed research on the methodology, and a review of learnings from the field were crucial to future decision-making in the field of construction.

This paper also highlights the number of issues with reconstruction using prefabricated materials. This research is intended for the policy makers, project planners, managers and scholars as it provides the decision-making support. Some recommendations are also provided in the conclusion section that help to choose between prefab or the permanent solution on a case-by-case basis.

1.1. Prefabricated construction technology

Prefabrication means a practice of manufacturing the components of building or structure in a factory environment and then transporting and assembling them onsite [4]. Prefabrication can be understood at different levels, considering the production of small parts and components of a building or entire house or volumetric building block which can be manufactured in the factory [8]. Prefabricated technology has numerous benefits over the conventional technology, some of which is listed below [9]:

- Improves the resource-efficiency.
- Improves productivity at site.
- Completes the project at shorter time.
- Allows better construction quality control.
- Minimizes construction waste, and
- Has lower adverse environmental impacts compared to conventional practices.

2. Literature review

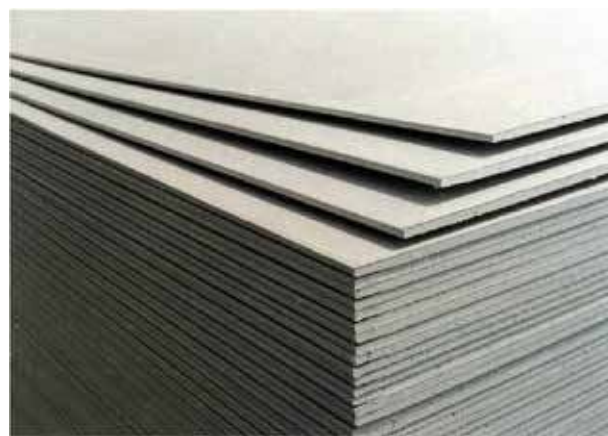
The MoHP initiated a detailed structural assessment in 14 hard-hit districts with the objective to determine the damage conditions of health facilities. The information collected was expected to lead to better planning and

prioritization of recovery and reconstruction. A digital data collection method was adopted using Kobo platform on tablets. The assessment contained detailed information on the damage status of the building/s, infrastructural properties (e.g., access to electricity, water, road, and to the Internet) and the information on site condition and land ownership [10]. A total of 774 facilities were assessed among which 722 were health posts and 40 PHCCs. Of all the facilities assessed 79.72 percent were connected to motorable roads and the remaining were not. Only 28.04 percent of the assessed health facilities were connected to all-weather roads. Further, more than 21 percent of the health institutions did not have access to electricity and 36.5 percent had 3-phase electricity connections [11]. Inaccessibility to roads and electricity were some of the biggest challenges to any construction activity and these were further intensified in prefabricated construction due to nature of the activities involved.

MoHP adopted a three-pillar strategy for the recovery and reconstruction. The immediate response prioritized provision of basic health services in the damaged facilities through temporary structures like tents, sheds or from rented buildings. Infrastructure wise, the intermediate response was more focused on repair and retrofit of usable buildings and the construction of prefab structures. The third and the



Solid wall panel



Cement board (PC: Everest industries)

Photo: Prefab options suggested by MoHP

medium-term strategy focused on building as per the concept of Build Back Better i.e., permanent structures in the areas where prefab structures were not built [2].

The key benefits of prefabricated construction over other methods were its shorter construction time because vital building components were already produced in factories and transportation and assembly was done at the site. This reduced the construction time. But the progress reports from the field regarding the reconstruction of these facilities were not as expected. According to the Joint Annual Review report, the total number of prefabricated health posts that were completed in 2015 was 31 [12], in 2016 it was 106 [13], and 137 in 2017 and 2018[14]. It took three years to complete the construction of 273 health facilities of 394 that needed immediate reconstruction. These used

were staff and beneficiaries of the health facilities and were selected randomly.

At the time of this research, 273 health facilities had been constructed using prefab technology [7]. The sample size of the study was 37, calculated by using online software developed by Creative Research System, considering population (N)=273 and confidence interval 15 percent. From the list of the health facilities that were constructed using prefab technology, 46 were randomly selected and of them in-person interviews and site visits were carried out at 16 health facilities. Telephone interviews were conducted in 30 health facilities.

A total of 16 people were interviewed at the respective health facilities. A consent form was signed by the interviewees preceding the interviews. Sixteen health posts were also visited for the observing the

Table 1: Damage status of health facilities

Damage Status	Health Facilities/ No. of blocks	Recommendations
Health Facilities		
Completely damaged	358	
Partially damaged	311	
Not damaged	115	
Building Blocks		
Completely collapsed	225	Reconstruction
Partially damaged - not repairable	249	Reconstruction
Partially damaged - repairable	195	Major repair
Superficial damage	265	Major repair
No damage	367	No intervention
Total	1301	

Source: MoHP report 2015

prefab technology [15]. This was against the MoHP's plan to complete the reconstruction of these units within three months from the starting date. Table 1 provides the overall damage status of health facilities.

3. Methodology

The primary data was collected through structured and semi-structured interviews with end users and officials at the MoHP and its supporting agencies. The end users

conditions after construction. The 30 others who were interviewed via telephone were mainly administrators at health facilities.

Some of the questions that were asked to end users were as follows:

1. What was the impact of the earthquake on health infrastructures?
2. How did the lack of infrastructure affect service delivery?

3. How do you feel about the prefab health facilities that were built?

Two MoHP staff who were directly involved in reconstruction-related planning and decision making were also interviewed. Some more questions were asked to the officials from MoHP and from its technical supporting agency in addition to above, which were as follows:

1. What did the MoHP do to resume health services right after the earthquake?
2. What were the short- and long-term recovery strategies planned by the MoHP?
3. Why were prefab structures preferred over other solutions?
4. What challenges did the MoHP face during the reconstruction?
5. What are your learnings and recommendations?

The stakeholders involved in the reconstruction including officials from development organizations, local members of the health facility construction committee, and contractors were also interviewed. A total of seven people were interviewed from different agencies and companies directly involved in the reconstruction. They were mainly asked questions on the implementation challenges during construction. Some of the questions that were asked were:

1. What challenges did you face during the construction process?
2. What are the benefits and drawbacks of the prefabricated construction?
3. Would you prefer the prefab construction over permanent construction?
4. What are your learnings and recommendations?

Literatures reviewed, academic research articles, progress reports and newspaper articles were used for secondary data. The data were collected from various publications of government and non-government organizations involved in the reconstruction process. The documents included publications and progress

reports from the MoHP, National Reconstruction Authority, Department of Health Services, Nepal Health Sector Support Program, International Medical Corps, UNICEF, etc. These publications have also guided the opinion of this paper.

The interviews were analyzed in different thematic areas. Nine key themes were identified from the interviews, and they were examined to gain a deeper understanding of participants' perception.

4. Results and discussions

This section presents the findings and discusses the observations during the research and information obtained from interviews and surveys. The members of this research team were directly involved in the reconstruction of health posts using prefabricated technology. This research is based on interviews with open ended questions, discussions, observations, and literature review thus the results cannot be quantified, which is a limitation of this study.

Prefabricated construction sounded promising at first but the implementing agencies (i.e., government agencies, development agencies, and construction companies) continued to face many challenges during the construction process. The 10 outcomes from the research are discussed below:

4.1 Lack of large number of construction companies with prefab expertise

The prefab technology was introduced in Nepal in the early 2000s. It was mostly used to add rooms in houses, for temporary living space and for partitioning office areas. Though introduced for the construction in city areas, the people were hesitant to build houses using prefab structures mainly due to the security concerns because houses built with concrete were sturdier and felt more secure [16]. During the interview with the contractors, one validated the statement above.

After the earthquake, MoHP made a policy decision to reconstruct health facilities using prefabricated technology. Nepal's construction industry lacked

much-needed experience with prefab for being able to carry out such a massive reconstruction task. With only a handful of construction companies with expertise in prefab construction, the challenge to build 270 health institutions was huge.

4.2 Lack of technical human resources

The lack of technical experts and skilled human resources was another pressing issue. Six of seven respondents cited this as one of the major reasons for the delay in construction against the expectation. During the interview with contractors, a couple of them said that they had to bring workers from India because of local unviability. One of the organizations also brought skilled workers from China to rebuild health facilities. The expenses on these workers were much higher than what local human resources would have cost because of their higher wages and travel costs.

4.3 Limited production capacity in Nepal

In 2015, there was no prefab manufacturer in Nepal who could supply the wall panels and other components for the planned reconstruction. In 2016, a company was established which supplied some prefab wall components, but the supply was negligible compared to the high demand. As a result, every prefab component that was required for reconstruction had to be imported either from India or China and some other countries. These materials had more than 60 percent cost implication in the overall building cost, which includes material, labor and transportation. Materials like iron columns, beams and truss components, prefab walls, ceilings, sanitary and electrical items were imported, among others. The calculation was done by analyzing the cost quoted by a contractor in the bid document submitted to one of the organizations involved in the reconstruction.

Due to the trade embargo imposed by India, the import of these materials was severely affected. This was when the construction had just started, and the

contractors could not supply the materials. The construction activities were adversely affected and that delayed the completion. Had local materials been chosen for the reconstruction, the work would most likely not have been affected on such a scale.

4.4 Remote location of health facilities

All health facilities that were visited by the research team did not have access to all-weather road, even though they were connected to a motorable road. These health facilities were accessible by vehicle only during the dry season. As per the assessment by MoHP, more than 70 percent of these facilities were disconnected from blacktopped roads, and some did not have access to any kind of roads [11]. In prefab construction, the transportation of massive structures like cement boards, blocks, and metal structures are required. However, due to the poor-quality roads, the damage rates during transportation were also high. Precautions had to be taken during the transportation so that materials were not damaged, which also increased the transportation cost.

One engineer from a development organization who had supervised health post construction said more than 50 percent of the prefab boards were damaged by the time they were delivered to the site, when the delivery was done by tractors. After that incident the organization hired a 4WD mini truck to transport the boards, which reduced the damage but at a much higher cost.

4.5 Lack of access to electricity

Among the 46 surveyed health facilities, 18 (39.14%) did not have access to electricity. Ten were connected to micro-hydroelectricity plants that produced power locally and 18 were connected to the national electricity grid. In those that were connected to the grid, intermittent supply of electricity was a big challenge. The equipment used during construction like welding and cutting machines required high ampere current to function. The lack of steady supply of needed electricity disrupted construction operations resulting in

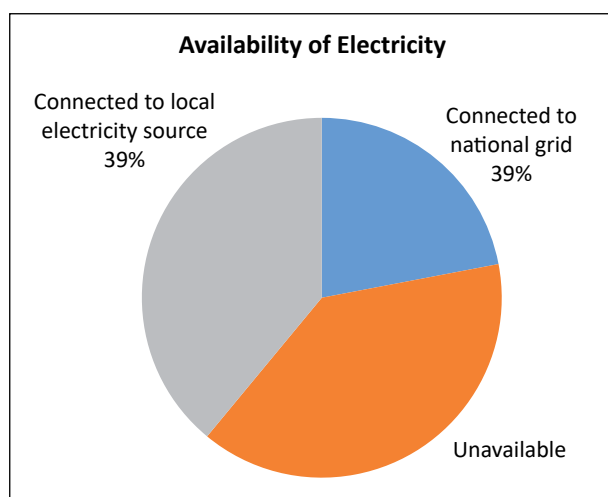


Figure 1: Availability of electricity

further delays and cost implications. Diesel generators were used as the solution in most cases, which had its own purchase and operation costs that were much higher than the cost of electricity from the grid.

4.6 Prefabs can be repurposed

While the challenges in the construction of prefabricated structures in the remote areas was high, the benefit of this technology was that its components could be reused, and the structure could be repurposed for other needs. Prefab was an intermediate solution proposed by the MoHP until a permanent structure was built. Most of the materials used in the construction can be salvaged and reused for building a new building. The scrap value of this structure is also high as compared to the permanent structure.

This methodology of construction was thoughtfully chosen because of its reusability. Prefab health facilities were never meant to permanently replace the destroyed ones.

4.7 Cost of construction

During reconstruction, some organizations paid around NRs. 8 million (USD 70,000) for a health post: the unit construction cost was more than NRs 60,000

(USD 600) per square meter. This was more than the unit cost of construction of a permanent structure with the same floor area. The increase in cost was primarily due to the high demand. Only a few companies were available in the market and it gave them the upper hand in deciding the price. Even the government was not able to mandate limits because the focus was on rebuilding and not necessarily on cutting expenses.

4.8 Better quality control

Since the onsite activities were less with prefabs compared to conventional construction, the quality control was much easier. The vital structural and other components of the building were already built in the factory as per the specifications. This ensured minimal quality compromise in the factory-made components. The overall quality in prefab construction thus, depended on a supervisor's ability to monitor material handling and proper assembly. This was one of the pros of using prefab because a supervisor could do the monitoring of more than one site when there was a shortage of technical expertise.

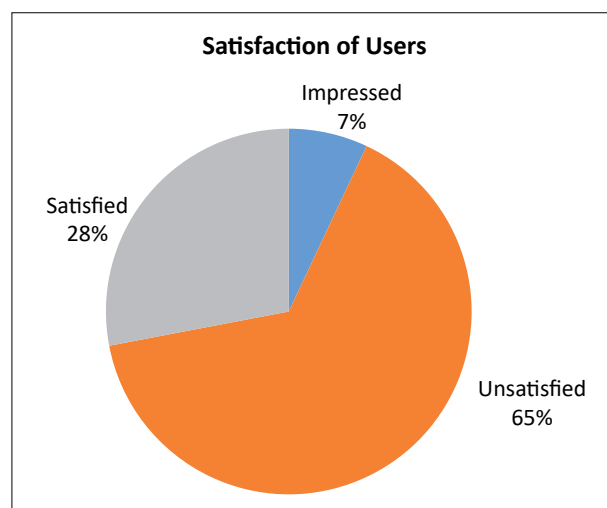


Figure 2: User satisfaction

4.9 Use cases and user experience

The experience of the end user is a major determining factor in measuring success of any project. The outcome of the survey carried out among health facility in-charges showed that 65 percent of regular building users were not satisfied with prefab structure. About 27.5 percent were satisfied with the building and felt building with prefab was not a bad decision in the given context. Only 7.5 percent of the responders were “impressed” by the prefab building.

The complaint of users, including the community people, was that the building did not “feel homely”. This was perhaps because of cultural and psychological sensitivities. In an interview a civil engineer working for one of the supporting agencies said, “prefab is not what Nepalis are used to, in sandwich panels the lining of the wall is metal and cement board and solid panels make sound when knocked.” Further, “walls (in Nepali homes) are not only used as partition and there are other applications too such as hanging clothes, clocks, calendars, etc., which was not possible in prefab walls”. This had made it difficult for people to adapt.

4.10 Disaster preparedness and response

In an interview a MoHP official said there were no reconstruction guidelines for massive natural disasters like earthquakes where many health facilities were simultaneously affected, let alone the selection of materials for the quick recovery and reconstruction actions. However, disaster precautionary measures were in place and were followed. There were proper design guidelines for construction of new health facilities.

After the earthquake, MoHP in consultation with the supporting agencies decided to opt for the prefabricated technology to reconstruct damaged health facilities to resume services in the affected communities quickly and effectively. The decision seemed prudent at first, given that the prefabricated structures could be set up quickly. However, things changed massively when the expected progress was not achieved

as there were many underlying reasons that delayed the reconstruction of health facilities.

5. Conclusion and recommendations

Through interaction with different stakeholders, end users, direct observations and literature review, the authors believe that building health facilities with prefabricated materials had more disadvantages than advantages in the Nepali rural settings. One of the major reasons for this was the lack of experience, expertise, and capacity of the construction industry to build a large number of health facilities quickly. The topography and road conditions were the other major constraints. Prefab technology had been proven for its short construction time compared to conventional methods and damaged facilities could be up and running quickly. It was expected that it would, at most take three months to complete the construction of a health post according to the type design. However, even three years after the earthquake, the implementing agencies were still building the structures.

The cost also turned out to be much higher for various reasons. While preparing the standard guidelines, MoHP had estimated that the construction cost of a Type 1 health post would be around NRs 4 million in city areas, or a little over NRs 30,000 (USD 270) per square meter. Prior to the earthquake, prefab construction companies were charging between NRs 18,000 (USD 160) to NRs 22,000 (USD 200) for the construction of residential buildings in Kathmandu [16]. It was believed that the cost of construction using prefab would be comparatively low because of the short construction time. But when the organizations started the reconstruction of the health facilities, the cost skyrocketed, with some health posts costing almost NRs 8 million (USD 75000).

However, a prefab solution would be a superior construction methodology if we are dealing with the reconstruction of bigger health facilities like hospitals or in some cases, PHCCs. The reconstruction of these facilities would take several years to complete, and prefab could have been an ideal solution until

the permanent construction was done. The prefab buildings can also be repurposed. Trishuli hospital in Nuwakot is a good example of prefabricated construction. However, given Nepal's low production capacity, using locally unavailable materials may not always be preferable. Prefab is definitely not the choice when building in remote areas with issues of access and electricity. For such situations, building enhanced temporary sheds for the time being until the permanent structure is built could be the option.

This study attempted to explore the appropriateness of prefabricated construction but discovered many underlying causes such as unpreparedness and ad-hoc decision making. Nepal's disaster preparedness strategy should also address curative measures rather than extensively focusing on the preventive ones. One approach would be to extensively research on disaster-resistant structures for permanent construction. The Nepali construction industry also needs to have a Plan B for buildings that collapse during unprecedented disasters. As hindsight, it is also apparent that given the infrastructural situation of health facilities before the earthquake, it would have been appropriate to have had some post-disaster recovery planning and strategies on hand, rather than drafting one after a disaster.

Acknowledgement

The authors appreciate the support and cooperation they received from everyone who were involved in the research, mostly from the people in the communities who use the health facilities. They are much obliged for the willingness of the MoHP and line agencies, bilateral agencies, development organizations and construction companies who had agreed to discuss the contents of this paper with the authors and had supported them by providing vital information for the research.

References

- [1] Annual Progress Report of Health Sector 2015/16, 2017. http://www.nhssp.org.np/NHSSP_Archives/jar/2017/Annual_progress_health_2015_16.pdf.
- [2] Annual Report 2071/72, 2016. https://dohs.gov.np/wp-content/uploads/2016/06/Annual_Report_FY_2071_72.pdf.
- [3] B., Poudyal, & Chhetri, M., 2018. Aftermath of Gorkha-Nepal Earthquake 2015: Lessons Learnt. *Oceanography & Fisheries Open access Journal*. 8(2).
- [4] Deciding Between Prefabrication and On-Site Construction: A Choosing-by-Advantage Approach, 2019. https://www.researchgate.net/publication/334363444_Deciding_Between_Prefabrication_and_On-Site_Construction_A_Choosing-by-Advantage_Approach/citations.
- [5] Goodier, C., & Gibb, A., 2007. Future opportunities for offsite in the UK. *Construction Management and Economics*. 25(6): 585-595.
- [6] Health Facility Damage Assessment, 2015. https://kc.kobotoolbox.org/healthinfraassessment/forms/hf_detailed_assessment_v2.
- [7] Joint Annual Review Report 2014/15, 2016. http://www.nhssp.org.np/NHSSP_Archives/jar/2016/JAR_Report_2014_15_march2016.pdf.
- [8] Modular construction: From projects to products [Internet], 2019. <https://www.mckinsey.com/~media/mckinsey/industries/capital%20projects%20and%20infrastructure/our%20insights/modular%20construction%20from%20projects%20to%20products%20new/modular-construction-from-projects-to-products-full-report-new.ashx>.
- [9] MoHP, 2015. Standard Guidelines for Reconstruction of Health Facilities.
- [10] National Joint Annual Review (NJAR) 2075/76 [Internet], 2019. <http://www.nhssp.org.np/Resources/HPP/NJAR%20Proceedings%20Report%20-%202019.pdf>.

- [11] NHSSP PD 1, 2015. Detailed Plan for Health Infrastructure in Three Focal Districts and Structural Assessments in 14 districts. http://www.nhssp.org.np/NHSSP_Archives/procurement/NHSSP_PD1_detailed_plans%20and_structural_november2015.pdf.
- [12] Post Disaster Needs Assessment [online]. https://www.npc.gov.np/images/category/PDNA_volume_BFinalVersion.pdf.
- [13] Post Disaster Recovery Framework [Internet], 2016. <http://www.nra.gov.np/uploads/docs/wQxn-gUUy2r160512083450.pdf>.
- [14] Progress of the Health and Population Sector, 2018/19, 2019. <http://www.nhssp.org.np/Resources/HPP/NJAR%20Progress%20Report-%202019.pdf>.
- [15] Progress of the Health Sector in FY 2017/18, 2018. http://www.nhssp.org.np/Resources/HPP/Health_Sector_Progress_Report_2018.pdf.
- [16] Safe and affordable [Internet], 2019. The Himalayan Times, [cited 17 May 2020]. <https://thehimalayantimes.com/business/real-estate/safe-and-affordable-prefab-homes>.



A Comparative Investigation of Seismic Standards Is1893:2016 and Nbc105:2020 in the Context of Seismic Design of Dharahara, a Historic Monument in Kathmandu Valley

Manohar Rajbhandari^a, Nima Sthapit^b, Srijana Sthapit^c

Keywords: Site specific response, PGA, response spectrum, base shear, drift, displacement

Abstract

Dharahara, a 61.88 m high historical monument built of brick masonry with lime mortar, collapsed during the Mw7.8 2015 Gorkha, Nepal earthquake. Considering its historical significance, a 72.96m high reinforced concrete tower with appearance similar to the previous structure was proposed for the reconstruction the same year. Numerical modeling of the tower was performed using a state-of-the-art 3-dimensional structural software SAP 2000v20.2. For design of the tower, Indian material and loading standards were followed. The site-specific response spectra were also generated for dynamic analysis of the tower following probabilistic seismic hazard assessment approach. The revised Nepali seismic standard was introduced in 2020, however, by then the design of the tower has already been completed. The objective of this study is to compare the design outputs obtained for the tower structure from two different seismic standards, namely: IS 1893:2016 and NBC105:2020. The comparison was made against base shear, drift and displacement estimated following both the seismic standards. Besides, Dharahara, two more case study buildings were also studied and seismic analysis outputs compared. The values estimated following NBC105:2020 were found significantly in excess of that estimated following IS1893:2016. This paper can be beneficial for designers who are willing to use NBC105:2020 for RCC buildings in Nepal.

1. Introduction

An intense ground shaking of Mw7.8 struck central Nepal on 25th April 2015 with the epicenter located in the Gorkha region [1], which was followed by hundreds of aftershocks, including one of M7.3 on 12 May

2020. The 25 April 2020 event was the largest one after the Mw8.1 Nepal-Bihar earthquake that struck eastern and central Nepal in 1934.

Historic buildings and monuments suffered heavy damage in the Kathmandu valley where seven World Heritage sites are located. One of the

^a Structure Engineer, MRB & Associates, Kathmandu, Nepal

^b Earthquake Engineer, MRB& Associates, Kathmandu, Nepal

^c Civil Engineer, MRB& Associates, Kathmandu, Nepal

historic monuments, the Dharahara, a 61.88m high brick masonry tower collapsed during the 2015 Nepal earthquake. The tower had been rebuilt after the 1934 earthquake that had destroyed Dharahara built in 1832 on the same site [2]. It had survived a large earthquake in 1834. It meant this was the third time that Dharahara was being built. The Dharahara that collapsed during the Mw7.8 2015 Nepal earthquake was built with brick masonry structure in lime surkhi mortar. Figure 1 presents pre- and post-earthquake photographs the Dharahara.

Following the earthquake, as part of the earthquake recovery efforts, it was decided to design and rebuild Dharahara that looked the same as the old one, using new materials and technologies. The proposal included a tube-in-tube 72.96m high tower structure with two level underground basement of reinforced concrete. For the design of the tower, Indian materials and seismic standards were employed. The particular concern was seismic design forces; however, it was decided to use Indian seismic loading standard IS1893:2016 [3] as the seismic loading standard was two and half decades old and was considered obsolete. To better understand seismicity of the site, a probabilistic seismic hazard assessment was also completed that provided hazard spectra for 100, 475, and 975 years [12].

The draft of the updated Nepali seismic standard, NBC105:2020 [5] was issued in 2019 and finalized in 2020. This triggered a comparison of Nepali and Indian seismic standards. The goal of this paper is to compare design outputs such as base shear, deflection and drift estimated following the Nepali and Indian seismic standards in the context of Dharahara.

2. Structural system and design parameters

Considering the proposed height of the new Dharahara, it was categorized as a tall building [6]. The main challenge in designing tall buildings can be summed up to lateral load effects, type of building, and soil condition. Considering the crucial role of the structural system in defining its behavior during lateral loads such as earthquake and winds, the following structural systems were explored for the proposed tower:

- Structural wall system
- Moment frame system
- Moment frame-structural wall system
- Structural wall system with flat slab floor system
- Core and outrigger structural system
- Core, outrigger and belt wall system
- Framed-tube system



Figure 1. Photo of Dharahara before (a) and after (b) the earthquake.

- Tube-in-tube system
- Multiple-tube system

While taking advantage of the shape and layout of Dharahara, the tube-in-tube system was selected for analysis. A structural system which is an extension of the tube structure, where there is an internal tube supplementing the external perimeter to enhance the

overall lateral global stiffness is known as tube-in-tube structure [6]. The 72.96m tower is supported by an 8.4 m deep two-level underground basement structure (Figure 2). The diameter of the coniform tower at its base is 13.97m which reduces to 9.004m at the top. The length and breadth of the structure at the basement level is 60.2m and 27.4m, respectively. The total area of the lower basement is 1908.43 square meters.

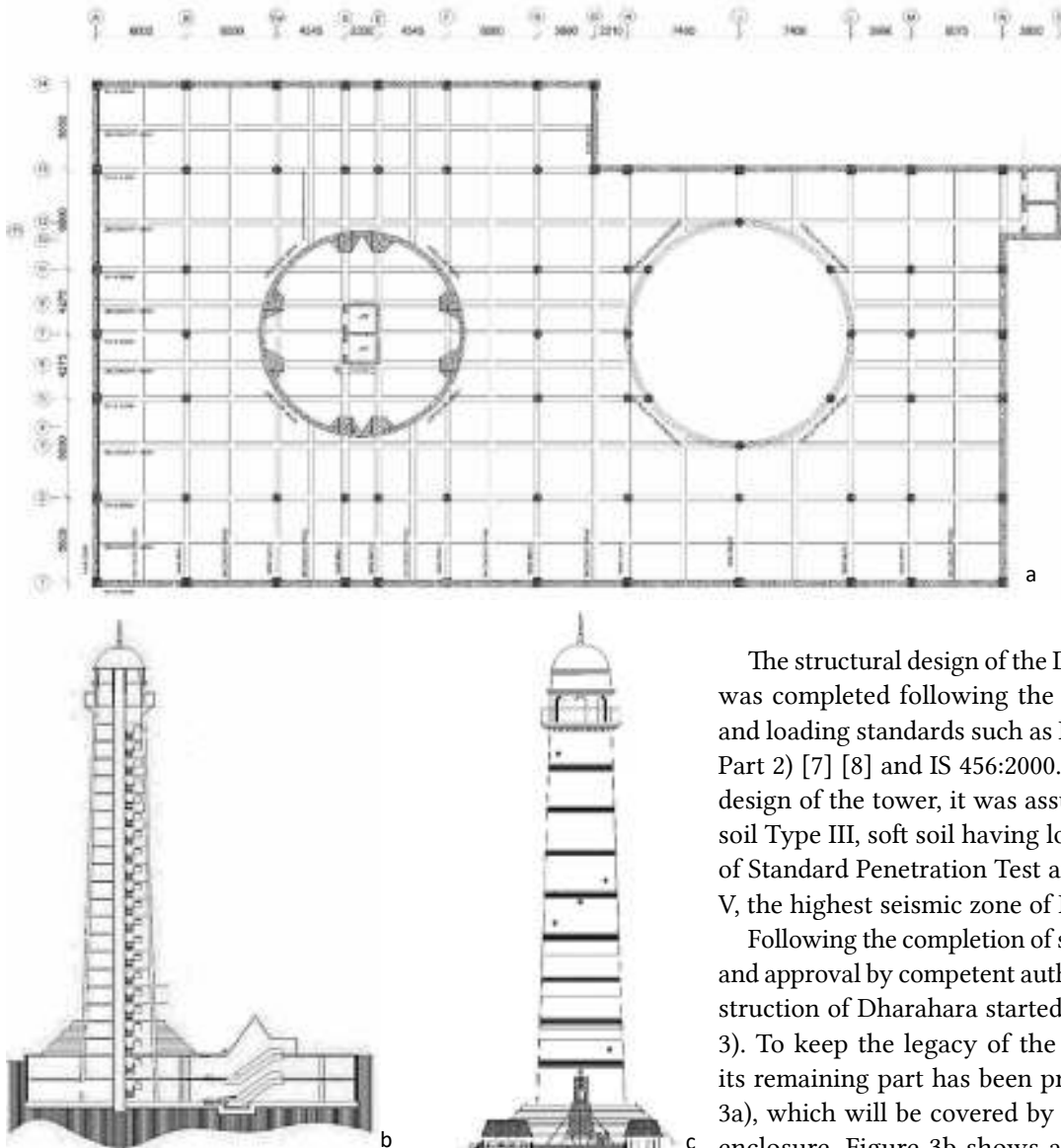


Figure 2. Plan (a), cross section (b) and elevation (c) of Dharahara Tower

The structural design of the Dharahara tower was completed following the Indian material and loading standards such as IS 875(Part1 and Part 2) [7] [8] and IS 456:2000. For the seismic design of the tower, it was assumed located in soil Type III, soft soil having low count $N < 10$ of Standard Penetration Test and seismic zone V, the highest seismic zone of IS 1893:2016.

Following the completion of structural design and approval by competent authorities, the construction of Dharahara started in 2017 (Figure 3). To keep the legacy of the old Dharahara, its remaining part has been preserved (Figure 3a), which will be covered by protective glass enclosure. Figure 3b shows a photograph of Dharahara under construction.



a.



b.

a. Preservation of collapsed "Dharahara"
b. New construction of "Dharahara"

Figure 3.
Dharahara being preserved and new construction of "Dharahara"

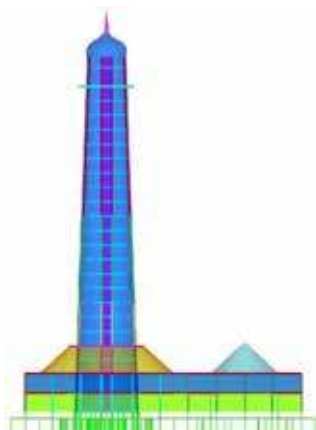
3. Methodology

This investigation was carried out to compare the structural outputs estimated employing IS 1893:2016 and NBC 105:2020 in the context of the Dharahara. The comparison has also been made with the outputs estimated employing the site-specific seismic hazard assessment completed for this site. For structural design and comparison, a numerical model of the tower (Figure 4) was constructed employing SAP2000v20.2, a state-of-the-art structural analysis and design software [9] [10]. The numerical model of the structure consists of 22- stories high tower and a two-level basement. The

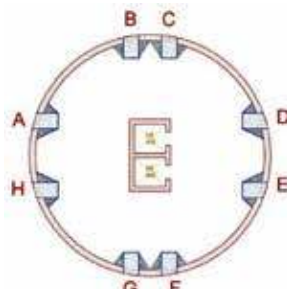
column and shear wall plan layout of the tower area has been shown in Figure 4. The naming A, B, C, D, E, F, G & H are the columns for which drift and deflection checks have been carried out.

For the comparison, the analysis of the structure was done in SAP 2000v20.2, a stand-alone finite-element-based structural program for the analysis and design of civil structures. Four different models were created using different combination of codes and response spectrums. The models were named Model 1, Model 2, Model 3 and Model 4 based on various seismic conditions which are presented described in Table 1.

Even though the actual analysis of the structure was completed considering Combination 3 (i.e. Model 3), the comparison of the results were based on Model 1 for the study purpose. Inter-story drift, top story deflection and base shear were compared to inform the effect of use of different code parameters on a structure.



a. Elevation of the model



b. Column and shear wall layout plan

Images from Dharahara model from SAP2000

4. PSHA based site specific response spectra

To understand site specific seismic requirements, a site specific probabilistic seismic hazard assessment (PSHA) was completed for the Dharahara site. For the PSHA and site-specific response analysis of soil, primary and secondary data, and published literature were reviewed [11] [4]. All the earthquake data since the year 1255 were collected around 300 km radius of the

Table 1: Case study model types with seismic parameter codes

Model Number	Attributes
Model 1	Design of the Dharahara using Indian seismic code IS 1893:2016 with Response Spectra provided in the same code.
Model 2	Design of the Dharahara using the Nepali seismic code NBC 105:2020 with Response Spectra provided in the same code.
Model 3	Design of the Dharahara using Indian seismic code IS 1893:2016 with Site Specific Response Spectra at Site.
Model 4	Design of the Dharahara using Nepal National Building Code (NBC 105:2020) with Site Specific Response Spectra at Site.

site and magnitude frequency relation was developed. Based on the investigation, the maximum magnitude of earthquake was estimated to be 8.5. The PSHA found peak ground acceleration of 298, 554 and 714 gals for 100, 475 and 975-year seismic events, respectively, for the soft soil condition found at the site. Soil amplification factor was found to be 1.4. Figure 5 shows the

site-specific spectral response of the Dharahara site. Similarly, the acceleration at rock and soil condition with amplification factor is presented in Table 2.

The site stiffness (average shear velocity for 30m depth V_{s30}) of the Dharahara premises is approximately 188m/s. Based on the V_{s30} , this is categorized as the seismic site category D (stiff soil site) towards

the lower side or site category E (soft soil) towards the higher side [12]. HVSR indicated that the predominant natural period of the surface layer is around 1 second which corresponds to the natural frequency of the surface layer to be 1Hz.

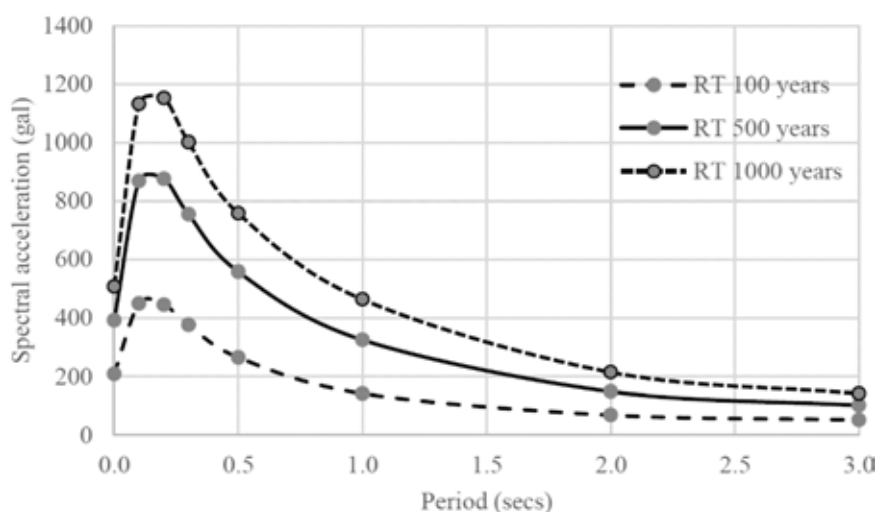


Figure 5. Site specific response spectra for Dharahara site [12]

Table 2. PGA of Bed Rock and Soil, Amplification of PGA*Acceleration at rock and soil condition*

Return Period (Y3)	Peak ground acceleration (gal) at		Amplification
	Rock	Soil	
100 Y3	208	298	1.412
475 Y3	392	554	1.404
975 Y3	508	714	1.417

5. Code-based response spectra

IS1893:2016

Figure 6 presents the shape factors for response spectra included in IS1893:2016 for Modal Response Spectrum Method (MRSM). Here, S_a/g is design acceleration coefficient for different soil types, normalized with peak ground acceleration, corresponding to natural period T of a structure. The design horizontal seismic coefficient (A_h) is then

calculated by substituting the values of seismic parameters and design acceleration coefficient in the formula given by:

$$A_h = \left(\frac{Z}{2} \right) \left(\frac{S_a}{R} \right) / \left(\frac{R}{I} \right)$$

Where, Z = zoning factor, I: Importance factor and R: Response reduction factor.

Seismic parameters calculated as per the Indian seismic standard are presented in Table 2 for the Model 1 and 3.

NBC 105:2020

Figure 7 presents the Spectral shape factor, $Ch(T)$ for the relevant soil type given in NBC105: 2020. As per the seismic standard, seismic zoning factor for Dharahara site which lies in Kathmandu is 0.35g and soil was categorized as Type D for the site. The design horizontal seismic coefficient was then calculated by substituting the values of seismic parameters and design acceleration coefficient in the formula given by:

$$C_d(T) = \frac{C_h(T) Z I}{R_\mu \Omega_u}$$

Where, $Ch(T)$ is shape factor, Z: Zoning factor, I: importance factor, R_μ : Ductility Factor for Ultimate Limit State and Ω_u : over strength factor for ultimate limit state.

Seismic parameters calculated as per this code is reported in Table 2 for the Model 2 and Model 4.

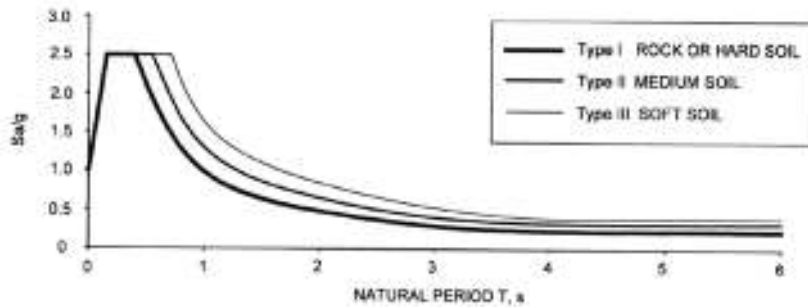


Figure 6. Design acceleration coefficient (S_a/g) (corresponding to 5 percent damping) [3]

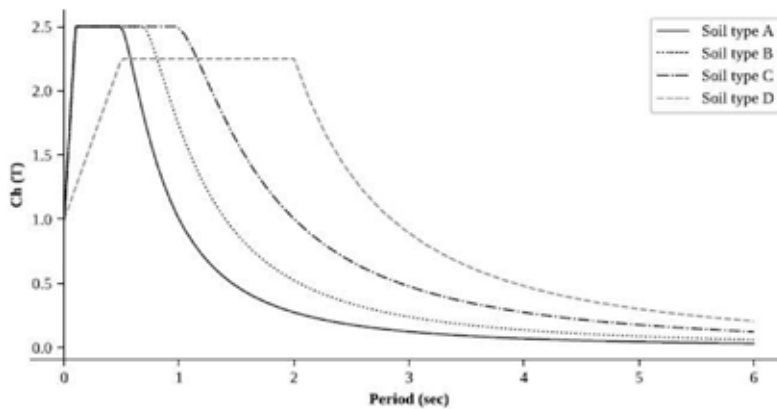


Figure 7. Spectral shape factors, $Ch(T)$ for Modal Response Spectrum Method, Nonlinear Time History Analysis, Vertical Loading and Parts and Components [13]

6. Seismic parameters

The design horizontal seismic coefficient is dependent on many factors which varies in every code. Basically, they are dependent on design acceleration coefficient for different soil types, type of structure, importance of the building, seismic zonation as per seismicity of the area, etc. Table 3 shows the seismic load parameters and their corresponding values derived from the related codes.

For MRS, spectral shape factors provided in the respective codes with appropriate seismic parameters were used whereas PGA values for the site-specific response was taken from figure 5.

Table 3. Seismic parameters and seismic design coefficients for 4 different cases.

Input parameters	Model 1	Model 2	Model 3	Model 4
Seismic zone factor (Z)	0.36	0.35	0.36	0.35
Importance factor (I)	1.5	1.25	1.5	1.25
Soil Type	III	D	III	D
Time Period (x/y)	2.42sec/2.40sec	2.38sec	2.42sec/2.40sec	2.38sec
Response Reduction Factor (R)	4	-	4	-
Ductility Factor (R_μ)	-	3.5	-	3.5
Over strength Factor (Ω_u/Ω_s)	-	1.4/1.2	-	1.4/1.2
Design Seismic Horizontal Coefficient (ultimate)	0.046	0.13	0.046	0.13

7. Result

Top story deflection and inter-story drift have been considered in a single column element in order to observe the variation at the same point among all four cases. The table below shows the increase in percentage keeping the values obtained from model 1 as the reference.

a. Base shear

Table 4 presents a comparison of base shears estimated for different models following different seismic standards. From the table it is apparent that there is a significant increase in the base shear if NBC105 is employed as compared to IS1893. Base shear increment in other two building cases is shown in Table 7 in which the increment decreases with the height decrement.

The chart in Figure 8 shows that the comparison between the base shear obtained from the Model 1, Model 2, Model 3 and Model 4. The base shear obtained from NBC 105:2020/code spectrum is significantly higher as compared to that of IS 1893:2016/code spectrum.

b. Top story deflection

Table 5 presents a comparison of top story displacement estimated for different models following different seismic standards. From the table it is apparent that there is a significant increase in the base shear if NBC105 is employed as compared to IS1893.

From Table 5, it is observed that the maximum top story displacement was obtained from Model 2, which increased by 206 percent in X-direction and by 211 percent in Y-direction in comparison to the top displacement obtained from model 1.

Table 4. Base shear comparison based on MRSM spectrum and site-specific response spectrum

		Base Shear(kN)	Percentage Increase
Model 1 (IS 1893:2016/CODE SPECTRUM)	X-direction	4307	
	Y-direction	4326	
Model 2 (NBC 105:2020/CODE SPECTRUM)	X-direction	11810	174%
	Y-direction	11834	
Model 3 (IS 1893:2016/SITE SPECIFIC SPECTRUM)	X-direction	8542	98%
	Y-direction	8581	98%
Model 4 (NBC 105:2020/SITE SPECIFIC SPECTRUM)	X-direction	11811	174%
	Y-direction	11810	173%

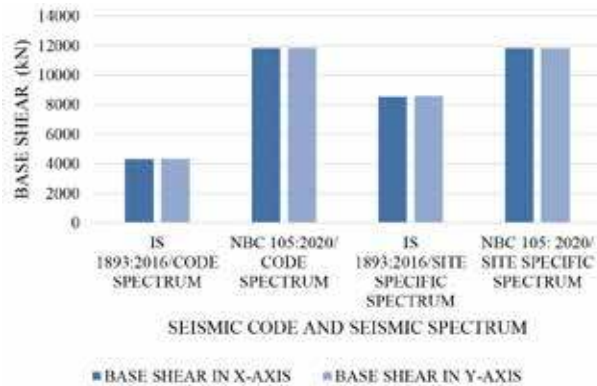


Figure 8. Comparative chart showing base shear in different seismic conditions

Figure 9 presents a comparison of deflection along the height of the tower that was obtained for the four numerical models.

b. Y-Direction

The IS1893 code has specified the maximum deflection at top level of the building as 0.04 times total height of building. The permissible top story deflection is 277.6 mm in both X and Y-directions. It can be observed that the deflection using NBC 105:2020/code spectrum is considerably higher as compared to the deflection using IS 1893:2016/code spectrum. The deflection of all the model is within permissible deflection. The top deflections are found out to be 32.9mm and 29.8mm using IS 1893:2016/code spectrum, whilst same using

NBC 105:2020/code spectrum is found to be 100.6mm and 92.6mm in X and Y-directions, respectively.

c. Inter-story drift comparison

Table 6 presents a comparison of inter story drift estimated for different models following different seismic standards. From the table it is apparent that there is a significant increase in the base shear if NBC105 is employed as compared to IS1893.

From table 6, it is observed that the increase in inter-story drift obtained from Model 2 increased by 206% in X-direction and by 211% in Y-direction compared to the base shear obtained from model 1.

Figure 10 shows the comparison between the inter-story drifts obtained from the four models discussed above. The inter-story drift was found to be 0.00067 and 0.00060 in X and Y-directions using IS 1893:2016/code spectrum, whilst the drifts increased to 0.00205 and 0.00187 in X and Y-directions using NBC 105:2020/code spectrum. There is a limit on inter story drift of 0.004 for design base shear for a load factor of 1 [3]. The values from both codes are within permissible value.

8. Additional examples

Besides Dharahara, two more case studies were developed for the comparison of IS1893:2016 and NBC105:2020. The new case studies included, i) one mid-rise (10 story + two level basement) and ii) one

Table 5. Top displacement comparison

Top Story Displacement (in mm)	Base Shear(kN) Increase		
Model 1 (IS 1893:2016/CODE SPECTRUM)	X-direction Y-direction	32.9 29.8	
Model 2 (NBC 105:2020/CODE SPECTRUM)	X-direction Y-direction	100.6 92.6	206% 211%
Model 3 (IS 1893:2016/SITE SPECIFIC SPECTRUM)	X-direction Y-direction	70.5 64.8	115% 118%
Model 4 (NBC 105:2020/SITE SPECIFIC SPECTRUM)	X-direction Y-direction	97.8 89.6	198% 201%

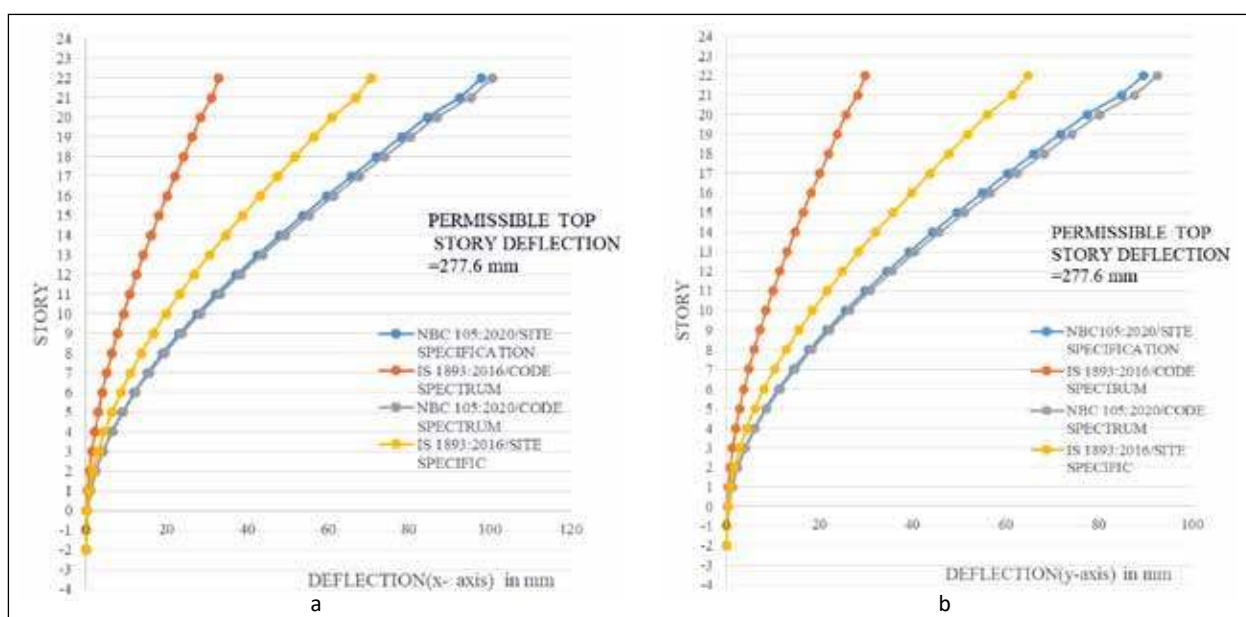


Figure 9. Comparative deflection plots along the height of the building (a)-X-Direction; (b)- Y-Direction

Table 6. Inter-story drift comparison

Drift (in mm)	Percentage Increase		
Model 1 (IS 1893:2016/CODE SPECTRUM)	X-direction Y-direction	0.00067 0.00060	
Model 2 (NBC 105:2020/CODE SPECTRUM)	X-direction Y-direction	0.00205 0.00187	206% 211%
Model 3 (IS 1893:2016/SITE SPECIFIC SPECTRUM)	X-direction Y-direction	0.00144 0.00131	114% 118%
Model 4 (NBC 105:2020/SITE SPECIFIC SPECTRUM)	X-direction Y-direction	0.00200 0.00181	197% 201%

low rise building (4-storey high) reinforced concrete buildings. These buildings were analyzed to compare drift, deflection and base shear. The medium rise building was 36.5m high with base dimensions of 21m X

23m and the low-rise building was 9.6m high with base dimensions of 8m X 21m. The abridged result is presented in Table 7.

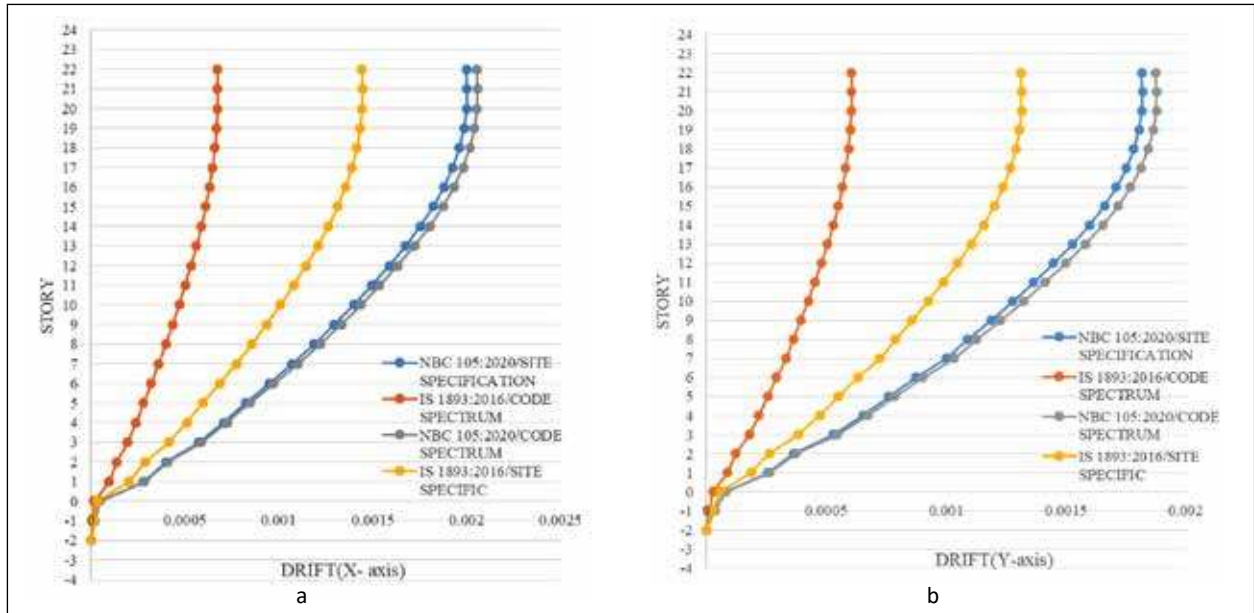


Figure 10. Comparative plots for inter story drift (a)-X-Direction; (b)- Y-Direction

9. Comparison for medium-rise and low-rise buildings

Table 7: Load parameters and results of other two building cases

Building Type	Medium Rise Building		Low Rise Building	
Complied code	IS 1893:2016	NBC105:2020	IS 1893:2016	NBC105:2020
Seismic zone factor (Z)	0.36	0.35	0.36	0.35
Importance factor (I)	1.2	1.25	1	1
Soil Type	III	D	III	D
Time Period	1.113 sec	1.589 sec	0.408 sec	0.511sec
Response Reduction Factor (R)	5	-	5	-
Ductility Factor(R_{μ})	-	4	-	4
Over strength Factor (Ω_u/Ω_s)	-	1.5/1.25	-	1.5/1.25
Design Seismic Horizontal Coefficient	0.0648	0.164	0.09	0.131
Deflection(mm)	38.996	105.3	24.6	30.5
% change in Deflection	170%	24%		
Drift	0.001207	0.003645	0.0034	0.004358
% change in Drift	202%	28%		
Base Shear (kN)	3482	8748	540.8	793
% change in Base Shear	151%	47%		

10. Discussion

Before promulgation of NBC105:2020, most designers followed NBC105:1994 and/or IS1893:2002 (Part 1) for the seismic design of building and other structures in Nepal. Initially, IS1893:2016 was used for design of Dharahara. The draft NBC 105 was released in 2019 and later finalized in 2020. At that time Dharahara was already under construction. The release of revised NBC105 triggered a comparison of structural outputs between IS1893 and NBC105.

The Dharahara case study shows that the seismic demands posed by the NBC 105:2020 were much higher than that of IS 1893:2016. The global drift, deflection and base shear values obtained in NBC 105:2020 are higher by 206 percent, 206 percent, and 174 percent, respectively, in the X-direction.

From the other case studies, it can be observed that the global drift, deflection and base shear values obtained in NBC 105:2020 in comparison to those obtained in IS 1893:2016 are higher by 202 percent, 170 percent and 151 percent, respectively. Similarly, for the low-rise building the difference was 28 percent, 24 percent and 47 percent, respectively.

The increment percentage of drift, deflection and base shear was different in all three cases and this could basically be due to the variation in time period in each model. It shows that the increment is higher as the building height increases. The increment in low-rise building was the least among all cases which can be due to the spectrum shape that was flat up to 0.7sec in IS1893 whereas in NBC105 it was up to 2 sec. The respective values of acceleration coefficient in the flat portion was 2.5 and 2.25. The high gradient drops of acceleration coefficient in IS1893 at 0.5sec (approx.) and low gradient drop of acceleration coefficient in NBC105 at 2.1sec (approx.) could be the cause of high drift, deflection and base shear in tall buildings.

11. Conclusions and recommendations

Base shear, inter story drift and deflection values obtained from models analyzed employing two

different codes; IS 1893:2016 and NBC 105:2020 were significantly different.

The Dharahara case study showed that the base shear, inter story drift and deflection value in X-direction were higher by 174 percent, 206 percent, and 206 percent, and in Y-direction by 174 percent, 211 percent, and 211 percent using NBC 105:2020 compared to IS 1893:2016.

The change in base shear, inter story drift and deflection in other two buildings under study showed that the change was more significant in high-rise structures compared to low-rise ones.

This paper was based on three buildings only and it is recommended to extend the study using variety of buildings with different shape and irregularities.

Acknowledgements

We would like to express our gratitude towards NRA members, especially Dr. Hari Ram Parajuli, for their cooperation and encouragement which helped us in the completion of this paper. We would also like to express our special thanks to Mr. Jitendra Bothara for his valuable advice. Lastly, we would also like to thank Miss Anamika Shah and Miss Priyanka Chitrakar for their dedication and support in writing this paper.

References

- [1] Charavande, 2019. Earthquake Analysis of RC Structure using Different Codes and Different Countries. Vol. 7, No. 9, September.
- [2] Govindaraju, 2021. Site-Specific Earthquake Response Study for Hazard Assessment in Kolkata City, India. Journal of the International Society for the Prevention and Mitigation of Natural Hazards. Vol. 61.
- [3] Infrastructure Engineering Research & Consult Pvt. Ltd., 2018 June. MASW combined with MAM, SRT, HVSR and Soil resistivity tests in Sundhara, Dharahara Premises and Preparation of Site Specific Response Spectral Curve at Sundhara Site. Government of Nepal, Department of Archaeology, Kathmandu.

- [4] Irwansyah, E., 2013 February. Earthquake hazard zonation using peak ground acceleration (PGA) approach. Journal of Physics Conference Series.
- [5] IS 16700, 2017 November. Criteria for structural safety of tall concrete buildings, Bureau of Indian standards.
- [6] IS 1893 (Part 1), 2016 December. Criteria for Earthquake Resistant Design of Structures, Sixth edition. Bureau of Indian Standards,
- [7] IS 456, 2000 July. Plain and Reinforced Concrete- Code of Practice. Bureau of Indian Standards, New Dehli.
- [8] IS 875, 1897. (Part 1-Dead Loads), Code of Practice for Design Loads (Other than earthquake) for Buildings and Structures. Bureau of Indian Standards, New Dehli.
- [9] IS 875, 1997. (Part 2-Imposed Loads), Code of Practice for Design Loads (Other than earthquake) for Buildings and Structures. Bureau of Indian Standards, New Dehli.
- [10] Melissah, Yang, 2015 April. Nepal Earthquake Destroys Dharahara Tower, A Significant Tourist Attraction in the Heart of Kathmandu.
- [11] Nepal National Building Code NBC 105, 2020. National Reconstruction Authority, Kathmandu.
- [12] Santos, 2013. "Comparative study of codes for seismic design of structures". Vol. 9, No. 1.
- [13] (USGS), United States Geological Survey, 2015. http://earthquake.usgs.gov/earthquakes/eventpage/us200002926/executive#impact_shakemap.



Mass Movements in the Region of 2015 Gorkha Earthquake: Examples from Five Most Affected Districts in Central Nepal

Megh Raj Dhital^a, Tara Nidhi Bhattarai^b, and Lekh Prasad Bhatta^c

Keywords: *Gorkha earthquake, coseismic landslides, mass movement hazard, seismic risk*

Abstract

The Mw 7.8 Gorkha earthquake of 25 April 2015 and its many strong aftershocks brought about massive destruction in central Nepal, including 8,790 deaths and 22,300 injuries. The earthquake also triggered thousands of mass movements. About 5000 landslides were mapped based on field survey and satellite image interpretation in the five most affected districts (Gorkha, Dhading, Rasuwa, Sindhupalchok, and Dolakha). A walkover survey was also carried out in those districts to assess the effect of landslips on communities, infrastructure, and agricultural land. This paper analyses the characteristics of pre-earthquake, coseismic, and post-earthquake landslides. The old deep-seated slides did not show any significant movement during the Gorkha earthquake. However, the excessive rainfall in 2020 adversely affected the region, and the resulting new slides and debris flows caused severe loss of life and property. Coseismic landslides were shallow in nature and occurred mainly on south-facing slopes, consistent with the seismic slip direction. Most rock falls occurred on steep (50°) slopes, rockslides were distributed on less steep (45°) inclines, and the colluvial slides were positioned on gentler (40°) gradients.

1. Introduction

The Mw 7.8 Gorkha earthquake rocked central Nepal on 25 April 2015 at 11:56 local time. The main event and its powerful aftershocks produced thousands of coseismic landslips which destroyed settlements, highways, and roads. The mass movements also affected hydropower projects and damaged cultivated land.

Some landslides were on the verge of reactivation, putting at risk the settlements in their vicinity. This research provides insights into the geomorphic features of coseismic landslips and the areas they had affected.

A large number of old landslides have existed in the region before the earthquake, and the intense rainfall that occurred after the earthquake, particularly

a Professor, Department of Geology, Tribhuvan University (Tri-Chandra Campus, Ghantaghar, Kathmandu 44600, Nepal)
E-mail: mrdhital@gmail.com

b Professor, Department of Geology, Tribhuvan University (Tri-Chandra Campus, Ghantaghar, Kathmandu 44600, Nepal)
E-mail: tnbbhattarai222@gmail.com

c Engineering Geologist, National Reconstruction Authority Government of Nepal, Kathmandu 44600, Nepal
E-mail: lorullekh.lpb@gmail.com

in 2020, have also triggered more such events. Thus, the landslides generated by different agents and at different times, cannot be considered similar in nature, particularly for their management. The research also elucidates the temporal as well as spatial behavior of mass movements. Since the pre-existing, coseismic, and post-seismic mass movements belong to a single geological process of mass wasting, the main objective of this research is to reveal their interrelationship in the earthquake-struck region of central Nepal. These results are expected to be used in controlling mass movement hazard for sustainable infrastructural development.

1.1 Geological setting

The north margin of Indian plate and south part of Eurasian plate collided about 50 Ma in the Eocene (Molnar and Tapponnier 1975). The collision led to extensive crustal shortening and upheaval, resulting in the formation of Himalaya. During post-collisional underthrusting of the Indian lithosphere, the overlying crystallines underwent partial subduction and metamorphism. They were ultimately detached from the subducting Indian plate and propagated to the south. This process resulted into a south-verging mega duplex where the Lesser Himalayan sequence is sandwiched between the Main Himalayan Thrust (MHT), supposed to represent the floor, and the Main Central Thrust (MCT), corresponding to the roof (Figures 1 and 2). The very thick (more than 15 km) Greater Himalayan thrust sheet constitutes the hanging wall of the MCT and forms two large open folds: the Great Midland Antiform in the inner zone and the Great Mahabharat Synform in the outer part. The MHT is also the sole thrust of the imbricate stack developed within the foreland fold-and-thrust belt (Dhital 2015, Dhital and Adhikari 2020).

The earthquake-affected region can be divided into the Lesser Himalayan Sequence, Greater Himalayan Crystallines, and the Tibetan–Tethyan Sediments (Dhital 2015). The Lesser Himalayan Sequence begins with the Palaeoproterozoic Kuncha Formation,

consisting of phyllites, metasandstones, and schists with some augen gneisses and very rare intrusives. This formation is succeeded by resistant quartzite bands, which are followed up-section by the variegated schists, slates, and carbonates. Further, stratigraphically upwards is the Mesoproterozoic grey Dhading Dolomite with columnar stromatolites and subordinate slate bands. The Dhading Dolomite transitionally passes into the black Benighat Slates with Jhiku carbonates. The uppermost units of the Lesser Himalayan Sequence are the Malekhu Limestone and Robang Formation represented by slates, phyllites, amphibolites, and quartzites (Stöcklin and Bhattarai 1977).

The Greater Himalayan Crystallines override the Lesser Himalayan Sequence along the MCT. They consist of schists, gneisses, quartzites, some marbles, and gneisses intruded by Palaeozoic and Miocene granites. The topmost unit is made up of calcareous schists, marbles, and augen gneisses.

In central Nepal, the Greater Himalayan Crystallines comprise the Bhimphedi Group (schists, quartzites, marbles, and gneisses) and the overlying Tibetan–Tethyan Sediments constitute the Phulchauki Group (Stöcklin and Bhattarai 1977). The Phulchauki Group begins with the Tistung Formation (biotite schist and quartzite) and is followed by the Sopyang Formation (limestone and slate), the Ordovician Chandragiri Limestone, Chitlang Formation (slates and quartzites), and the Silurian beds of dolomite (Figure 2).

1.2 Seismicity

When the converging Indian and Eurasian plates are locked in some sector of the Himalaya, the stored energy is suddenly released in the form of earthquakes (Seeber and Armbruster 1981, Avouac 2015; Bilham 2019). The background seismicity of Nepal is concentrated in the Great Himalayan foothills and the epicenter of Gorkha earthquake was no exception (Figure 3). It lies near Barpak (28.147°N, 84.708°E), about 80 km NW of Kathmandu (USGS 2015) and its hypocenter was at a depth of about 15 km (Figure 2) on the MHT dipping 11° due north (Elliott et al. 2016). The

event ruptured the thrust by about 150 km along the strike (NNW-SSE), and about 60 km along the dip (NE), and with a maximum slip of 5.8 m (Liu et al. 2016). But the rupture did not appear on the surface (Figure 2). The mainshock slip propagated south-eastwards

was confined mainly to five most affected districts (i.e., Gorkha, Dhading, Rasuwa, Sindhupalchok, and Dolakha) of central Nepal (Figure 4). Many seasonal as well as perennial streams and rivers dissect this mountainous terrain. The district headquarters are

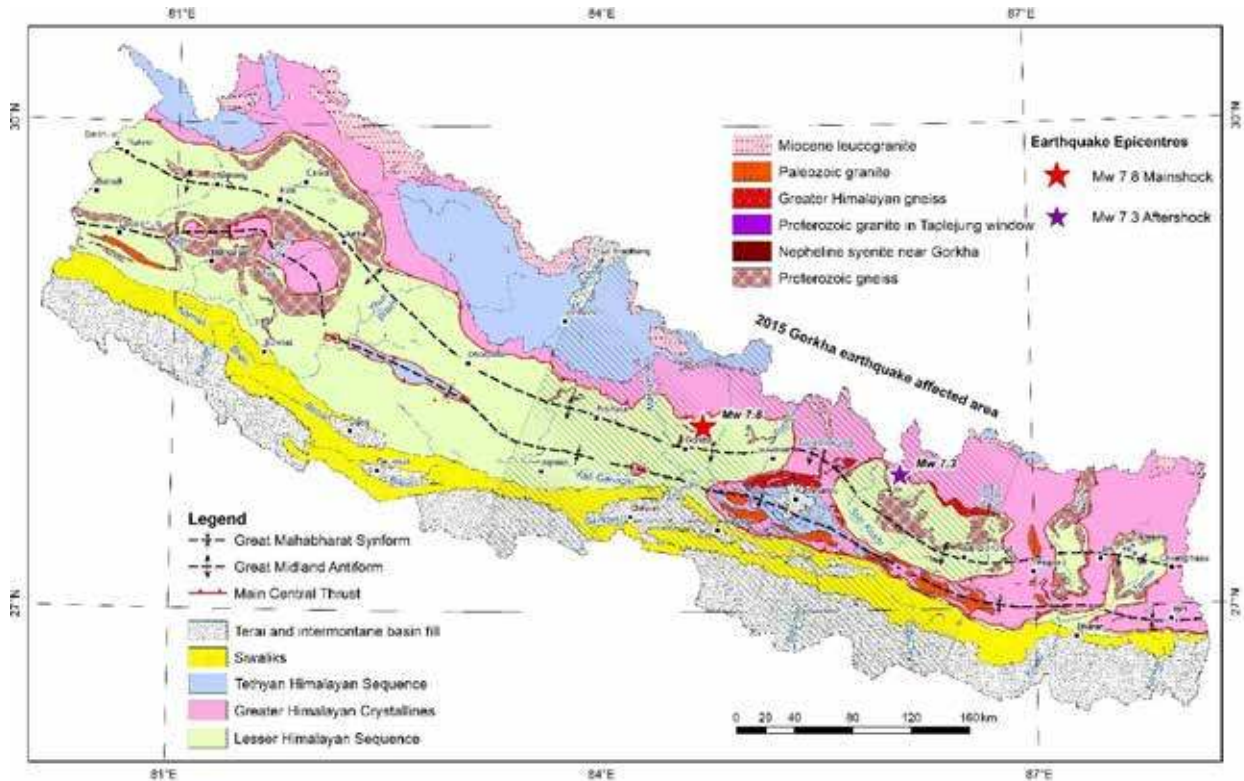


Figure 1: Generalised geological map of Nepal. Source: Modified from Dhital (2015)

from the hypocenter with a peak displacement of 4–6 m beneath Kathmandu (USGS 2015). The strongest aftershock of Mw 7.3 (Figure 3) happened after 17 days, on 12 May 2015 (Rajaure et al. 2016).

2. Materials and methods

Damage from coseismic landslides sometimes exacerbates the destruction from strong shaking and fault rupture (Keefer 1984). Though central Nepal did not differ much from other parts of the country in terms of landslide occurrence, the situation changed drastically after the earthquake. Considering this, the study

connected by national highways and some towns are also accessible by graveled roads. But many villages are reachable only by foot trails. Since geology, climate, land use, and river dynamics play important roles in triggering mass movements, these factors were analyzed based on field investigation and literature review. Geological field investigation was limited to some critical locations. For the rest of the locations, published geological maps and satellite images were interpreted. The topographic maps published by the Department of Survey, Government of Nepal, were used to plot the data collected. Attempt was made to understand the state of hazard on the basis of natural hillslopes, rock

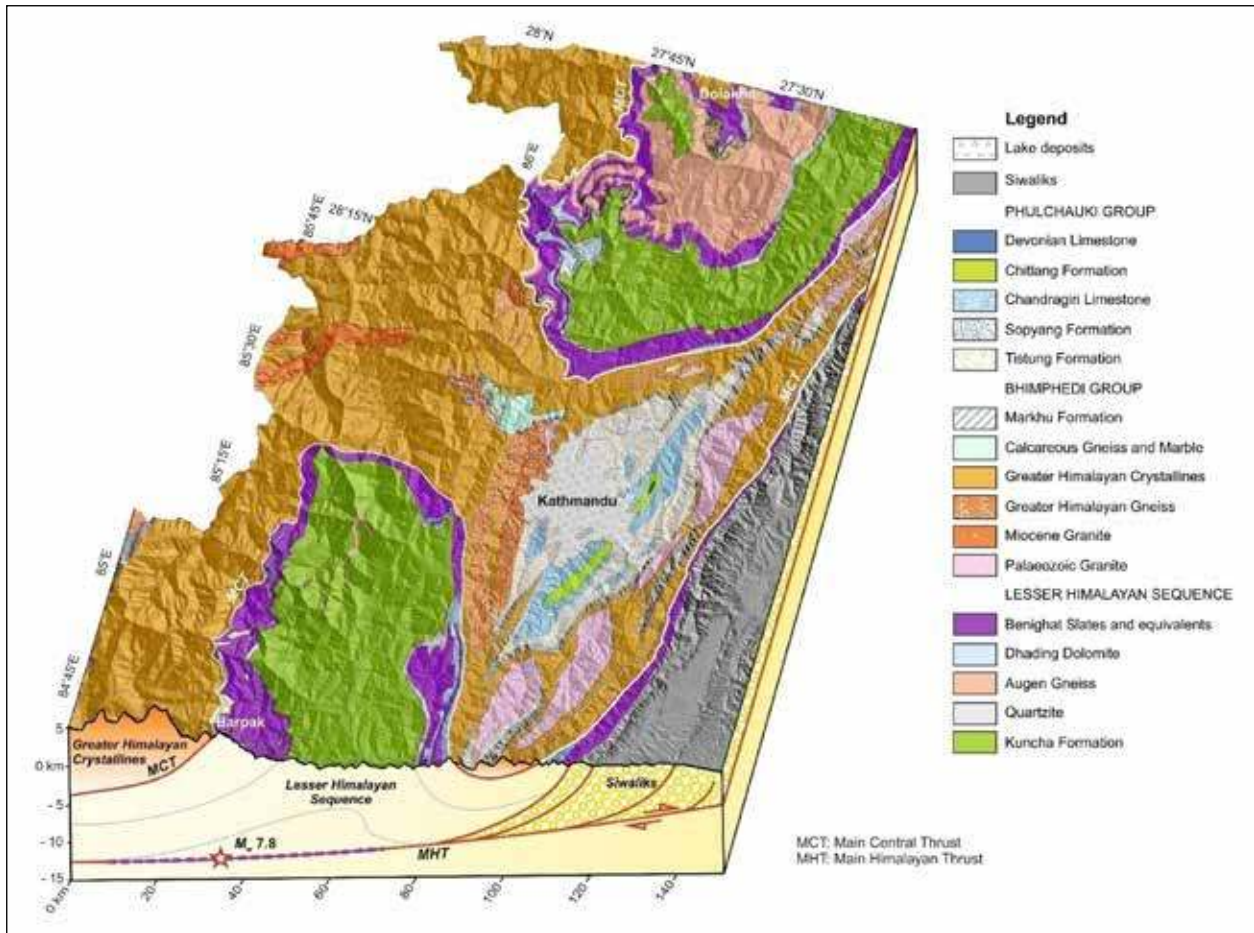


Figure 2: Geological block diagram of earthquake-affected region in central Nepal. Source: Surface geology from Stöcklin and Bhattarai (1977)

types, soil types, discontinuities and their orientation, weathering grade, and vegetation cover.

In the field, landslips were classified into various categories (Varnes 1978). Also, their dimensions, runout route, present status, role of groundwater, and future propagation trend were assessed together with the vulnerability of community or infrastructure. The volume of surveyed mass movements ranges from about 20 m³ to 12,500,000 m³ (Figure 5).

3. Results

A large number of mass movements from five most affected districts were investigated in the field. Short descriptions of some of them are given below.

3.1 Gorkha district

Since the epicenter of the mainshock was within the Gorkha district, it suffered from coseismic failures (Figure 6). Though Barpak was very close to the epicenter of mainshock, its vicinity did not have many

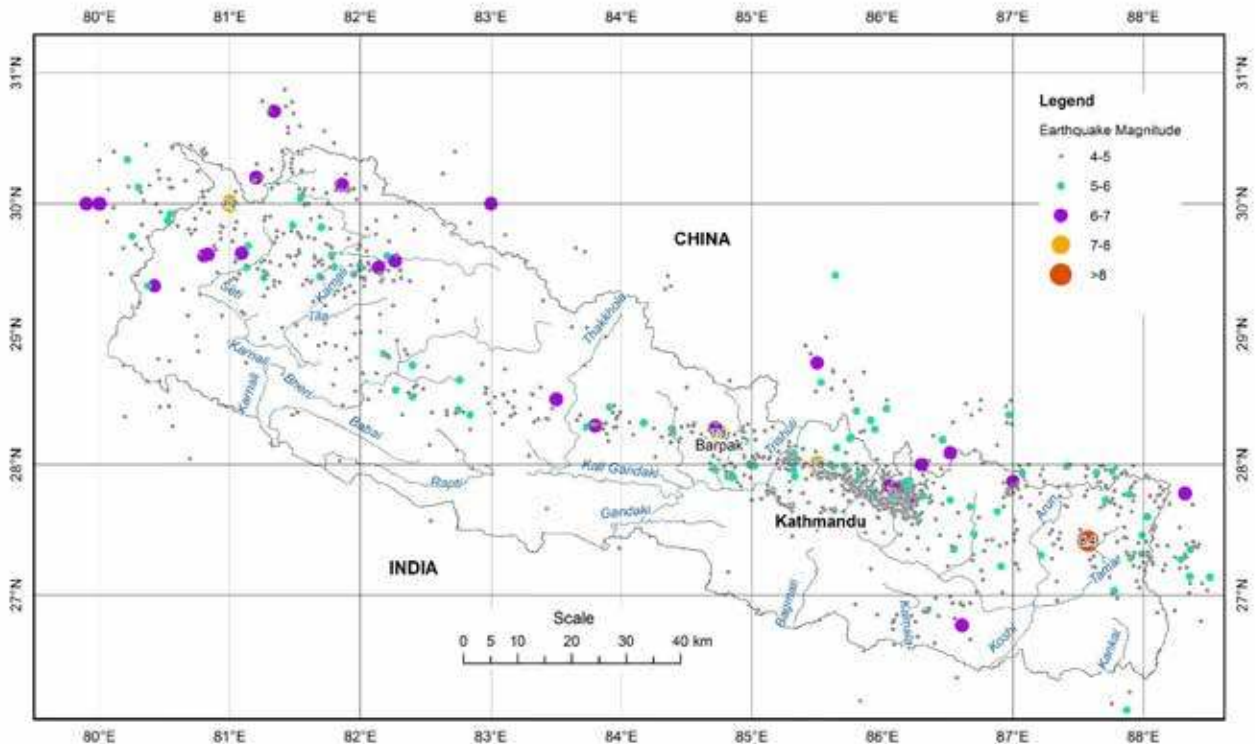


Figure 3: Background seismicity of Nepal (>Mw 4) between 1995 and March 2016. Also are shown some historic earthquakes.
Source: Department of Mines and Geology, Kathmandu

large and deep failures. Nonetheless, the region was riven with many shallow slides, cracks, and fissures. These vulnerable slopes were further damaged by the monsoon of 2015. At the south end of the village, many tension cracks are crisscrossing a foot trail. The cracks are up to 27 m long, about 40 cm deep, and have a lateral displacement of about 25 cm and a vertical slip of about 20 cm. An active debris slide is observed on the Barpak–Laprak road. The slide is about 100 m long, 52 m wide, 5–8 m deep, and actively expanding towards its crown and flanks.

On the north slopes of Laprak, the earthquake reactivated an old soil slide, which is about 300 m wide, 100 m long, and 20 to 25 m deep. About 50 m wide, 5–10 m deep, and 70 m long reactivated debris slide at Kusku Pakha has damaged the cultivated land. A wide and large crack zone is found in the western hillslope

of Laprak, where numerous cracks are randomly oriented and a cultivated terrace has subsided by about 60 cm. On the way to Gumda from Laprak, many active landslides occur on the south hillslope.

The Budhi Gandaki River valley is one of the most severely affected regions in the Gorkha district. In the past, there were many incidents of rock sliding with some cases of landslide damming. At the eastern end of Arkhet Bazar, close to Galane, an alluvial soil slide occurs on the left bank of the Budhi Gandaki River. It is about 30 m long, more than 100 m wide, and 2–4 m deep. The landslide was reactivated by the earthquake. The alluvial deposits consist of sand, gravel, and boulders of up to 2.5 m in diameter. The slide is facing west with a dip of 35° in its deposition zone, and its main scarp is almost vertical.

A debris slide lies on a convex slope, about 500

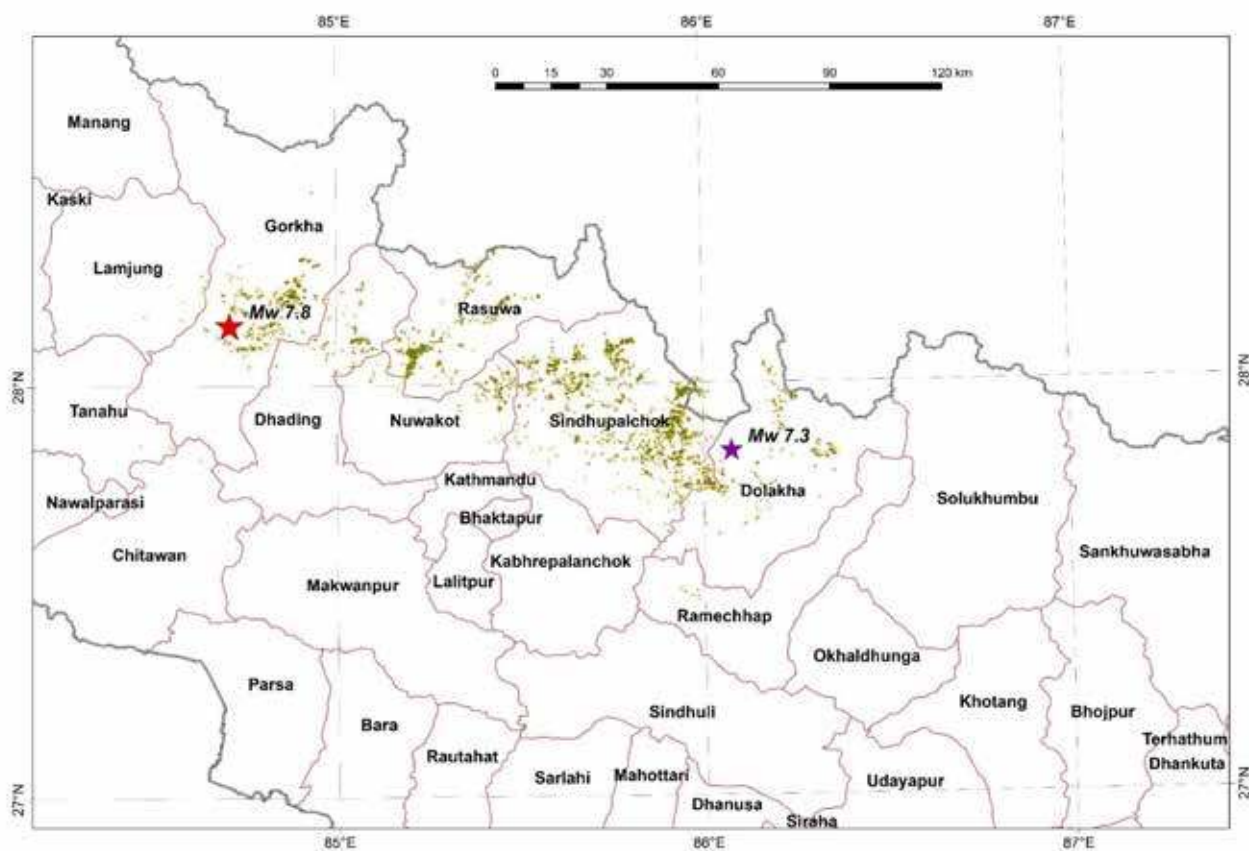


Figure 4: Density of coseismic landslips in five most affected districts of central Nepal

m downstream from the Soti Bazar, and about 300 m above the Budhi Gandaki River. The landslide is about 300 m long, 200 m wide, and 5–8 m deep. The failure has taken place on schist and the failed slope is about 40°.

Rock falls affect the road between Soti and Arughat with a significant risk to Soti Bazar, where multiple extension joints are present in the rock cliff and about 10 houses are situated within its runout zone. The cliff is about 50 m high with a steep (70–80°) face. At Soti Bazar, the Budhi Gandaki River is also undercutting its right bank by scouring about 10 m high alluvial terrace for a length of about 300 m, where several buildings are located a meter away from the cliff.

A large landslide and many smaller ones are distributed between Shyamchet to the west and Ghamling

Gaun to the east for a distance of about 2 km. Many tension cracks are also distinct in the southwestern slope of Shyamchet. Most of the paddy field is left barren due to ground deformation and subsidence. Some of the houses from Shyamchet are relocated near Ghamling Gaun.

Large rock falls and debris flows are widespread at Khani Gaun. About 6 m deep and 3–5 m wide erosive gully has many cracks in its both banks for a length of about 1.5 km. The cracks also extend to an adjacent paddy field. Debris flows from the gully had accumulated a huge mass on the bank of the Budhi Gandaki River. A reactivated landslide is also present at the bottom of the slope. An actively eroding gully of an average depth of 6 m and width of 8 m runs through the lower part of Keraunja, where most of the houses

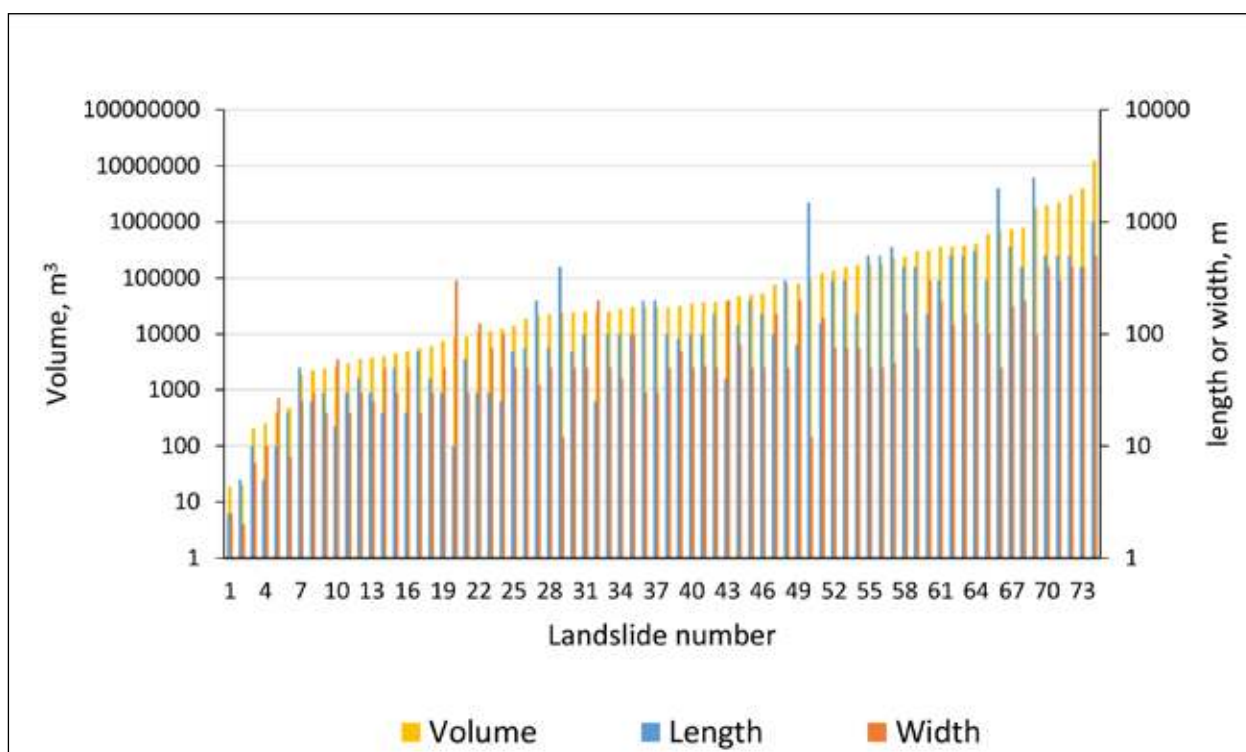


Figure 5: Dimensions of field investigated landslides

are damaged by debris flows and floods. Keraunja also suffered from massive destruction of houses due to rockslides and falls, especially towards the upper reaches of the gully (Figure 7).

An old landslide lies about 20 m below the school of Rumchet. Its crown has a deformed ground that has subsided by about 3 m. The failed slope dips about 60° due north. About 1 km upstream from the suspension bridge at Dobhan, a huge landslide has accumulated enormous amounts of debris on the left bank of the Budhi Gandaki River. The failure propagated through an alternating succession of quartzite and gneiss. The concave slope before failure was dipping at an angle of about 70°. At present, the landslide is about 500 m long and 400 m wide, and it was partly reactivated by the earthquake.

The upper slope of Sirdibas is composed of very jointed and fractured gneiss with some schist and quartzite bands. The village lies on a southeast-dipping

slope comprising old landslide debris. A spring appears on the left flank of the slope. The runout from a rock fall may affect the village lying about 125 m below a cliff.

An actively eroding gully passes through the mid portion of Padi, whereas a large landslide occurs near its lower reach. The ground around the landslide is wet and moving towards the gully.

At Khorlabesi, a debris flow has reached the banks of Budhi Gandaki River and damaged a few houses. Falls originating from the jointed rock slope above Khorlabesi have destroyed several houses (Figure 8).

3.2 Dhading district

The earthquake mostly affected its north part (Figure 9). Above the school of Tawal, a large rockslide – rock fall occurs periodically. This slope failed at first during the earthquake and then several times in the rainy season. Its runout zone is about 200 m long, 200 m

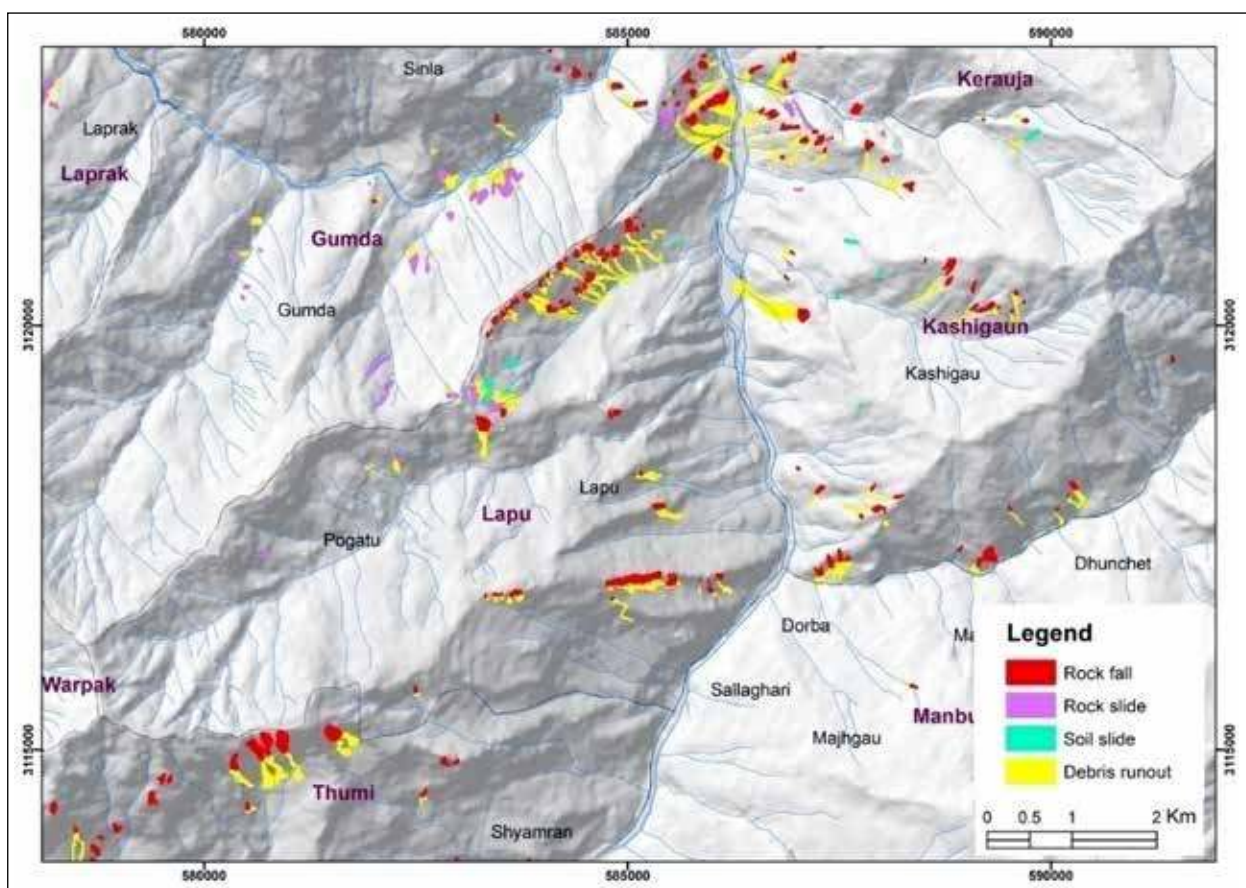


Figure 6: Mass moments in Budhi Gandaki Valley, near Gumda and Lapu of Gorkha district

wide, and lies 150 m above the school. A wedge slide – fall is also seen on another cliff, about 75 m east of the main debris cone.

At the south end of Latap, about 100 m long and 50 m wide strip of paddy field is seen to the west of a developing soil slide along with gully erosion. The slide is 5–7 m deep, about 20 m wide at the crown, contains boulders (10–3 m) of quartzite with a wet matrix of silty sandy clay. Tension cracks appear in the crown within a breadth of about 50 m and length of about 300 m.

On the way to Tajumrang, a rock cliff is suffering from wedge failure at the junction of two trails, where massive, cliff-forming, grey, pelitic quartzite and biotite schist are exposed. Many shallow rockslides, debris

slides, and rock falls affect the slopes around Kichet (Figure 10).

A large rockslide devastated Gangmrang, where many tension cracks are seen in the trail below the abandoned village. The failure propagated towards the village as a wedge slide (Figure 11).

At Puru, a landslide occurs below the road on 2–4 m thick colluvial soil and bedrock. The slide is 50–70 m long, 50 m wide, and has a straight slip surface with about 600 m long runout path. The slide is actively expanding upwards due to the presence of a stream and steep topography. The tension cracks in the crown are 5–7 m away from the main scarp.

At Pyang Gaun, the runout debris from a rockslide reaches a stream. The debris consists of quartzite and

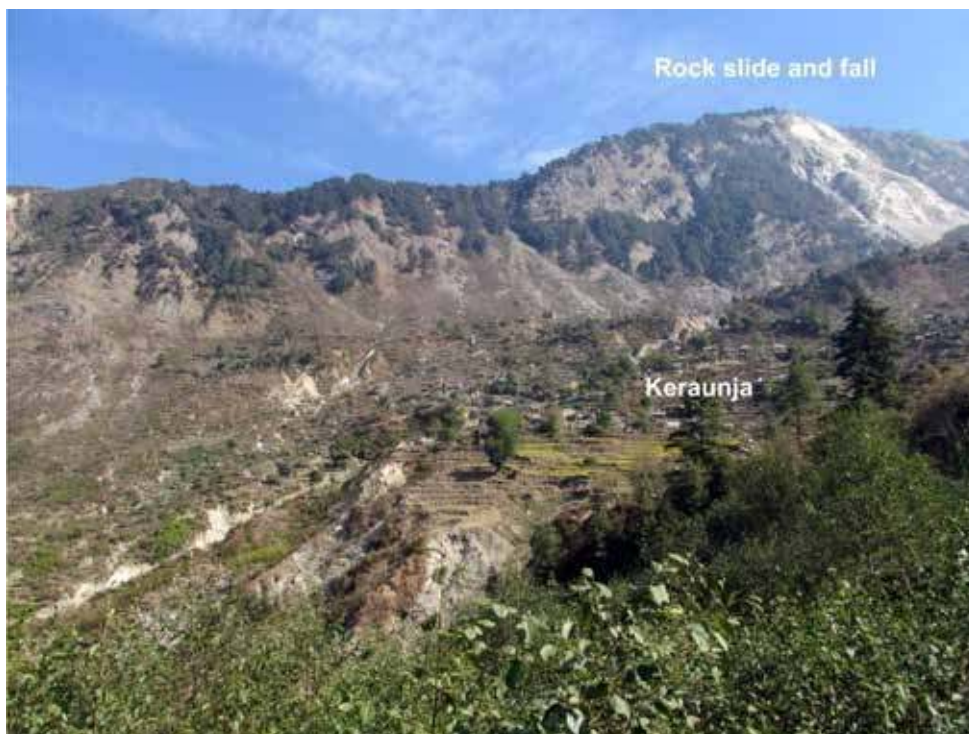


Figure 7: View of Keraunja affected by many landslides and gullies

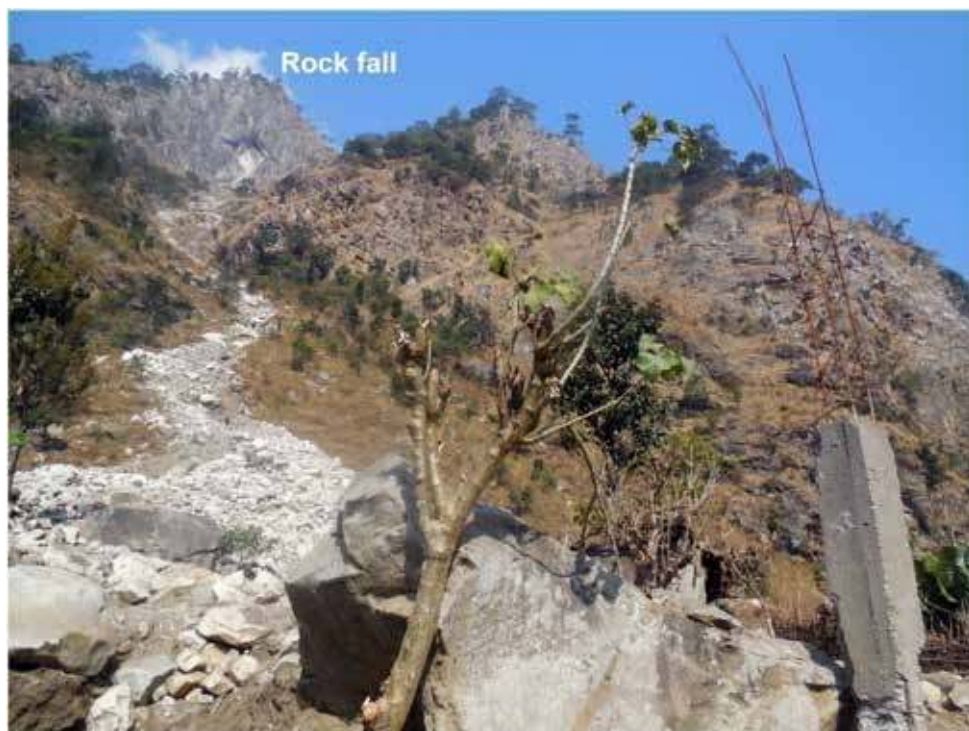


Figure 8: At Khorlabesi, rock fall destroyed a building (a damaged column is visible at the lower right corner). View to W

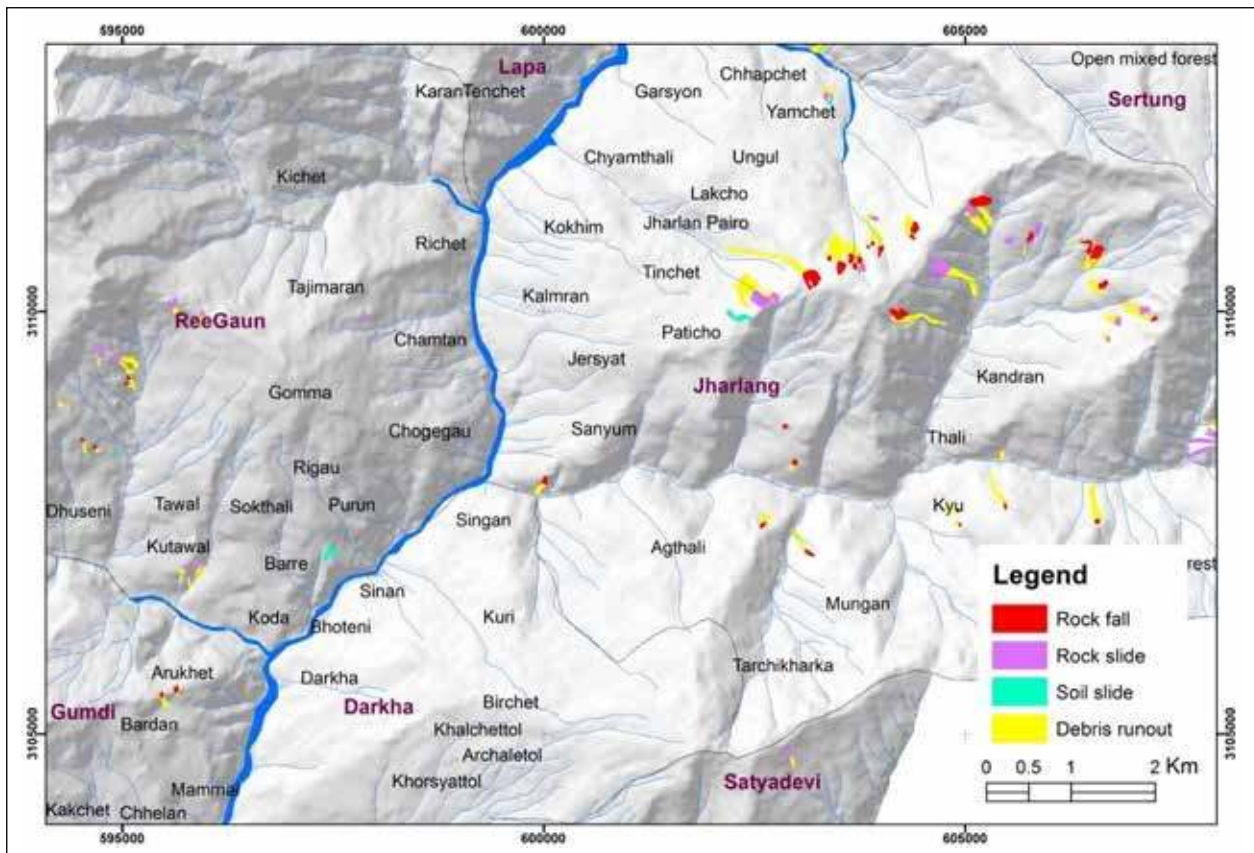


Figure 9: Mass moments around Jharlang in Dhading district



Figure 10: In the vicinity of Kichet, many shallow slides and falls occur on steep rocky slopes. View to NW



Figure 11: A large wedge slide at Gangmrang. View to NW

schist boulders of up to 1 m in diameter and they come from a scarp at the hilltop, about 1 km away from the stream.

A roughly 300 m wide landslide-affected area lies to the north of a high school below Lawadung, where several reactivated landslides (mainly wedge failures) occur. The runout from them extends for about 500 m and damages cultivated land.

About 100 m east of Tipling Thulo Gaun, a shallow rock fall is about 5 m long and 10 m wide, and its runout path is about 200 m long. The fall begins from the upper slope made up of very jointed (at least 3 sets) schist. The clasts in the landslide debris range from a few centimeters to 1 m.

About 50 to 60 m east of Tipling Thulo Gaun, a rock fall – rockslide occurs on the cultivated land of stepped topography. The landslide started from a straight and steep (70–80°) upper slope containing 2 or 3 tension cracks in the crown. The active slide is 15 m long and 60 m wide with more than 200 m of runout distance.

Near Hindung, rockslides occupy the upper slope of a west-facing hill and their runout threatens to reach the village. Another rockslide is situated near

the primary school of Hindung, and one more occurs below the main village. The upper slide gives way to an erosive gully and the debris flow from it affects the village.

At Newor, a rockslide begins on the mid slope and passes through the settlement. Its runout length is approximately 500 m and width is 40–50 m. After the earthquake, the houses are relocated to the paddy field, about 200 m above the village.

Two rockslides occupy a north-facing slope, about 200 m south of Sertung. One of them is a reactivated slide and the other is a fresh failure. They affect the village with more than 200 houses. Many tension cracks extend for 10 m beyond the main scarp in the paddy field. They record a lateral displacement of 60 cm and a vertical drop of 50 cm. The natural slope below the slide is about 25°, whereas the failed slope is about 70°.

The Borang–Sertung trail crosses about 30 m long and 20 m wide rock fall with a failed slope of about 80° (Figure 12). The failure occupies the west-facing upper slope of Gobregaun. Its runout debris has travelled for more than 300 m and can even reach a distance of 1000 m.

Figure 12: Rock fall affecting the trail above Gobregaun



The steep west slope of Kapurgaun suffers from rock falls, located at a distance of 60–70 m. Wide tension cracks are also observed at their crowns. Past rock fall-prone slopes were reactivated by the Gorkha earthquake. Due to the falls, the houses were relocated to a nearby safer place.

About 30 m long and 25 m wide rock fall – rockslide appears about 500 m south of Rannen, on the Dundure–Borang trail. Open-jointed and medium-banded schist has produced large (up to 2 m) boulders that have travelled for 300 m to the Ankhu Khola.

Many slides and falls cover both banks of the Lisne Khola, where the block size is up to 5 m. The debris has moved up to the Ankhu Khola. A large alluvial fan lies at the confluence of the Lisne and Ankhu Khola. The fan has damaged the powerhouse of a micro hydro-electric project. These landslides also affect a road as well as a suspended bridge.

About 50 m long, 30 m wide, and 3 m deep, colluvial soil slide is located approximately 40 m above the

Ankhu Khola, at the lower end of Chyamthali. A house lies very close to the right flank of the slide. In the crown, tension cracks record a vertical displacement of 5–7 cm and lateral shift of 10–50 cm. The runout from the slide has also reached the Ankhu Khola.

Near Kalmrang, in the road section, the runout from about 200 m long and 30–35 m wide rock fall – rockslides has reached the Ankhu Khola. The clast size is up to 1.5 m. Very foliated and jointed schist is exposed on the southwest-facing steep slope. Another scarp is developing about 15 m above the main scarp. A house lies on the right flank of the landslide, and the road between the two scarps is damaged.

From Kalmrang, positioned on the left bank of Ankhu Khola, a rockslide is observed on the opposite bank of the river, about 300 m above Richet. The village is generally north-facing and the constituent slope dips at an angle of about 40°, whereas the failed slope is steeper (about 60°). Tajumrang is located on the eastern slope and is about 100 m away from the

main landslide scarp. The landslide is 50–60 m long and 30–40 m wide. A large rock fall zone lies towards Tajumrang, above the Ankhu Khola (Figure 13).

About 60 m long and 30 m wide soil slide occurs at Singan. The size of clasts in the landslide reaches 1 m. The slide occupies the right bank of the Rangsel Khola and has damaged the cultivated land and a trail.

At Dharna, about 150 m long and 50 m wide, an old reactivated rock fall – rockslide contains large (up to 1.5 m) blocks and the debris has travelled for about 500 m to the river. A road passes through the middle of the slide. The landslide is saturated with water, as a stream is flowing through it (Figure 14).

From approximately 300 m above Dharna, several rock falls are bringing down boulders of up to 6 m in diameter. Another landslide is positioned roughly 200 m west of the road to Dharna. It is about 100 m long and 30–40 m wide. Since headward expansion of the slides continues, the settlement of Dharna is at a high risk of failure, as it is located at a distance of 60–70 m from the landslide head scarp. A greater part of the village is situated on an old landslide containing colluvial soil with large (up to 5–7 m in diameter) boulders.

Many soil slides are distributed along the Lapang Khola, nearly 50 m upstream from its confluence with the Ankhu Khola. In this area, the colluvial soil is 3 to 5 m thick and the landslide zone is 30 to 50 m long, 180 m wide, and its failed angle is about 70°. The slides affect the Lapang–Dundure road and adjoining forestland.

Near Lapang, the Lapang Khola has a gorge, where rockslides and falls occupy both banks. The threat led to the relocation of three houses. On the left bank, about 5 m long and 2 m wide plane rockslide is present, and the debris from it has reached the riverbed. Close to the riverbed, the lower river terrace is converted into a paddy field. A steep slope and highly jointed rocks are the main triggering factors of this landslide.

3.3 Rasuwa district

In the Rasuwa district, the Trishuli, Mailung Khola, and Bhote Koshi River valleys were severely affected by mass movements (Figure 15). On the left bank of

the Bhote Koshi River (Figure 16), near the Friendship Bridge, more than 300 m high and about 50 to 100 m wide rock fall destroyed many office and residential buildings. The fall killed about 30 people and also blocked the road to Rasuwa Gadhi for several months.

The office building site of the Rasuwa Gadhi Hydropower Project is located on the left bank of the Ghatte Khola and the Bhote Koshi River. It stretches along the foothill of a large rock cliff with talus cones (Figure 17). This area suffered from severe rockslides and rock falls, which significantly damaged the five buildings under construction. Many large boulders and debris came down from about 400 m high cliff. Much of the material also came down when a series of rainfall events hit the area. The boulders destroyed roofs, columns, and the ground floors of the buildings.

The earthen road leading to the two portals of valve chamber and access tunnel was severely affected by the earthquake and rainfall. The two portals are located within the rock fall zone from about 150 to 200 m above a rock cliff and gully (Figure 18).

The beautiful Langtang Valley, lying at an altitude of about 3400 m, is the third most popular trekking destination in Nepal. At Ghodatabela, at an altitude of about 3011 m, rock falls and slides are very common. The area lies in a high hazard zone (Figure 19). In the Lama Hotel area, the rock falls have also affected the main building, causing loss of both human life and property.

A mixture of snow, ice, and rock debris, which originated at the snowfield on the slopes above Langtang, fell into the Langtang River as an avalanche, and buried the village. The buried area occupies about 0.5 sq. km. The extent of damage incurred in this area can be surmised by examining the buried Langtang valley and the river channel. The wind blast during the avalanche ripped and uprooted trees and aligned them in the direction of the blow.

At Thulo Haku, a large landslide occurs in about 3 m deep residual soil where gully erosion is also intense in the cultivated land. The gully is approximately 2 km long, comes from the upper part of the village, and confluences with the Trishuli River. Many cracks

Figure 13: Some large rock falls and rockslides at Richet and Tajumrang. View to W



Figure 14: Dharna colluvial slide affecting Dundure–Dhading Bensi road



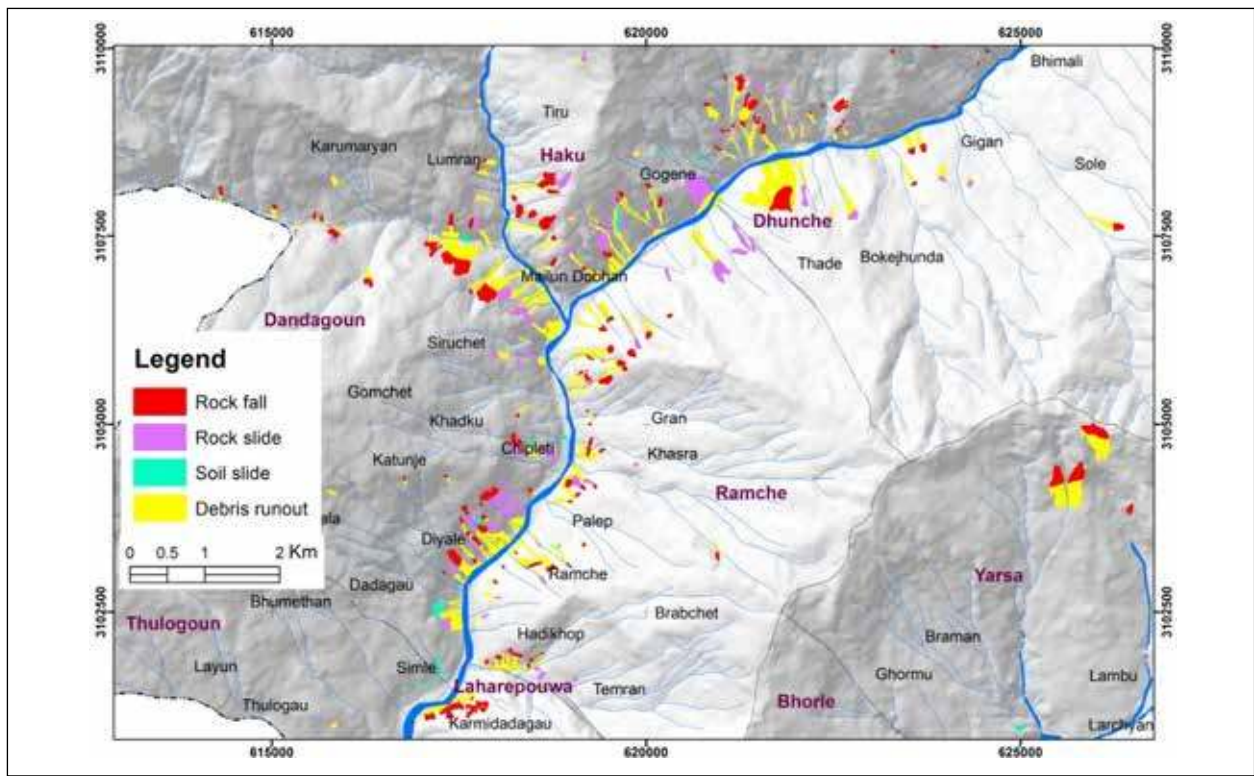


Figure 15: Mass moments in Trishuli Valley, near Dhunche and Haku of Rasuwa district



Figure 16: Massive rock fall near Friendship Bridge of Rasuwa Gadhi. View to NE

Figure 17: Buildings of Rasuwa Gadhi Hydropower Project damaged by rock fall. View to E



Figure 18: Rock fall near valve chamber and damaged road at Rasuwa Gadhi. View to SW



are present in the cultivated land in the vicinity of the gully, where erosion is intense. The actively moving, deep-seated, very large old slides at Grang, Mulkharka, and Ramche were not badly affected by the earthquake (Figure 20).

The Trishuli River valley below the Mailung Khola

confluence was devastated by rockslides, debris slides, and rock falls (Figure 21). At the weir of Trishuli 3A Hydroelectric Project, on the left bank, two debris cones, about 30 m wide and about 10 m high (upper) and about 15 m wide and 7 m high are positioned. The material comes down from about 100 to 150 m above



Figure 19: Rock fall at Ghodatabela in Langtang Valley



Figure 20: Actively moving deep-seated landslide at Ramche. View to N

the riverbed (Figure 22) causing rock fall mainly in the monsoon period.

The upper slope of the desander area contains large (1 to 5 m) angular gneiss boulders. Some are old and others were newly brought down by the earthquake. Mainly, wedge failures (with vertical joints) are prominent.

At Gairigaun, soil slides and gully erosion have destroyed cultivated land. Besides, rock falls are prominent on the banks of the Phalakhu Khola. These are at a distance from the settlements, but destroyed the

cultivated land situated in the vicinity of the crown. At Kaphali, a rockslide has damaged the cultivated land.

3.4 Sindhupalchok district

The Sindhupalchok district is the hotspot of old deep-seated as well as new coseismic landslides (Figures 4 and 47). The Arniko Highway suffers the most from deep-seated slides that have been active at least since the glacier lake outburst flood of 11 July 1981, from Tibet (Xu Daoming 1985). The cloudburst of 30 June

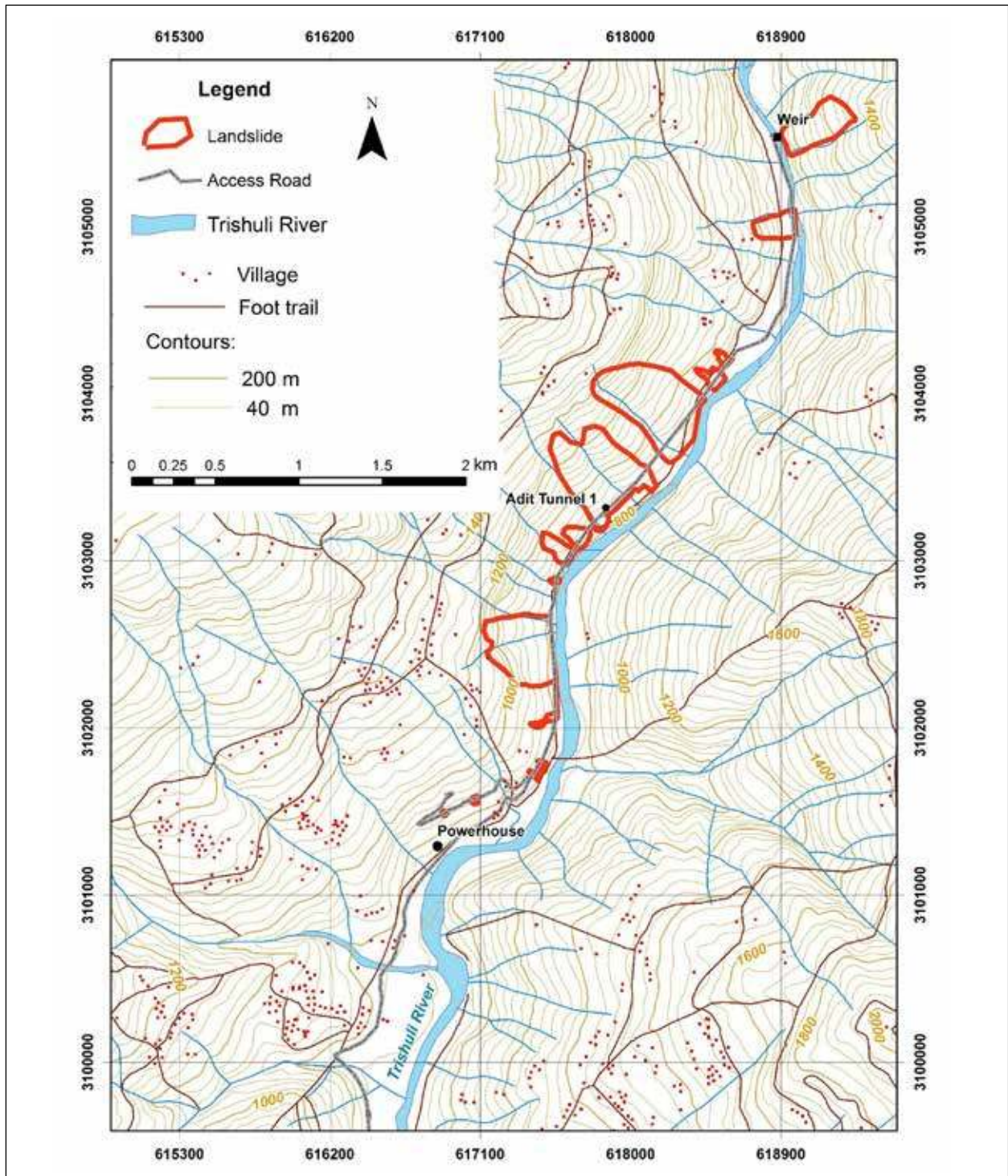


Figure 21: Earthquake-induced landslides on the earthen road through the right bank of the Trishuli River



Figure 22: About 150 m high rockslide–rock fall with a large talus cone on left bank of Trishuli River. View to E

1987 also devastated the Sun Koshi River valley. The prolonged monsoon rainfall of 2020 was responsible for the recent cycle of disasters in the district.

The Arniko Highway between Balephi and Liping follows the Bhote Koshi River valley (Figures 23 and 24). Between Lamosanghu and Khorang, debris slides or flows develop on the upper hillslope, whereas rockslides and falls are frequent on cliffs and steep slopes.

The highway between Khorang and Dandakateri has numerous rock falls, rockslides, and topples, especially on the right bank of the Bhote Koshi River (Figure 25), where the rock contains four prominent joint sets. At Dandakateri, rock topples, falls, and debris flows originate from rock quarries. Kinematic analysis of joints

reveals three prominent discontinuity sets and two of them are adversely orientated (Figure 26).

A large wedge slide (Figure 27) occurs on the Arniko Highway, about 2 km south of the Last Resort. The failed zone is about 30 m wide and 10 m high. Many boulders, soil, and tree branches block the highway. This failure was triggered by the heavy rain after the earthquake.

The vertical to sub-vertical joints in the cliff south of Chaku (Figure 28) are responsible for rock and debris falls. Kinematic analysis of discontinuities (Figure 29) shows that the rock between Sakhuwa and Chaku consists of more than four prominent joint sets. A partial landslide dam is observed to the south of Chaku (Figure 30).

The right bank of the Bhote Koshi River west of Chaku is made up of grey, massive, calcareous quartzite. Some shallow but long (more than 50 m) rockslides and rock falls with talus cones are seen upstream, in the Bhote Koshi River (Figure 31).

Rock fall severely affects Chaku and its surroundings. Most of the people have left their houses after the earthquake due to the continuously falling rock blocks from the high cliff above the village. Besides, the highway to the north of Chaku is also affected by rock falls and the bridge over the Chaku Khola is partly damaged by falling rock blocks. The highway and the village are both at a high risk of rock fall. Here, mainly four prominent joint sets form wedges and rock topples (Figure 32).

Various mass movements are found on a few hundred-meter-high rock cliff (monocline) between the Upper Bhote Koshi powerhouse and Khokundol (Figure 33). The Khokundol Khola is following the strike of bedrock. Its left bank has suffered from many dip-slope failures and wedge slides that have transferred to rock falls at the road level. These earthquake-triggered slides originated from the upper edge of the slope and destroyed the penstock pipe and powerhouse of the hydropower project (Figure 34).

On the left bank of the Khokundol Khola, a large plane failure is observed on calcareous quartzite. The rock also contains thick beds of grey dolomite,

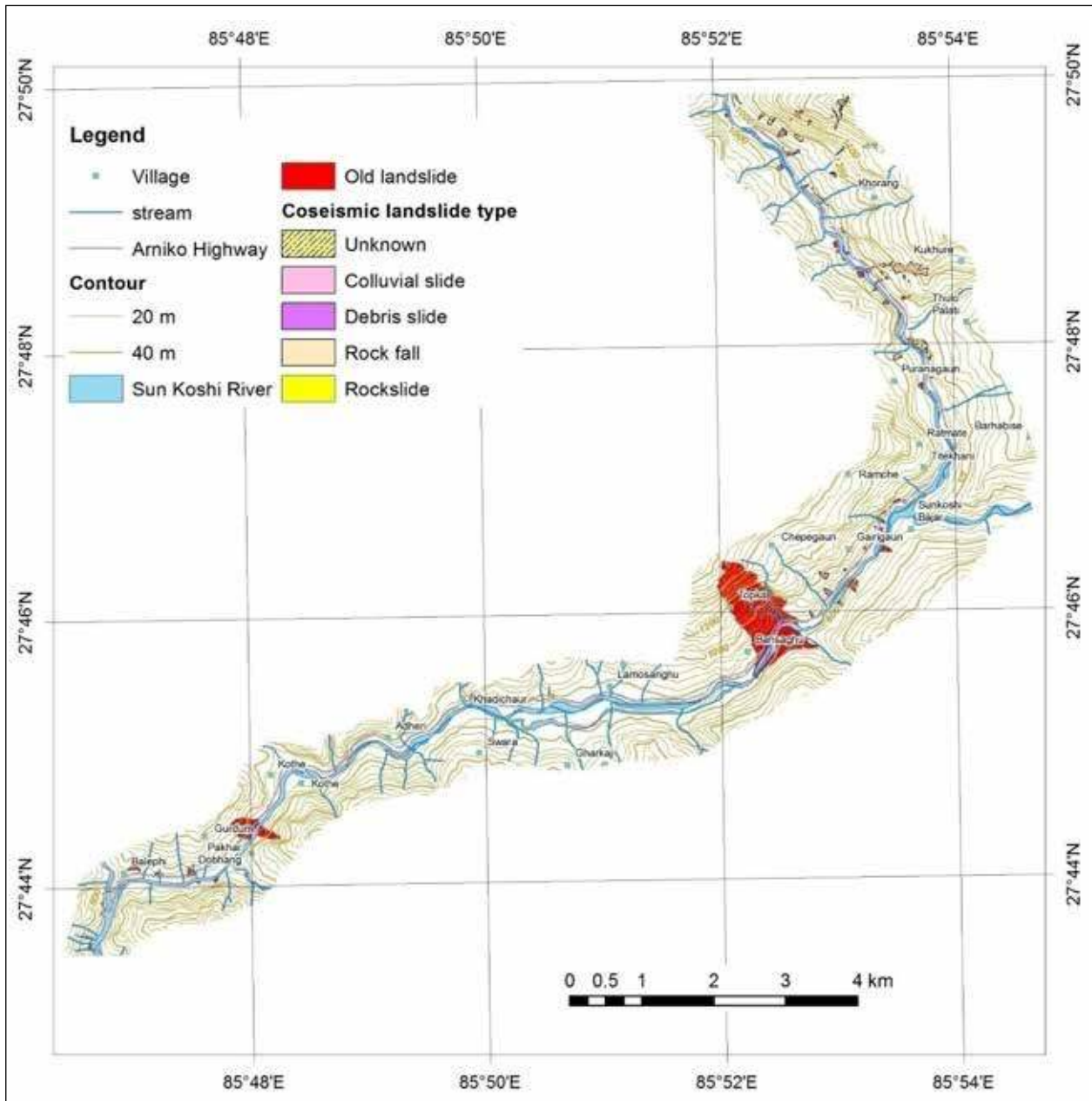


Figure 23: Landslides on the stretch of Arniko Highway between Balephi and Sakuwa

crystalline limestone, graphitic schist, and garnet schist.

On the right bank of the Bhote Koshi River, above the dam of the Upper Bhote Koshi Hydropower Project, a large alluvial fan is formed from a distant rockslide

on the dip slope. It is an old fan (formed before 1987), which has reactivated owing to rock sliding on the upper slopes of the mountain, from where the boulders of schist and quartzite are moving into a gully. The slide has made a large fan encroaching upon the reservoir.

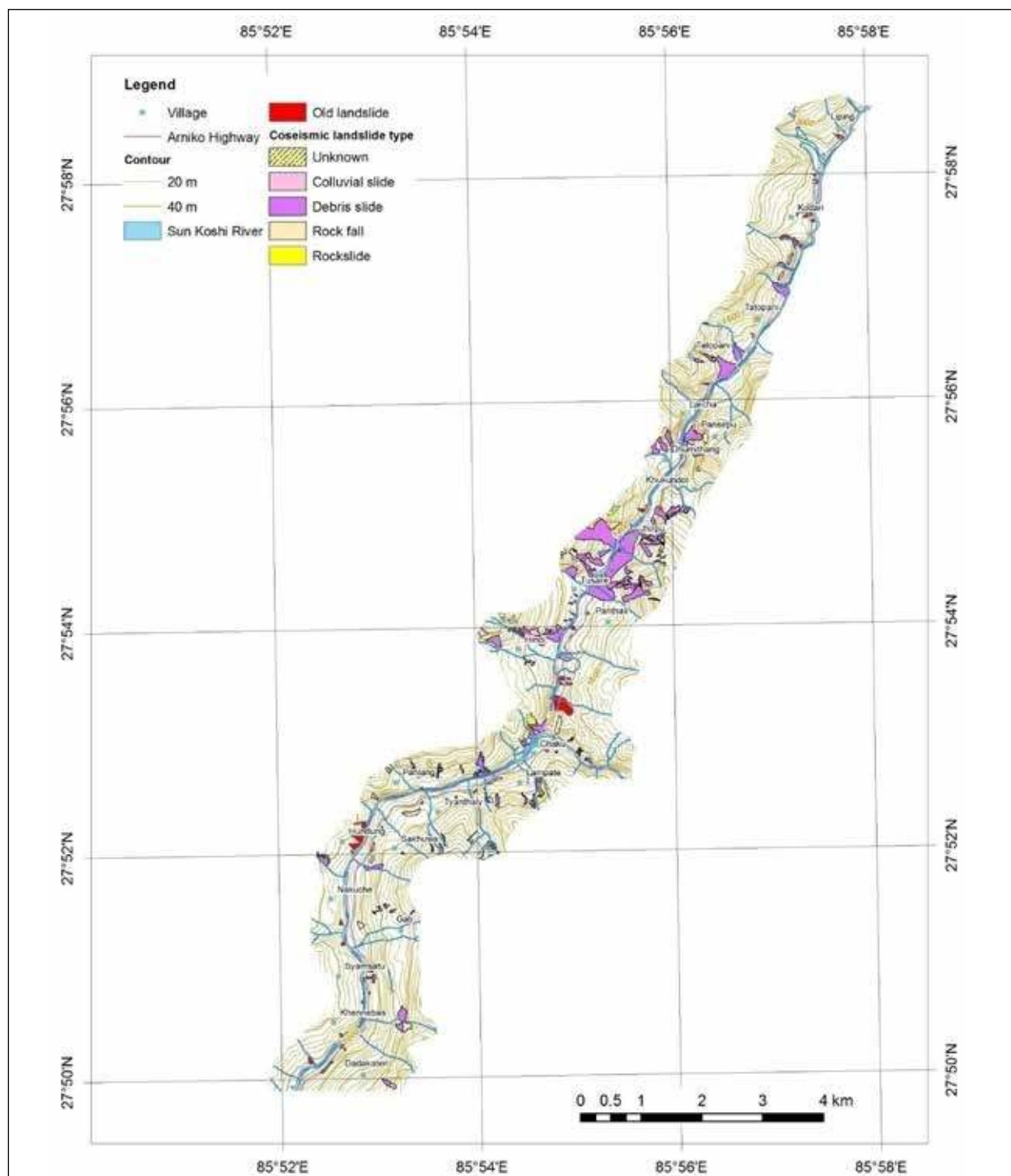


Figure 24: Landslides on the stretch of Arniko Highway between Sakhuwa and Liping

Figure 25: Many shallow rockslides and rock falls triggered by earthquake in Bhoté Koshi watershed, north of Dandakateri. View to N

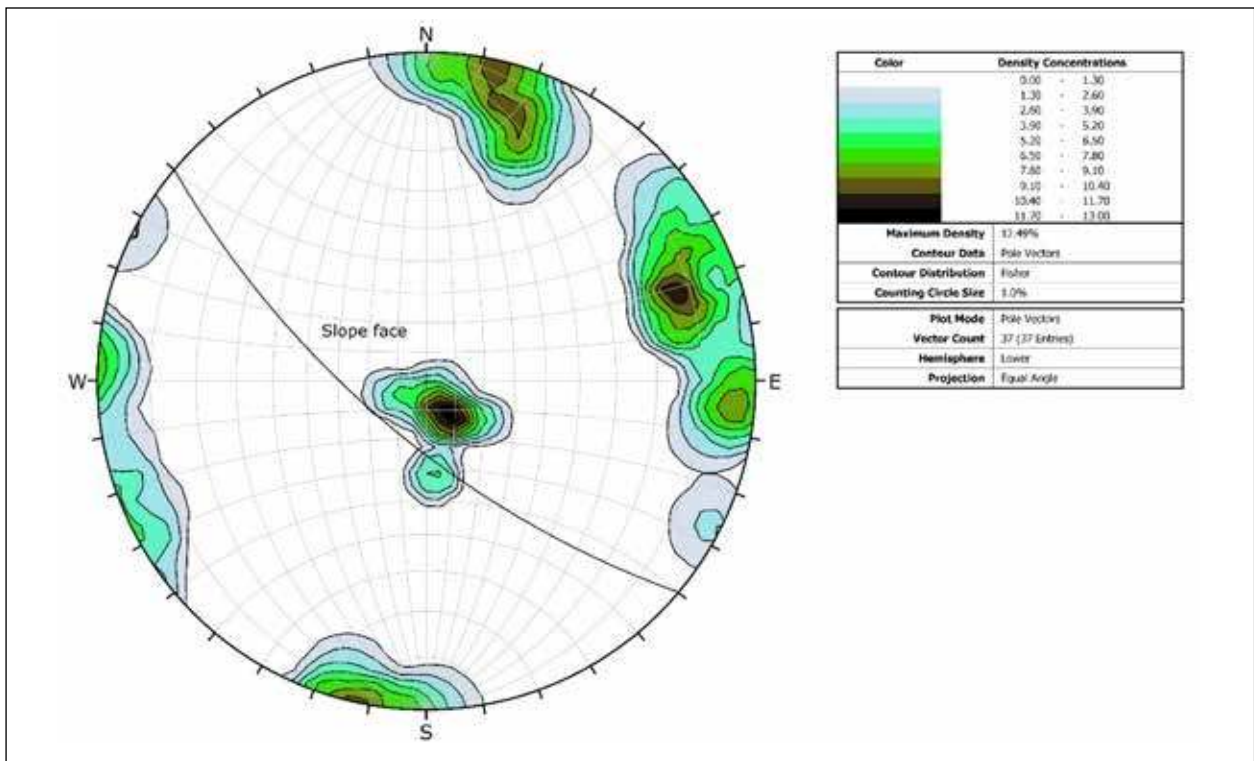


Figure 26: Stereographic projection of joints and slope face indicating potential for rock toppling at Dandakateri



Figure 27: Wedge rockslide with large boulders, blocking Arniko Highway. It was triggered by first heavy monsoon rain after earthquake. View to NW



Figure 28: Unstable rock cliff with vertical joints near Chaku, where rock falls destroyed a vehicle. View to N

There have been many past incidents of debris flow from the gully and it has been reactivated by the earthquake and subsequent rainfall.

Rock falls have affected Larcha, where big rock blocks (about 6 m³) are observed along the highway (Figure 35). Such rock fall events are more prominent around Larcha, Tatopani, and Liping as the 12 May aftershock had hit this area. In addition, steep rock slopes are formed mainly on hard rock such as quartzite, augen gneiss, and garnetiferous schist with two major joint sets making them susceptible to rock fall. The area around Larcha has three major discontinuity sets responsible for plane rock failure, wedge failure, and topple (Figure 36).

Rock falls most severely hit the settlement of Liping (Figures 37 and 38) with unprecedented loss of life and property. The gneiss boulders rolled down through old alluvial deposits and open-jointed augen and banded gneisses. The size of boulders sometimes exceeds 10 m.

3.5 Dolakha district

In the Dolakha district, many plane rockslides, wedge slides, debris slides, debris falls, and rock falls are observed in the Tama Koshi watershed, between Charikot and Lamabagar. Most of them are shallow slides, such as those observed near Sundrawati.

A large debris slide at Km 10+500 m of the Upper Tama Koshi Road (Figure 39) was not disturbed by the quake. It is an old reactivated debris slide, where about 50 m long road stretch had subsided by more than 5 m and laterally shifted by about 12 m in the monsoon of 2012.

Singati was devastated by numerous shallow rock falls and debris falls (Figure 40). A shallow but relatively wide wedge slides and rock falls are seen on the left bank of the Tama Koshi River, south of the Tinkhu Khola confluence. It is an old slide reactivated by the earthquake and subsequent monsoon rain. On the left bank of the Tama Koshi, upstream from the Gongar Khola, a large rockslide–rock fall with a wide talus deposit is observed. It is an old slide reactivated by the earthquake.

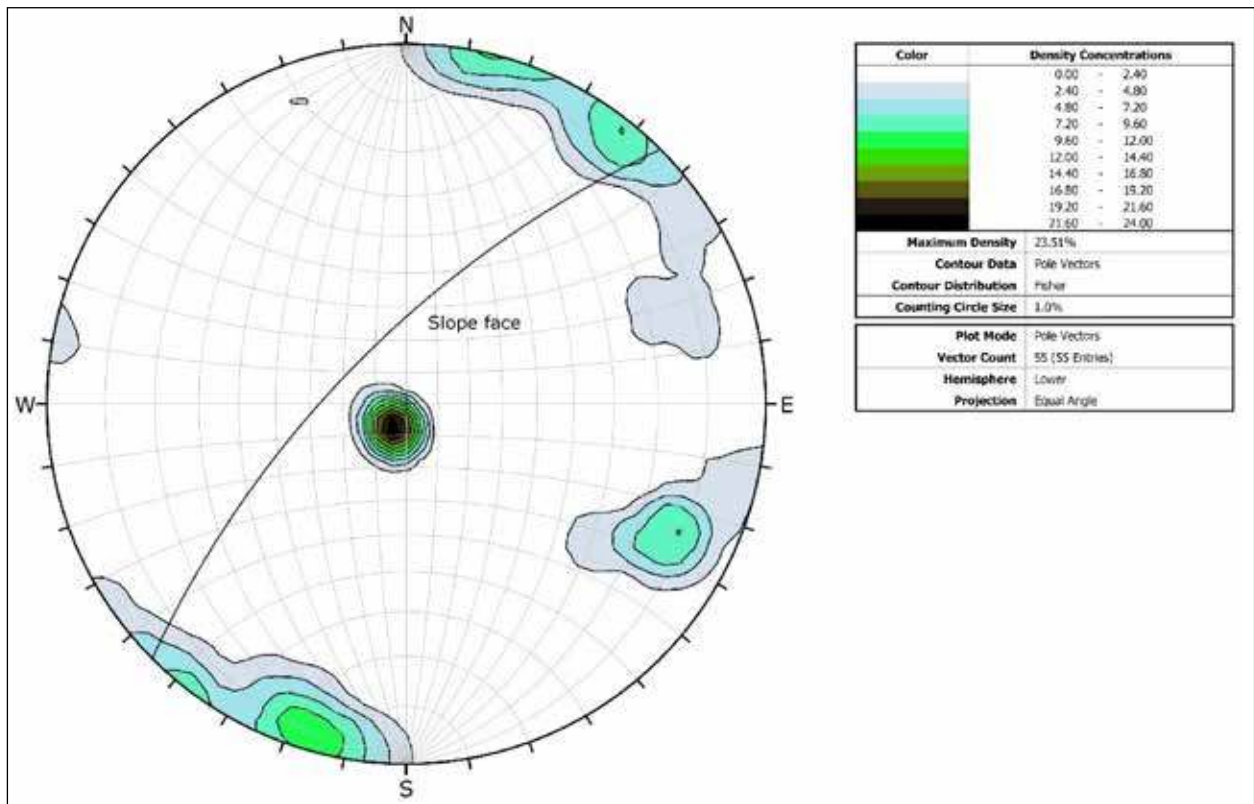


Figure 29: Potential for wedge slide and rock topple around Syamsatu indicated by stereographic projection of joints and slope face

Figure 30: Partially dammed Bhoté Koshi River by a coseismic landslide on its right bank near Chaku. View to SW





Figure 31: Shallow rockslides, rock falls, and talus cones opposite Chaku in Bhote Koshi River. View to NW

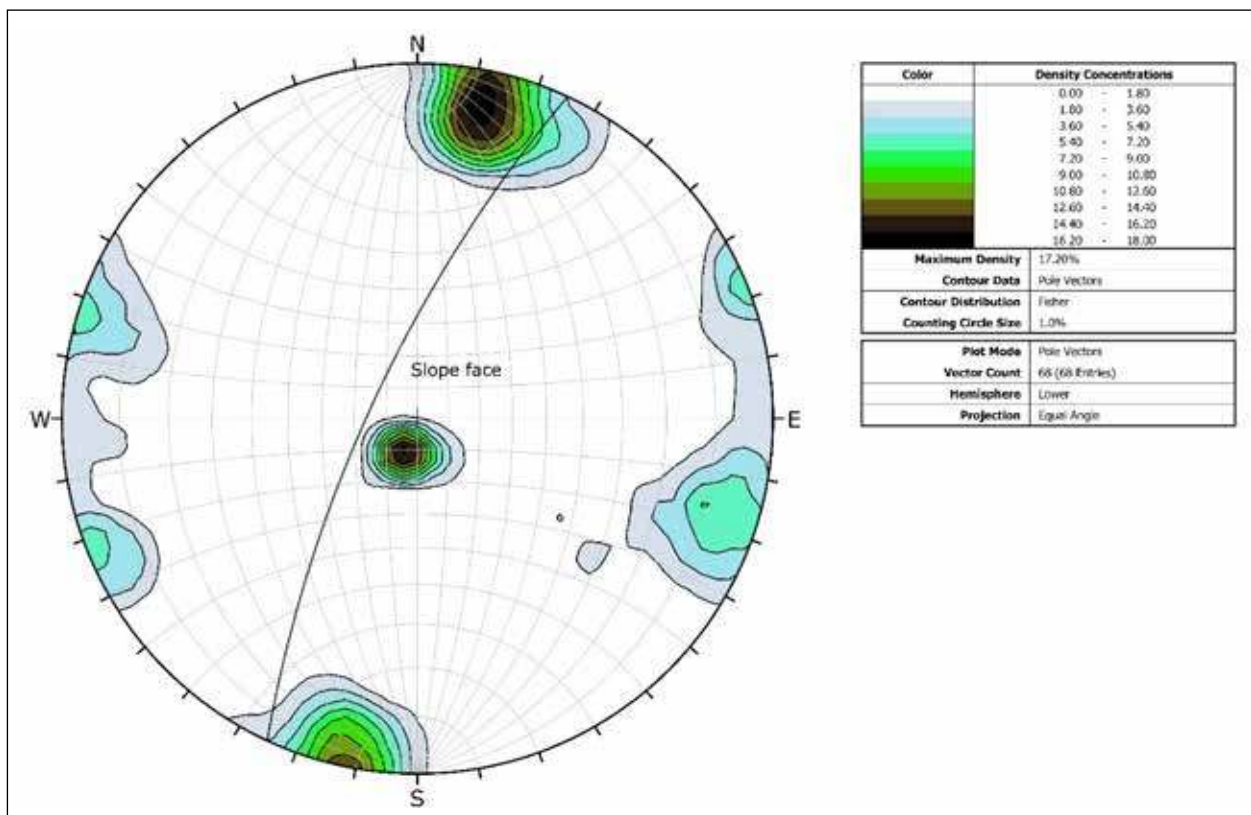


Figure 32: Stereographic projection of joints and slope face indicating wedge failure and rock toppling around Chaku

Figure 33: Coseismic mass movements developed on rock cliff adjacent to Upper Bhote Koshi Powerhouse. Three joint sets are prominent. Rock falls damaged powerhouse and penstock pipe. View to ESE



Figure 34: Damaged penstock pipe of Upper Bhote Koshi powerhouse. View to W

4. Discussion

Many investigators have studied the coseismic failures caused by the Gorkha earthquake and the number varies from about 5000 to 25000 (Kargel et al. 2015, Collins and Jibson 2015, Roback et al. 2017). This paper has discussed some fundamental characteristics of coseismic landslides in comparison with the old slides, and those triggered by the monsoon rain.

4.1 Landslide distribution and triggers

Since the seismicity of 2015 Gorkha earthquake was confined almost linearly to the midlands and high hills (Figure 3), coseismic landslides were concentrated in this narrow zone (Figure 4). In terms of geological structures (Figures 1 and 2), this area consists of the Great Mahabharat Synform, Great Midland Antiform, and MCT. As a result, the rocks are highly fractured and jointed, forming enormous detached blocks on hillslopes. In conjunction with the features, steep topography, high relative relief, heavy precipitation, erosive rivers, and retreating glaciers are collectively



Figure 35: Failed rock blocks at Larcha, damaging settlement and road. View to S

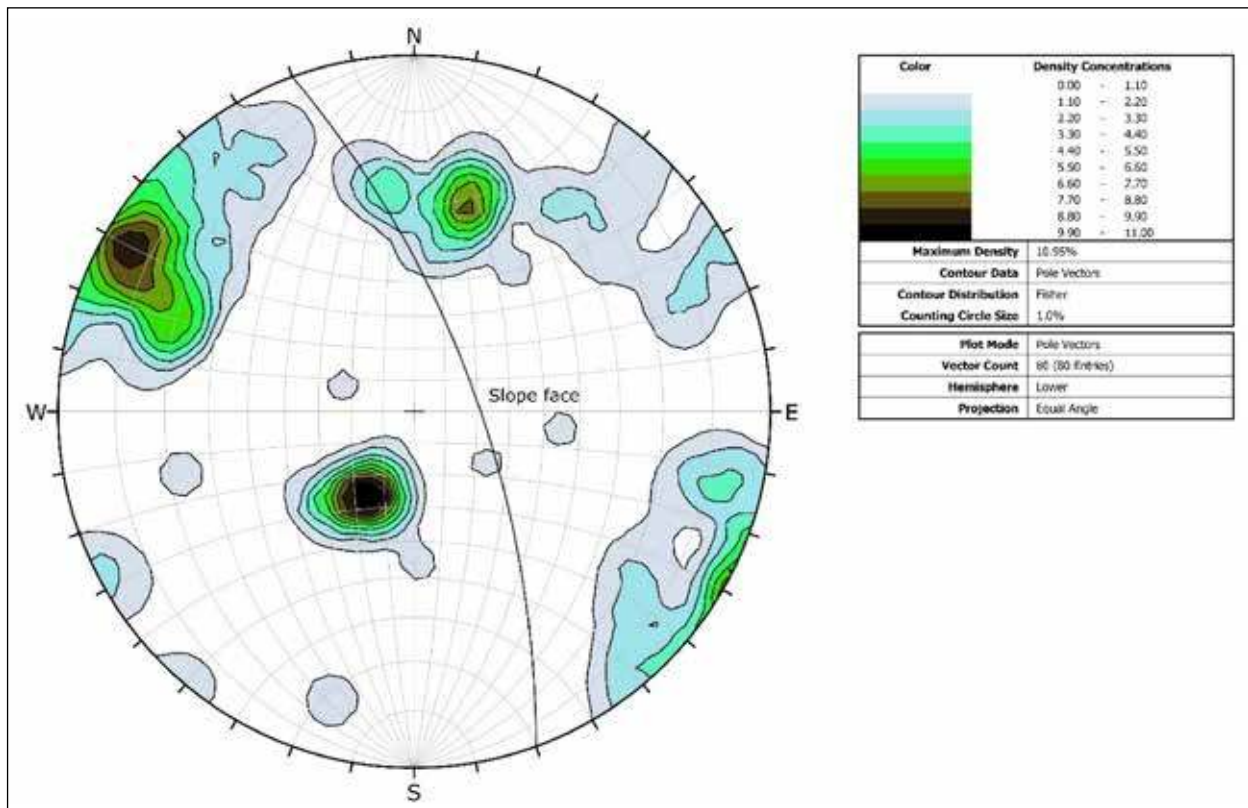


Figure 36: Stereographic projection of joints and slope face indicating possibility of toppling, wedge failure, and plane failure at Larcha



Figure 37: Many large boulders and debris flow splash on buildings of Liping. View to E



Figure 38: Liping devastated by large boulder falls. Khasa (Jhangjhangmu) in China is seen in the background. View to N

Figure 40: Rock and debris falls from south-facing slope of Singati. View to N



Figure 39: Soil slide at Km 10+500 of Upper Tama Koshi Road. View to W

responsible for making the country landslide-prone. Some anthropogenic factors, such as lack of land use planning and unscientific road construction practices, are also contributing to the instability. Consequently, this zone may again suffer from a future high-magnitude earthquake whose hypocenter is expected on the MHT. Further, hydrologically-triggered landslides may also occur annually, depending upon the intensity of the rainfall.

4.2 Landslide characteristics

A comparison of pre-earthquake landslides with the coseismic ones indicates that there was a significant increase in their number and area (Figure 41). The landslide aspect of coseismic slips was mainly due south, consistent with the seismic slip direction (Figure 42). The coseismic landslides were shallow (mean: about 5 m), ranging from rockslides to rock falls, colluvial slides, and alluvial slides. The runout debris from coseismic mass movements contributes to about half of the landslide area (Figure 43). The hillslope angle significantly controlled the distribution of various landslide types (Figure 44). The majority of rock falls occur on steep (about 50°) slopes, rockslides are distributed on less steep (about 45°) slopes, and the colluvial slides are positioned on gentler (about 40°) slopes. Rockslides and rock falls were the two most common failure modes. The rock falls range in size from about 250 m³ to 340000

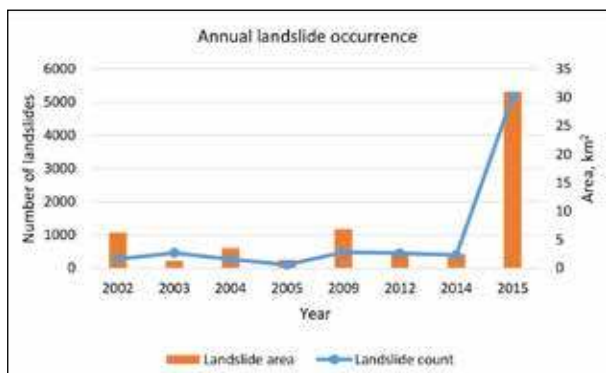


Figure 41: Frequency of annual landslide occurrence in five most affected districts. Note significant increase in landslide occurrence due to Gorkha earthquake.

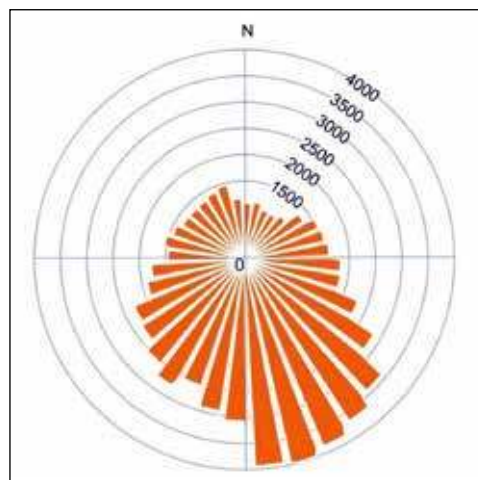


Figure 42: Rose diagram of 20 m x 20 m coseismic landslide pixels showing their aspect. Note predominating southwards movement, consistent with seismic slip direction of Gorkha earthquake.

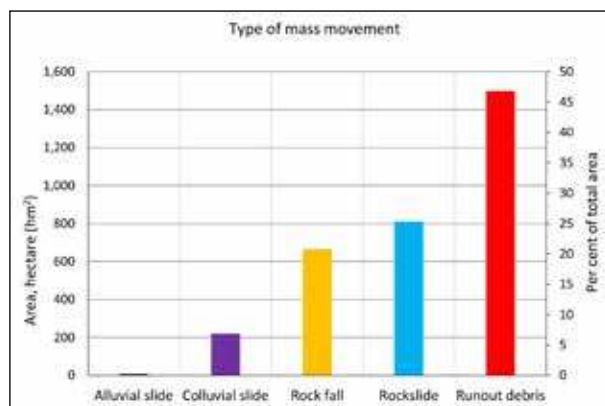


Figure 43: Classification of coseismic mass movements. Almost half of total affected area is occupied by runout debris.

m³ (Figure 45) and the length-to-width ratio of most rockslides ranges from about 1 to 3 (Figure 46).

4.3 Newmark displacements

The relationship between shaking and coseismic failures was investigated in the most severely-affected region of Bhote Koshi watershed in the Sindhupalchok district (Figure 47). The distribution of landslides is strongly controlled by their position in the landscape, where many of them originate from a high crest

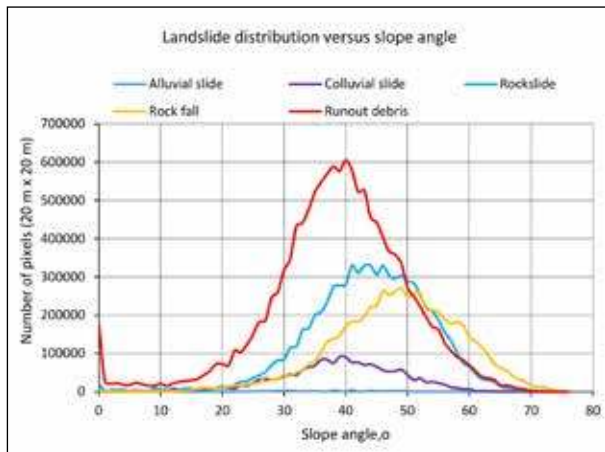


Figure 44: Distribution of coseismic landslide types with respect to slope angle in five most affected districts. Rock falls occur on steepest slope (about 50°) and colluvial slides develop on gentler slope (about 40°).

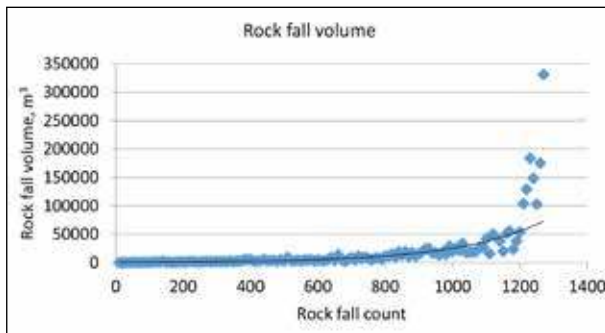


Figure 45: Size of coseismic rock fall in five most affected districts. An extremely large value of about 340000 m³ is also present.

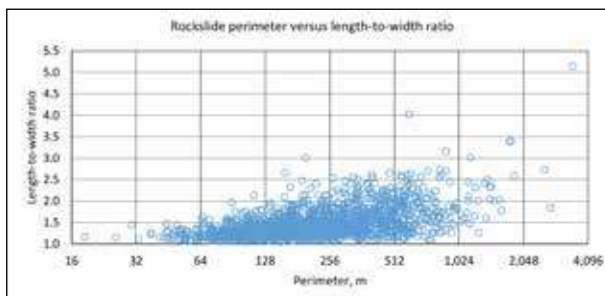


Figure 46: Relationship between rockslide perimeter and elongation. Coseismic rockslides vary in elongation from about 1 to 3.

or peak. A comparison of Newmark displacements (Newmark 1965, Jibson 1993) with landslide distribution shows that the slides are not positioned in the area with a maximum displacement, but the slopes with high internal relief suffered the most from the seismically-triggered failures. In contrast, old and large landslides confined to river valleys (see below), were insensitive to earthquake shaking. Ground vibrations were significantly higher towards mountain tops and along crests than those at their respective bases due to topographic effects and ridge amplification (Hashash et al. 2015). Therefore, apart from Newmark displacements, secondary effects can also play a decisive role in triggering shallow falls and slides.

4.4 Landslides before Gorkha earthquake

It is quite natural for the decision-makers to turn their attention to the coseismic landslides. But several parts of the study area have been severely affected by hydrological disasters since many decades. Some cases from the Sindhupalchok district are described below.

4.4.1 Landslides along Arniko Highway

An old landslide zone north of Balephi lies on the right bank of the Sun Koshi River. The material has been slowly creeping at least since 1987. Near the Pakhar Khola confluence, the road and surrounding area about 50 m above the riverbed has been subsiding. Generally, the pavement is undulating and many tension cracks are seen on the road, parallel to the slope. The Kothelandslide (Figure 48) is made up of multiple slips reaching a depth of 75 m. The landslide generally moves a few centimeters a day in the monsoon period but is stable during the dry season.

An old and shallow landslide on alluvial slope is observed about 1 km north of Bahrabise Bazar, at Khursani Bari. The loose pebbles, cobbles, and boulders composing the slope are easily detached, and form talus cones or roll down as boulder falls. The unstable zone is about 100 m wide and 50 m high.

A deep-seated rotational slide occurs on the Arniko

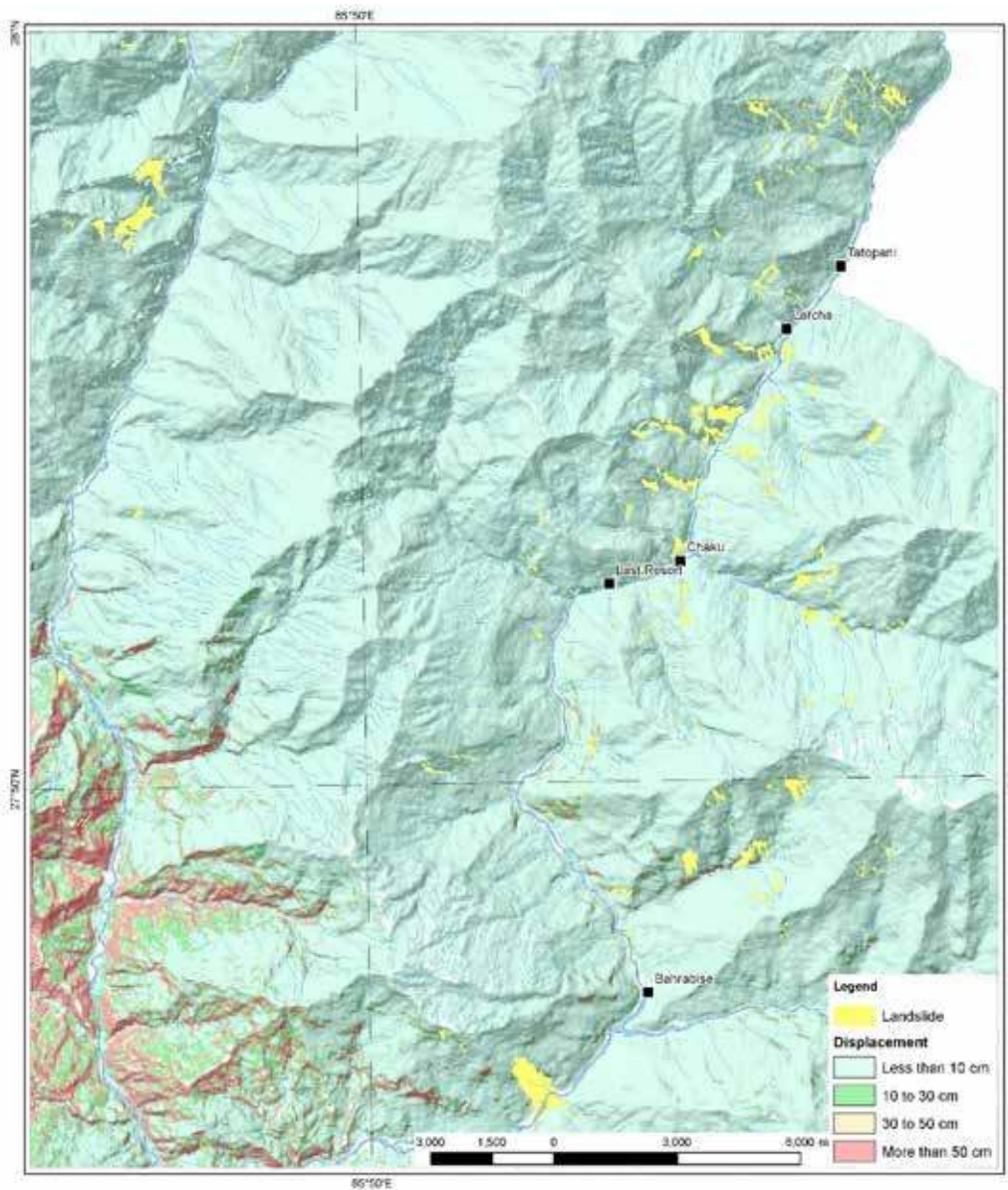


Figure 47: Newmark displacements in Sindhupalchok district due to 2015 Gorkha earthquake

Highway north of Khursani Bari, where the road has been realigned at least for three times since 1981. The landslide has destroyed about 200 m road and damaged many retaining walls. The failure is about 75 m long, 150–200 m wide, and more than 20 m deep.

About 800 m road length at Daklan has been gradually sinking at least since 1981. The unstable ground can be divided into the southern debris slide and flow

zone and northern zone of about 300 m wide, 150 m long, and more than 50 m deep rotational slide (Figure 49). The whole slope seems to be a huge rock collapse. On the right bank of the Bhote Koshi, another major landslide has occurred. These two, deep old slides have almost blocked the Bhote Koshi River.

A large stream at Km 112, about 500 m south of Kodari, has many slides and debris flows since

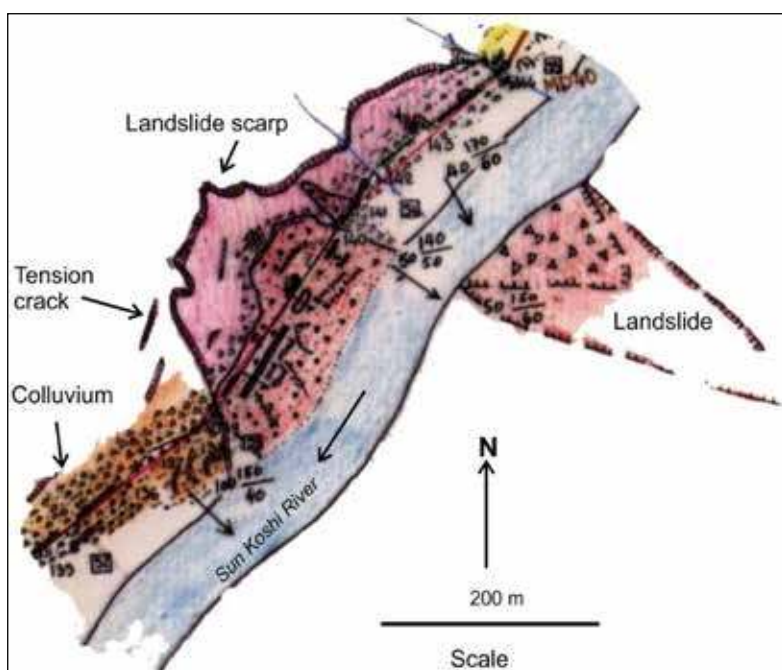


Figure 48: A large, deep-seated old landslide of Kothe. Note the slides occur on both banks and there is a possibility of landslide damming. Source: Modified from ITECO (1989)

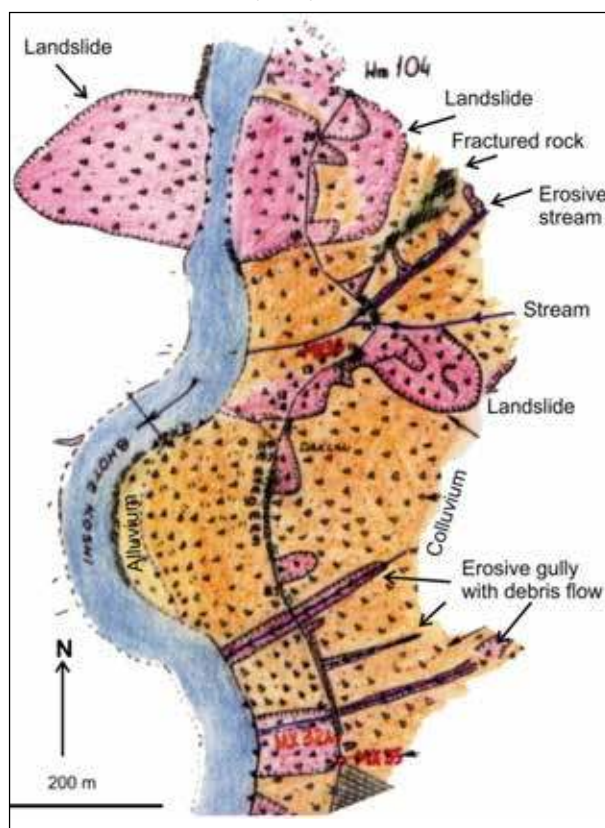
Figure 49: Large, deep failure of Daklan, where river is constricted by two twin slides on both banks. Source: Modified from ITECO (1989)

1981 (Figure 50). The debris flows have damaged about 100 m of road width, especially its south-facing slope on the left bank. The colluvial slopes around Kodari (Figure 50) have been actively undercut by the Bhote Koshi River and the deep-seated slides have damaged about 400 m wide road stretch.

The landslides and rock falls around Liping occur (Figure 51) after the 1981 glacier lake outburst flood destroyed the earlier Friendship Bridge over the Bhote Koshi River at Kodari. The new Friendship Bridge at Liping was partly damaged by subsequent rock falls.

4.4.2 Jure rock avalanche

The Jure rock avalanche (Figure 52) occurred on 2 August 2014, on the right bank of Bhote Koshi River and destroyed about 1 km of the Arniko Highway. The disaster started about 800 m above the riverbed, from where huge rock masses travelling at a speed of about 60–70 km/sec crashed on the Arniko Highway. The avalanche is about 1500 m long, more than 500 m wide, and about 25 m deep. It created a landslide dammed lake (about 30 m deep, 450 m wide, and 3



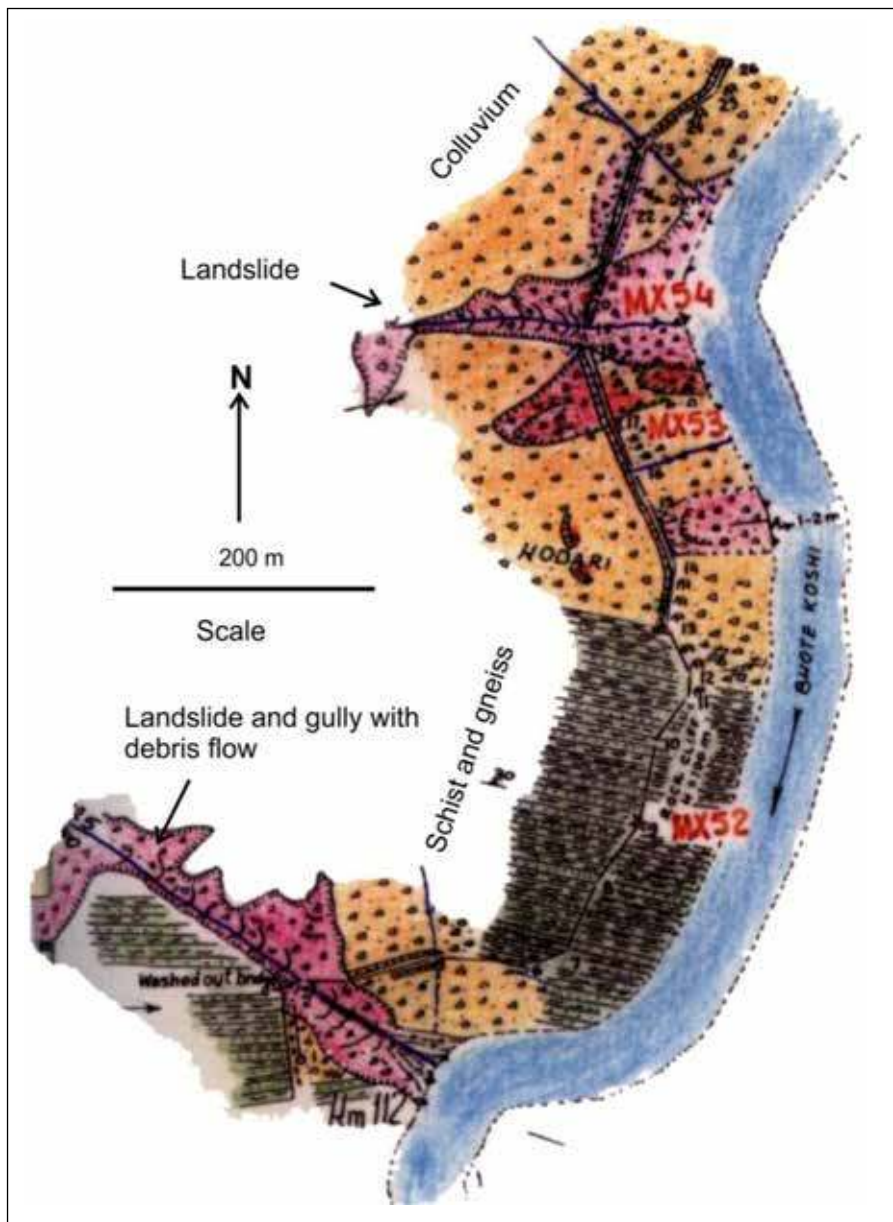


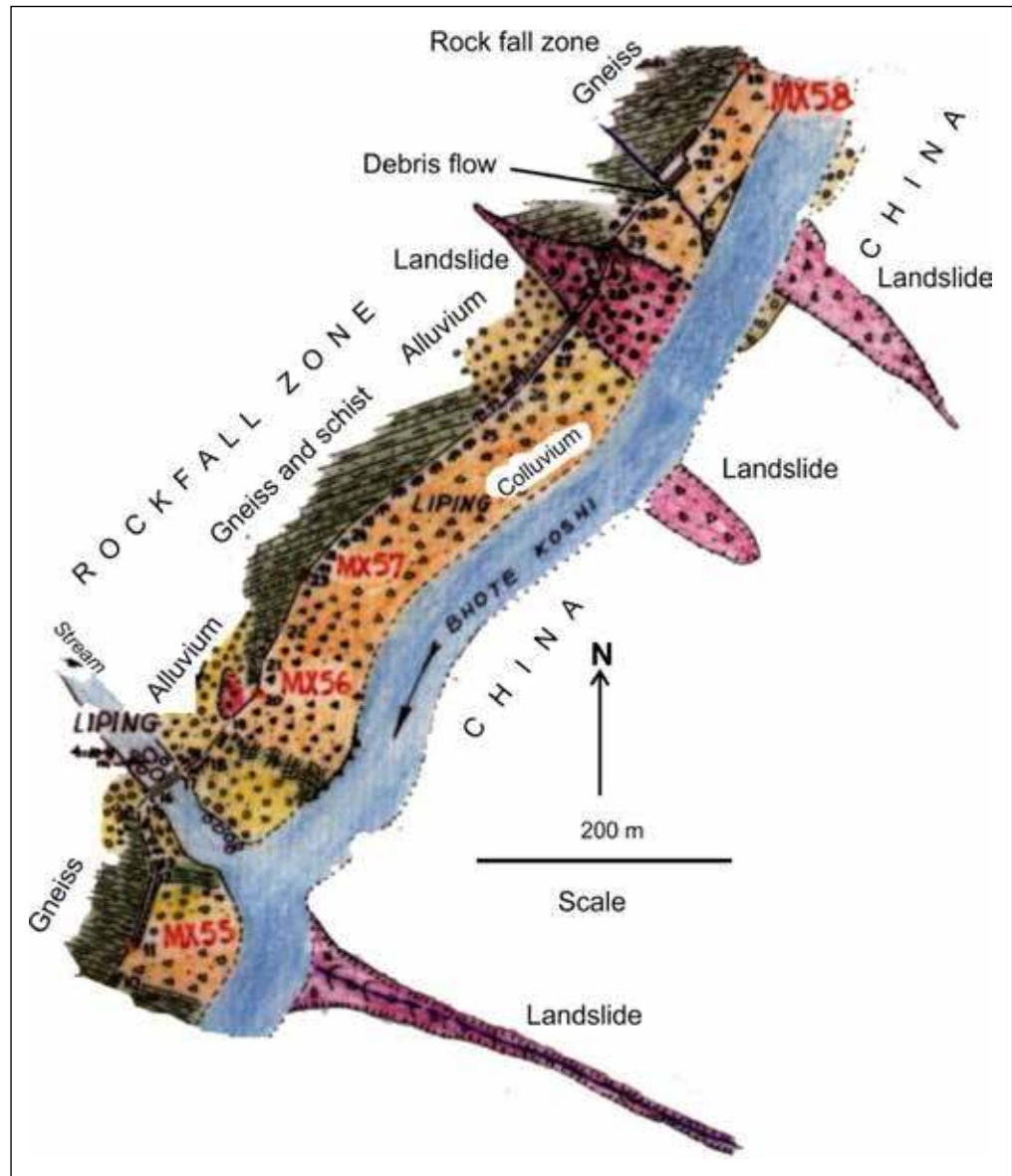
Figure 50: Debris flow and many deep failures at Kodari. Source: Modified from ITECO (1989)

km long), killed 156 people and injured 27. Forty-two houses were also destroyed. The highway remained submerged in the lake for more than two months until the dam was breached.

The slope at Jure had been deteriorating since 1987 when shallow rockslides developed and propagated

upwards. The instabilities accelerated in the subsequent five years. The source rock contains three joint sets and two of them are steep (about 80°) and mutually perpendicular. The orientation of joints indicates a possibility of rock toppling leading to the avalanche (Figure 53).

Figure 51: Lipping affected by rock and boulder falls. Source: Modified from ITECO (1989)



4.5 Landslides after Gorkha earthquake

As stated earlier, the government's priority has been to manage the coseismic landslides of 2015. But the year 2020 indicated that the hydrologically induced landslides can become even more disastrous – a point that decision-makers had not been giving due

consideration. A case of the Sindhupalchok district is discussed below to illustrate such disasters.

The rainfall in 2020 began in winter and continued up through mid-September (Figure 54). The mean daily cumulative precipitation was about 10 percent higher than that of the normal. But, in some districts, such as Sindhupalchok, there were incidents of extreme



Figure 52: Jure rock avalanche on Arniko Highway. View to N

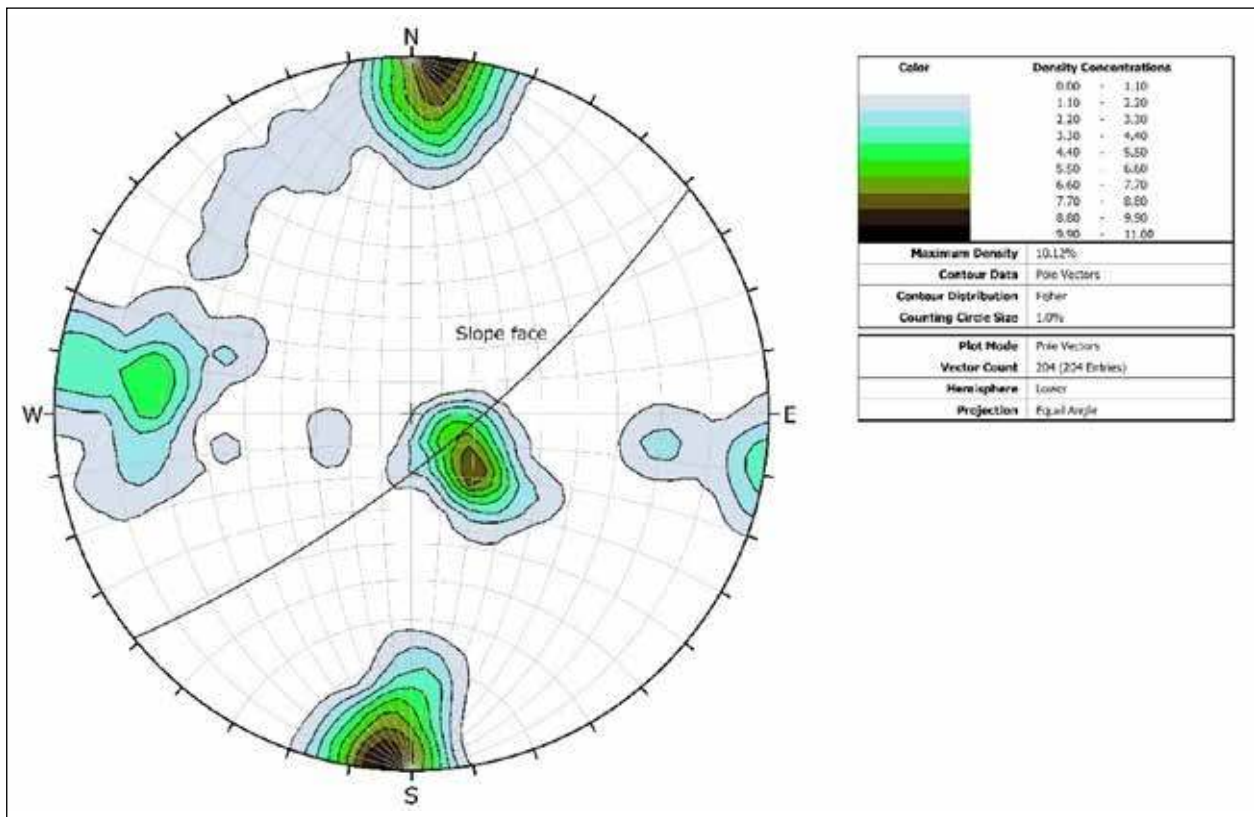


Figure 53: Stereographic projection of joints from rock avalanche area, indicating toppling failure Landslides after Gorkha earthquake

precipitation between July and September. As a result, the debris flows at Jambu killed 23 people on 8 July, a landslide at Melamchi killed 9 people on 2 August, and the landslide at Lidhi killed 39 people on 15 August. Apart from these, a large number of other landslides and debris flows caused severe loss of property and agricultural land. Most of them were new mass movements that belonged neither to the reactivation of coseismic landslips nor to the movement of any dormant failures.

5. Conclusion

The 2015 Gorkha earthquake demonstrated that the young and tectonically active Himalayan range is vulnerable to mass movements. There were already a large number of active landslides in central Nepal, the Gorkha earthquake further exacerbated the ground conditions. The pre-earthquake landslides were positioned mainly on foothills and stream banks, whereas the coseismic ones developed on upper and middle steep slopes and crests, mainly on those facing south. The runout from coseismic slips and subsequent debris flows extended far beyond their places of origin. Most of the old slides were deep-seated (more than 10 m), but the coseismic rock falls and rockslides were shallow (less than 5 m). Most of the rainfall-induced landslides that occurred in 2020 were not the reactivation of coseismic landslips, which indicated that landslide-prone geomorphic features differ with triggering agents.

The Himalayan range is seismically active and large earthquakes are expected. But they are difficult to predict in space and time. Further, the high-intensity rainfall affects some part of the country during every monsoon season and adversely impacts on the mountain slopes. Hence, infrastructural development in such regions remains a formidable task. Therefore, we need to learn to live with landslides following the principles of geoscience.

Acknowledgement

This research was supported by the UNDP, ICIMOD, and Tribhuvan University. The co-operation provided by the National Reconstruction Authority is highly appreciated.

References

- [1] Avouac, J.P. et al., 2015. Lower edge of locked Main Himalayan thrust unzipped by the 2015 Gorkha earthquake. *Nat Geosci.* 8:708-711.
- [2] Bilham, R., 2019. Himalayan earthquakes: a review of historical seismicity and early 21st century slip potential, in: Treloar, P.J. & Searle, M.P. (Eds.) *Himalayan Tectonics: A Modern Synthesis*. Geological Society, London, Special Publications, 483. <https://doi.org/10.1144/SP483.16>.
- [3] Collins, B.D. and Jibson, R.W., 2015. Assessment of Existing and Potential Landslide Hazards Resulting from the April 25, 2015 Gorkha, Nepal Earthquake Sequence. USGS Open-File Report 2015-1142, Version 1.1, August 2015. <https://doi.org/10.3133/ofr20151142>
- [4] Dhital, M.R. and Adhikari, B.R., 2020. Thrust Sheets, Tectonic Windows, and Intermontane Basins in the Nepal Himalaya, in: T. K. Biswal et al. (Eds.), *Structural Geometry of Mobile Belts of the Indian Subcontinent*. Society of Earth Scientists Series, Springer Nature Switzerland AG, 233-254. https://doi.org/10.1007/978-3-030-40593-9_11.
- [5] Dhital, M.R., 2015. *Geology of the Nepal Himalaya. Regional Perspective of the Classic Collided Orogen*. Springer, Switzerland, p. 498.
- [6] Elliott, J.R. et al., 2016. Himalayan megathrust geometry and relation to topography revealed by the Gorkha earthquake. *Nature Geoscience*. 9 (2), 174-180. ISSN 1752-0894.
- [7] Hashash, Y.M. et al., 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

- [8] ITECO, 1989. Arniko Highway rehabilitation programme, Nepal. Inventory report, volume 3, Annex 1, Geological survey. Affoltern, Bern, Switzerland, unpublished report, p. 81.
- [9] Jibson, R.W., 1993. Predicting earthquake-induced landslide displacements using Newmark's sliding block analysis. *Transportation Research Record*. 1411, 9–17.
- [10] Kargel et al., 2015. Geomorphic and geologic controls of geohazards induced by Nepal's 2015 Gorkha earthquake. *Science*. doi: 10.1126/science.aac8353
- [11] Keefer, D.K., 1984. Landslides Caused by Earthquakes. *Geological Society of America Bulletin* 95, pp. 406–421.
- [12] Liu, C. et al., 2016. Rupture processes of the 2015 Mw 7.9 Gorkha earthquake and its Mw 7.3 aftershock and their implications on the seismic risk. *Tectonophysics*. <http://dx.doi.org/10.1016/j.tecto.2016.05.034>.
- [13] Molnar, P. and Tapponnier, P., 1975. Cenozoic tectonics of Asia: effects of a continental collision. *Science*, vol. 189, pp. 419–426.
- [14] Newmark, N.M., 1965. Effects of earthquakes on dams and embankments, *Geotechnique*, vol. 15, no. 2, pp. 139–160.
- [15] Rajaure, S. et al., 2016. Characterizing the Kathmandu Valley sediment response through strong motion recordings of the 2015 Gorkha earthquake sequence, *Tectonophysics*. <http://dx.doi.org/10.1016/j.tecto.2016.09.030>
- [16] Roback, K., et al., 2017. The size, distribution, and mobility of landslides caused by the 2015 Mw7.8 Gorkha earthquake, Nepal. *Geomorphology*. <http://dx.doi.org/10.1016/j.geomorph.2017.01.030>
- [17] Seeber, L. and Armbruster, J.G., 1981. Great detachment earthquakes along the Himalayan arc and long-term forecasting. *Earthquake prediction – an International review Maurice Ewing Series 4*. American Geophysical Union, pp. 259–277.
- [18] Stöcklin, J. and Bhattarai, K.D., 1977. *Geology of Kathmandu Area and Central Mahabharat Range, Nepal Himalaya*. HMG/UNDP mineral exploration project, technical report, p. 86. (with 15 maps), unpublished
- [19] USGS, 2015. http://earthquake.usgs.gov/earthquakes/eventpage/us20002926#general_summary
- [20] Varnes, D.J., 1978. Slope movement types and processes, in: Schuster R.L., Krizek R.J. (Eds.) *Landslides, Analysis and Control*, Special Report 176: Transportation Research Board. National Academy of Sciences, Washington, DC, pp. 11–33
- [21] Xu Daoming, 1985. Characteristics of debris flows caused by outbursts of glacial lake in Boqu River in Xizang, China, 1981. *Lanzhou Inst. Glaciol. Cryopedology, Acad. Sinica*, 24 pp.



Structural Features of the Kasthamandap, and its Post-earthquake Reconstruction

Prem Nath Maskey^a, Minesh Ratna Tamrakar^b, Bipin Kumar Gautam^c

Keywords: *L-shaped brick quoins; timber joint system; modal analysis; tensile stress; timber post.*

Abstract

Kasthamandap, the monumental pavilion in the heart of old Kathmandu dating back to the 7th century, collapsed during the 2015 Gorkha, Nepal earthquake. The main objective of this study was to investigate the seismic vulnerability of the structure and its sub-structure, and to determine the strengthening measures for withstanding future earthquakes. The study consisted of numerical modeling of the unreinforced brick masonry with timber structures, and determination of seismic capacity of the structure. The other parts of the research included the testing of the sub soil, investigation for the adequacy of the existing foundation and testing of other materials. The results indicated that the Kasthamandap pavilion had a robust structural system. The four brick quoins located at the four corners along the second layer of the plan were the main lateral load resisting elements in the structure. These unreinforced brick masonry quoins were subject to high compressive and tensile stresses due to lateral loads during an earthquake. In order to make the brick quoins resist the induced tensile stresses during major earthquakes, it is recommended to embed a number of vertical and horizontal timber posts inside the wall at the strategic locations.

1. Introduction

Kasthamandap, the monumental pavilion built in the 7th century, collapsed during the 2015 Gorkha, Nepal earthquake. Seven people were killed when the monument was destroyed. Kasthamandap is located at Maru Tole, ward no. 20 of Kathmandu Metropolitan City. A file photograph of Kasthamandap before 2015 Gorkha earthquake is presented in Figure 1.

The main objective of this study was to identify

the structural and seismic features of the original Kasthamandap pavilion to determine the seismic capacity of the original system and to provide recommendations for the restoration of the structure. The investigation for the adequacy of the existing foundation system and the identification of necessary repairs and maintenance measures, are other parts of the study. A detailed analysis was carried out for the purpose of restoration of the Kasthamandap using the original structural system, materials, technology and

^a Institute of Engineering, Tribhuvan University, Kathmandu, Nepal

^b Resilient Structures Private Limited, Kathmandu, Nepal



Figure 1: File photograph of Kasthamandap (Manfred, 2011)

construction details. Additional structural elements have been proposed and corresponding details have been recommended for making the structure resilient.

1.1 History

The history of the Kasthamandap dates back to 7th century as per the archaeological investigation carried out by Durham University (Coningham, Acharya, & Davis, 2015). The earliest reference to the Kasthamandap is found in the manuscript *Nama sangiti* dating back to 11th century. Another manuscript, *Paramartha Namasangiti*, (12th century) also referred to the Kasthamadap (Thapa, 1968). The Kasthamandap is the largest and the oldest *mandap* (pavilion) inside Kathmandu Valley. The Kasthamandap is also known as Maru Sattal, a name that was popularized in the 16th century (Korn, 1996). Legend has it that the Kasthamandap was built out of timber from a single

tree and the leftover from the same tree was used to build Sikhamu Bahil and Sinha Sattal (Korn, 1996) in the vicinity.

1.2 Structural system

The Kasthamandap was a three-storied structure constructed on a square plinth base of 18.73 meters (m) X 18.73m. All the three stories have spaces for large open halls, set on top of one another. The total height of the structure above the plinth level was 16.3m. The first measured drawing of the Kasthamandap was prepared by Wolfgang Korn (Korn, 1996). The plan, elevation and section of the Kasthamandap, extracted from the book are presented in figures 2 and 3. There are massive, 800mm thick L-shaped brick masonry quoins at each of the four corners of the ground floor along the second layer of the plan, which extends to the first floor. The first layer (or core) of the ground floor is formed by

four massive wooden posts. On these massive posts, another set of four smaller wooden posts existed on the first floor. On the second floor, a square with 24 posts, formed the structure (Korn, 1996). Additionally, there were four pavilions at the four corners of the structure. These pavilions could have been added later. The drawings showed that the fourth layer of timber columns in plan were of size 130 mm X 130 mm. The second layer and third layer of timber columns were of size 220 mm X 220 mm. The first layer columns were of larger size, of 370 mm X 370 mm (refer Figure 2).

A typical traditional joinery detail is presented in Figure 4. The typical detail shows a dressed natural stone (*Ilohan*) or a wooden threshold (*Lakansin*), supporting the wooden post (*Than*). The wooden bracket (*Meth*) transferred the load from the lintel (*Nina*) and the beams (*Dhalin*) to the posts. A long peg (*Sa*),

extending from the post, passed through the bracket into the beam and held the three structural elements in position (Korn, 1996).

2. Methodology

Structural analysis was carried out to understand the structural behavior and its performance in large earthquakes. The structural model was developed using the original details of the Kasthamandap.

2.1 Numerical modeling

Structural analysis was carried out using the finite element-based software SAP 2000 Version 20.1.0. Full three-dimensional finite element model was prepared for the purpose of structural analysis. All the elements

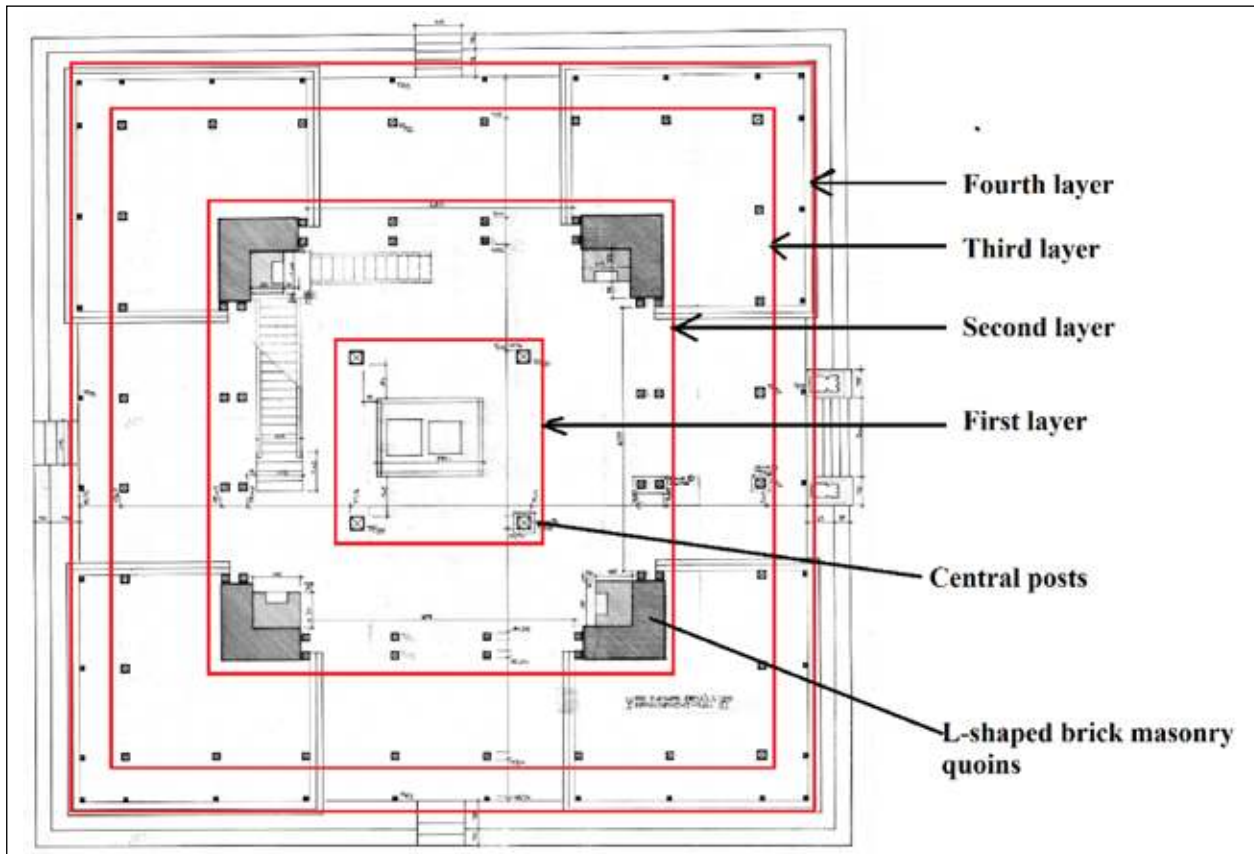


Figure 2: Ground floor plan of Kasthamandap with nomenclature (Korn, 1996)

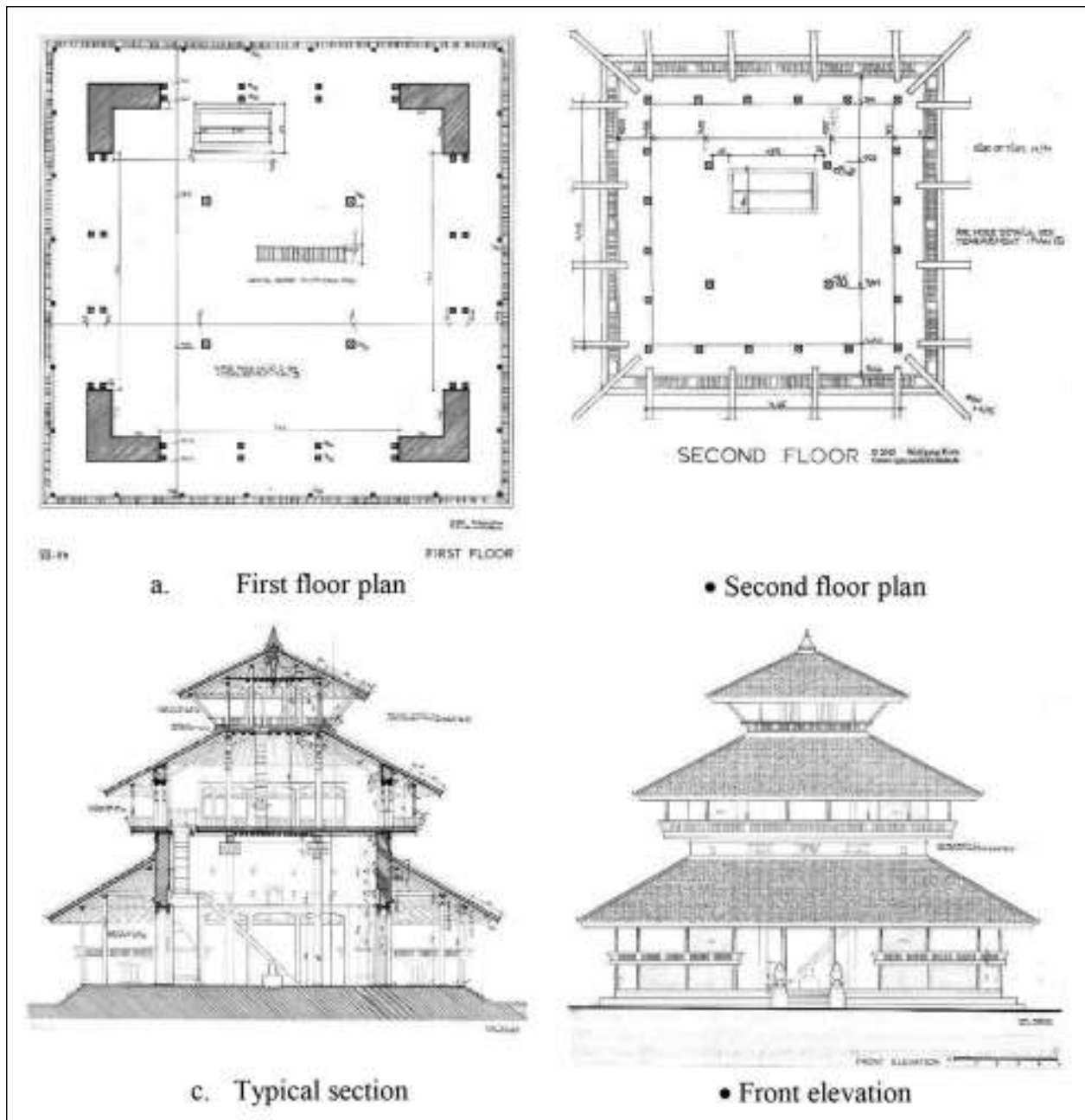


Figure 3: Typical drawings of Kasthamandap (Korn, 1996)

except the four pavilions at the four corners of the Kasthamandap have been considered in the structural model. Four-noded shell elements were used for modelling the masonry, timber floor and timber roofs.

Frame elements were adopted to model the timber posts and timber beams. Masonry walls were modelled using macro-modelling approach. In macro-modelling, the masonry is considered a homogenous material. For

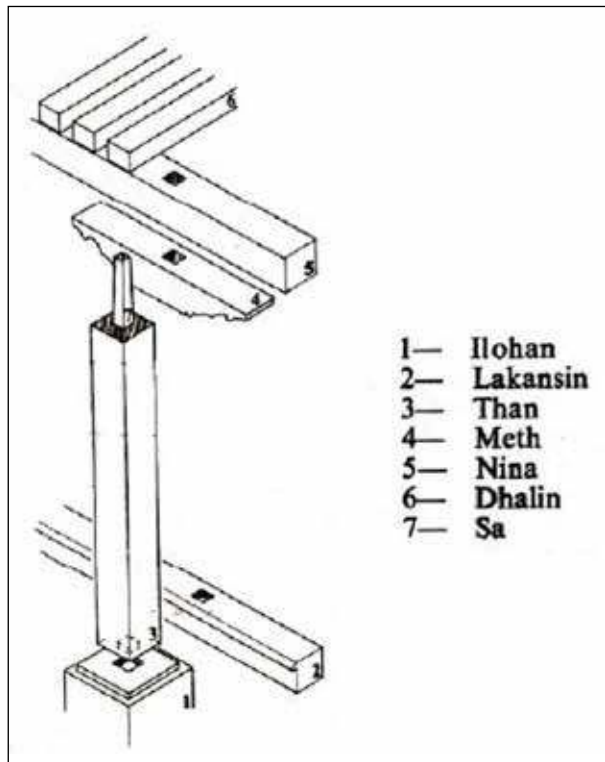


Figure 4: Traditional timber joinery (Korn, 1996)

obtaining the global behavior of the masonry structure, this approach was the most feasible and logical choice (Asteris, 2014).

The plinth level of the structure was considered the superstructure-substructure interface. Therefore, the superstructure was modelled above the plinth. Structural supports were applied in the structure at the plinth. A simpler support system without consideration of soil/foundation stiffness was used. Pinned support was used for both masonry wall and timber frame elements. To model the pinned behavior of the timber posts, torsion, and bending moments in both axes were released at the top and bottom ends of the post. The three-dimensional model of the structure is shown in Figure 5.

2.2 Material properties

The materials used in the buildings were primarily burnt clay bricks (*Ma apa*), mud mortar and timber beams/ joists. Compressive strength of mud mortar was assessed by taking it to be low strength mortar, and determining the value as per IS 1905 (IS 1905, 1987).

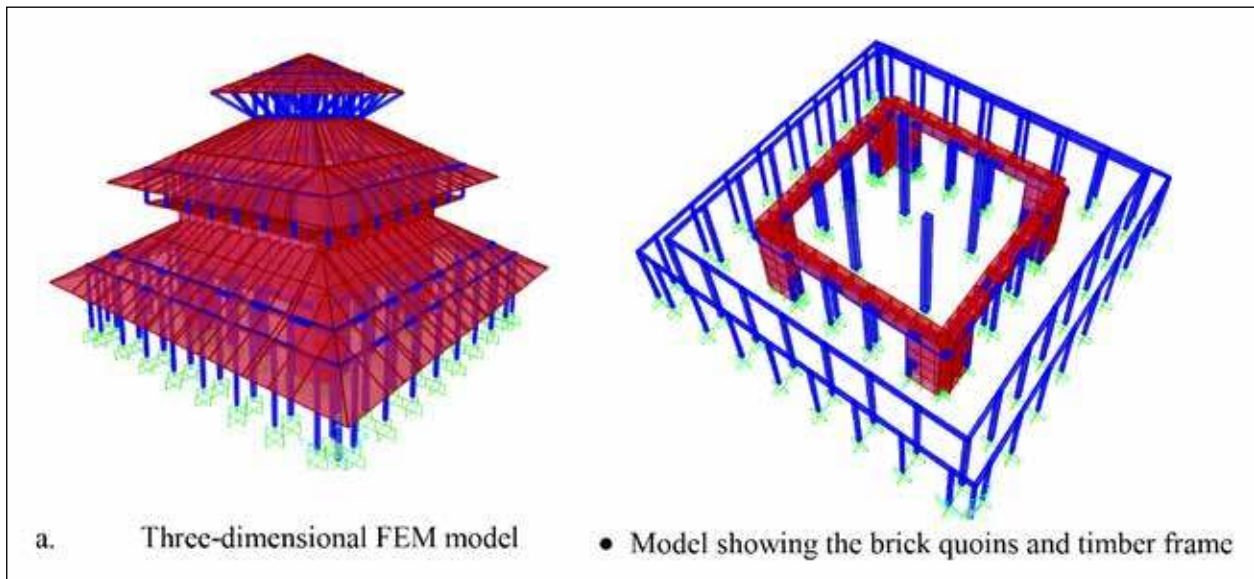


Figure 5: Finite element model of the Kasthamandap

Masonry compressive strength of the unreinforced masonry was determined using the empirical relation suggested by Eurocode 6 (2005) and Kaushik, Rai, & Jain (2007). The empirical expression relating the brick unit, mortar and masonry compressive strengths were as shown in the following equation:

$$f'_m = K f'_b f'_j \dots \dots \dots (1)$$

Where:

f'_m = characteristic compressive strength of masonry, in N/mm²

K = constant

α, β = constants

f'_b = mean compressive strength of the units, in N/mm²

f'_j = compressive strength of the mortar, in N/mm²

The Modulus of Elasticity (E_m) was determined using the empirical relation suggested by (FEMA 306, 1998), which is as follows:

$$E_m = 550 f'_m \dots \dots \dots (2)$$

Timber properties for Sal wood was as suggested by NBC 112 (1994). The properties of masonry and timber used in the numerical model are given in Table 1.

2.3 Loading

Calculation of dead loads due to self-weight of walls and superimposition was based on type of materials as per part I, IS 875 (IS 875, 1987). Calculation of live loads induced in the buildings was based on functional use of floors as per part II, IS 875 (IS 875, 1987). The earthquake load was calculated as per NBC 105

(NBC 105, 1994). As per clause 8.1.7 and Table 8.1, an important factor of 1 was chosen for the structure. Seismic Zoning factor of 1 was chosen as per Clause 8.1.6 and figure 8.2. Structural performance factor of 3 was adopted. The sub soil of the site has been assumed to be of category Type III (Soft soil sites).

2.4 Analysis

Linear static analysis using seismic coefficient method as per clause 10.1.1 of NBC 105 (NBC 105, 1994) was carried out.

3. Results

3.1 Modal analysis

Modal analysis was carried out in order to understand the dynamic behavior of the structure. A summary of the modal analysis is presented in Table 2. Mode shapes of mode 1, 2 and 3 are shown in figure 6.

3.2 Drifts and displacements

Table 3 shows the drift induced in the structure due to earthquake loading.

3.3 In-plane stress in L-shaped brick masonry quoins

The compressive stress due to gravity load of 0.15 MPa only. The tensile and compressive stress due to earthquake loading was 1.16 MPa and 1.35 MPa as shown in figure 7.

Table 1: Material properties used in numerical model

Type	Density (kN/m ³)	Permissible Compressive Strength (N/mm ²)	Permissible Tensile Strength (N/mm ²)	Permissible Shear Strength (N/mm ²)	E (N/mm ²)	V (Poisson's ratio)
Masonry	19	-0.35	0	-	745	0.2
Timber	8.65	-9.2	13.7	0.9	12500	0.3

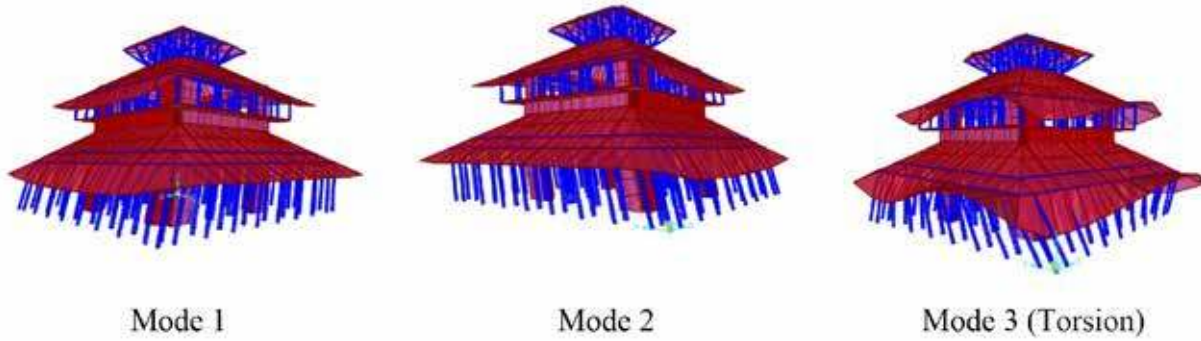
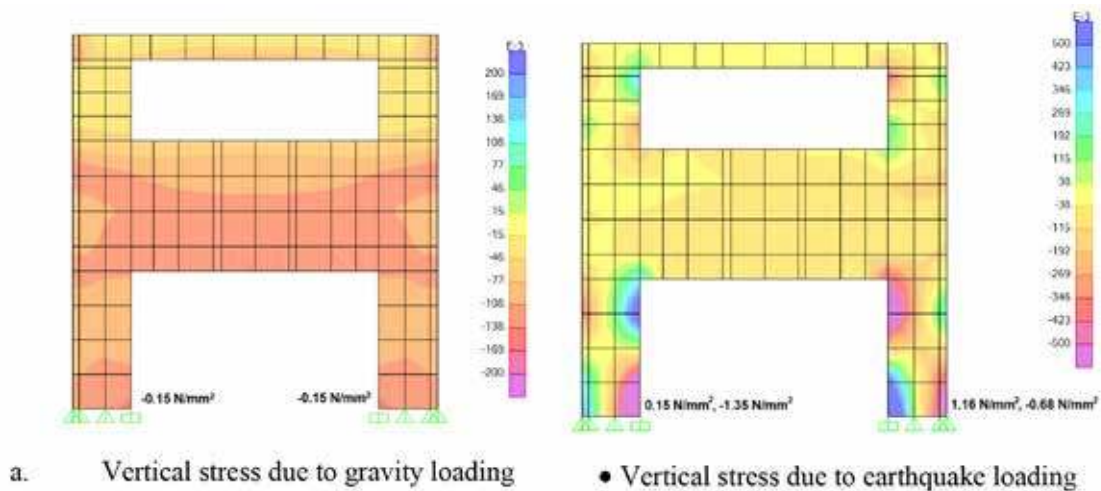
Table 2: Modal Analysis results

Modes	Period (Secs)	UX	UY	ΣUX	ΣUY
1st Mode X-direction	0.543697	0.9451	0.0007	0.94507	0.00066
1st Mode Y-direction	0.543692	0.0007	0.9451	0.94573	0.94578
Torsional Mode	0.461403	1E-09	5E-13	0.94573	0.94578
2nd Mode X-direction	0.417272	3E-05	1E-08	0.94576	0.94578
2nd Mode Y-direction	0.413736	0.0047	2E-06	0.95042	0.94579

Note: Here U_x and U_y denote modal participation along X-direction and Y-direction, respectively.

Table 3 Drift induced in the structure due to earthquake loading

Floor	Displacement (mm)	Floor height (mm)	Drift
Second	29.4	3600	0.0019
First	22.59	4900	0.0009
Ground	17.95	7600	0.0024

*Figure 6: Mode shapes of the Kasthamandap**Figure 7: Vertical stresses due to gravity and earthquake loading*

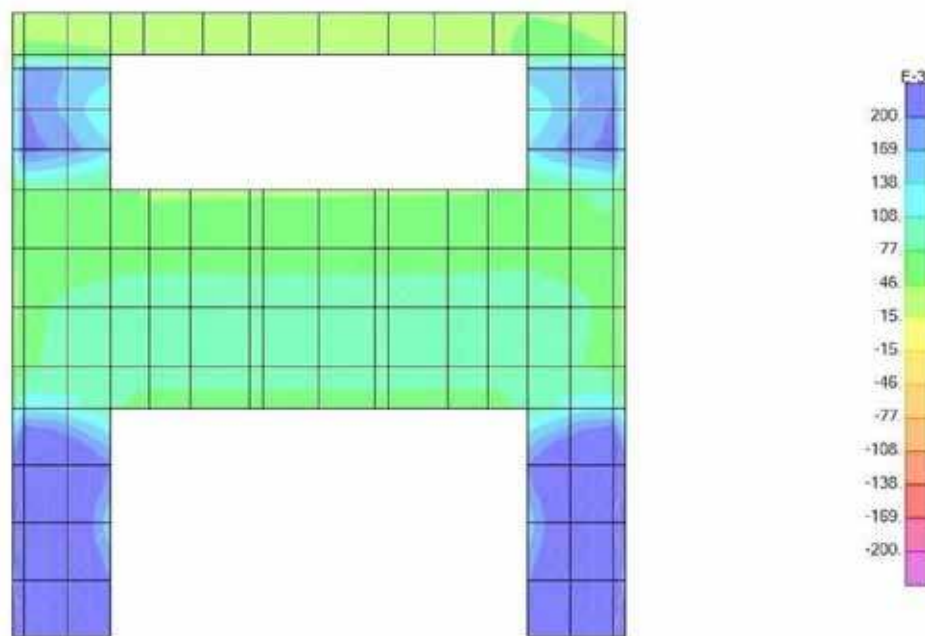


Figure 8: Shear stresses due to earthquake loading

The maximum induced shear stresses in brick quoins walls were around 0.46 N/mm^2 as shown in figure 8.

were basically subjected to gravity loads only. Summary of the induced stress is presented in Table 4.

3.4 Axial load in timber posts

As the lateral earthquake load was practically resisted by the L-shaped brick masonry quoins, timber posts

3.5 Flexural stress in timber beams

Timber beams were also subjected to gravity loads only. Summary of the flexural stress in timber beams are tabulated in Table 5.

Table 4: Axial stress in timber posts

Post ID	Axial Load, P (kN)	Breadth, b (mm)	Depth, D (mm)	$\sigma = P/bD \text{ (N/mm}^2\text{)}$
First layer	-235	350	350	-1.92
Second layer	-202	200	200	-5.1
Third layer	-14.5	200	200	-0.36
Fourth layer	-34.6	150	150	-1.55

Table 5: Bending stress in timber beams

Beam ID	Moment, M (Nmm)	Breadth, b (mm)	Depth, D (mm)	Z (mm ³)	$\sigma = M/Z \text{ (N/mm}^2\text{)}$
First layer	17019009	350	350	7145833	2.38
Second layer	234706	200	300	3000000	0.08
Third layer	1319489	150	200	1000000	1.32
Fourth layer	2521863	150	150	562500	4.48

3.6 Stress in timber joints

Even though, timber members resist smaller earthquakes, the joints need to be checked for induced shear force. In other words, the tenon (S_a) should be able to resist the induced shear force due to earthquake loading. The induced shear forces in different joints are given in Table 6.

3.7 Foundation bearing pressure

The foundation details of the Kasthamandap from the archaeological investigation showed that footing for perimeter timber frames, and for inner L-shaped brick quoins was a continuous strip footing of width 890 mm and 1160 mm, respectively. The footing for the central wooden post was a pedestal of size 1050 mm (Coningham, Acharya, & Davis, 2015). Analysis of the foundation showed that the bearing pressure for pedestal footings below the central post was around 172 KN/m². The details of the bearing pressure calculation are tabulated in Table 7.

Table 6: Shear stress in timber joinery

Post ID	Shear force, V (kN)	Breadth, b (mm)	Depth, D (mm)	τ_v (N/mm ²)
First layer	6.2	115	115	0.47
Second layer	4.18	65	65	0.99
Third layer	3.26	65	65	0.77
Fourth layer	2.56	50	50	1.02

Table 7: Foundation bearing pressure

Foundation ID	Axial load, P (kN)	Length, L (mm)	Breadth, B (mm)	Bearing pressure (kN/m ²)
First layer	207.7	1100	1100	171.66
Second layer	5638.6	-	1200	113.50
Third layer	518.25	-	850	9.27
Fourth layer	1115.3	-	850	17.54

4. Discussion

The structural analysis showed that earthquake load was primarily resisted by the masonry brick quoins. Timber frame members were subjected to axial stresses due to earthquake loads. The modal analysis or eigen value analysis showed that the fundamental mode of vibration was in a translational mode with more than 90 percent of effective modal mass participation. This showed that the structure was regular in both horizontal and vertical directions. Drift of the structure due to design earthquake loading was found to be within the limit of 0.01 as per NBC 105 (NBC 105, 1994).

Significant in-plane stresses were induced in the brick quoins. Both tensile and compressive stresses exceeded the permissible levels. Similarly, the brick quoins were subjected to significant shear stress. All the timber posts had axial stresses within the permissible limits. Flexibility of the beams in situations of stress, were also found to be within the permissible limits. The sizes of tenon of second and fourth row timber posts were not adequate to resist the induced shear force.

The analysis result showed that the foundation of first layer, i.e., brick pedestal foundation for the central timber post was more stressed than the rest. However,

there was no evidence of differential settlement and distress in the foundation systems. This fact leads to the deduction that the existing foundation system had been able to resist the induced high bearing pressure. There had been no renovation and modification in foundation structure since its construction during the 7th century as indicated in the archaeological investigation (Coningham, Acharya, & Davis, 2015). We therefore concluded that the existing foundation was robust and strong enough, and no modification and repair was required.

5. Conclusion and recommendation

The four brick quoins present at the four corners of the second layer wall were the main lateral load resisting elements in the structure. These unreinforced brick masonry quoins were subjected to high compressive and tensile stresses due to lateral loads during an earthquake.

In order to make the brick quoins resist the induced tensile stresses, it is recommended that a number of vertical and horizontal timber posts be embedded inside the wall at the strategic locations.

The sizes of tenon in timber posts needed to be increased to resist the induced shear force. The brick piers supporting the central columns were isolated and no ties were present to connect these brick piers. The cross walls abutting these piers were sized at the width of a brick. However, these cross walls were not bonded to the brick piers and added in later renovation (Coningham, Acharya, & Davis, 2015). The study of these details show that these cross walls in fact partially acted as lateral support to the brick pier foundations.

Acknowledgements

We would like to extend our gratitude to the Kasthamandap Reconstruction Committee for providing us the opportunity to work on the reconstruction of the Kasthamandap. In particular, we thank Mr. Rajesh Shakya, member of parliament, Bagmati Province, and Chairperson of Kasthamandap Reconstruction

Committee for the support and guidance provided during the duration of work.

References

- [1] Asteris, P.G., 2014. Seismic vulnerability assessment of historical masonry structural systems. Elsevier Limited.
- [2] Coningham, R., et al. 2015. *Post Disaster Urban Archaeological Investigation, Evaluation and Interpretation in Kathmandu Valley World Heritage Property*. UNESCO, Durham University and Nepal Government, Kathmandu.
- [3] Eurocode 6, 2005. *Design of Masonry Structures - Part 1-1: General rules for reinforced and unreinforced masonry structures*. CEN, Brussels.
- [4] FEMA 306, 1998. *Evaluation of Earthquake Damaged Concrete and Masonry Wall Buildings*. Redwood City, Applied Technology Council, California.
- [5] IS 1905, 1987. *Code of Practice for Structural Use of Unreinforced Masonry (Third Edition)*. Bureau of Indian Standards, New Delhi.
- [6] IS 875, 1987. *Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures (Part I to V)*. Bureau of Indian Standards, New Delhi.
- [7] Kaushik, H.B. et al., 2007. Uniaxial compressive stress-strain model for clay brick masonry. *Current Science*, Vol. 92, No. 4. 497-501.
- [8] Korn, W., 1996. *The Traditional Architecture of the Kathmandu Valley*. Ratna Pustak Bhandar, Kathmandu.
- [9] Manfred, S., 2011. Nepal – Kathmandu – Durbar Square – Kasthamandap Temple – 231, May 2. Retrieved from flickr: <https://www.flickr.com/photos/asienman/26615398180>.
- [10] NBC 105, 1994. *Seismic Design of Buildings in Nepal*. DUDBC, Ministry of Physical Planning and Works, His Majesty's Government of Nepal, Kathmandu.
- [11] NBC 112, 1994. *Timber*. DUDBC, Ministry of Physical Planning and Works, His Majesty's Government of Nepal, Kathmandu.
- [12] Thapa, R.J., 1968. *Ancient Nepal, Journal of the Department of Archeology*. The Department of Archeology, His Majesty's Government of Nepal, Kathmandu.

PROJECT EXPERIENCES



विकास
VIKAS

www.nra.gov.np & www.npc.gov.np



Practical Approaches to Build Back Better with Inclusive Recovery from Earthquake Disasters: A Discussion Based on the 2015 Nepal Earthquake Recovery Project by JICA

Kozo Nagami^a, Tomoki Miyano^b, Naoki Nishimura^c, Yoji Toriumi^d,
Nanako Tsukahara^e, Ayuko Nakamura^f

1. Introduction

“Build Back Better (BBB)” has been recognized as one of the priority actions in the Sendai Framework for Disaster Risk Reduction (SFDRR) (UNDRR 2015) adopted in March 2015. According to the UNDRR (2017a), BBB is defined as *“the use of the recovery, rehabilitation and reconstruction phases after a disaster to increase the resilience of nations and communities through integrating disaster risk reduction measures into the restoration of physical infrastructure and societal systems, and into the revitalization of livelihoods, economies and the environment.”*¹ However, what disaster risk and resilience specifically mean has long been discussed, with different views depending on academic fields, countries, regions, languages, cultures, nature-views, and religions being put forward. Also, the definition of BBB does not say anything about the threshold beyond which the efforts for reducing

disaster risks can be deemed to be BBB. Suppose if a house made of straw, which had collapsed in a disaster, were reconstructed as a house made of wood that is still not enough strong to withstand future possible disasters, should we regard this as BBB? Thus, it should be no surprise that the various subjects such as governments, NGOs, and the private sector have interpreted BBB differently. There is also a big question whether BBB should be granted only for efforts achieving certain criteria or for any efforts achieving any improvement, literally “better,” from pre-disaster situations. No international criteria to evaluate the validity for BBB actions have been fully established.

Given the limited development of criteria for international standardization of BBB, there have been discussions on a new concept for disaster recovery called “Inclusive Recovery (IR)”² in recent years. In the 4th World Reconstruction Conference (WRC4) held in May 2019, IR was one of the main themes of

a Deputy Director General, Disaster Risk Reduction Group, Global Environmental Dept., Japan International Cooperation Agency, e-mail: Nagami.Kozo@jica.go.jp

b Deputy General Manager, Architecture Dept., Oriental Consultants Global, e-mail: miyanot@ocglobal.jp

c Representative, Nepal office, Japan International Cooperation Agency, e-mail: Nishimura.Naoki@jica.go.jp

d Representative, Nepal office, Japan International Cooperation Agency, e-mail: Toriumi.Yoji@jica.go.jp

e JICA Expert, e-mail: nanako.prr@gmail.com

f Representative, Nepal office, Japan International Cooperation Agency, e-mail: Nakamura.Ayuko@jica.go.jp

1 Textual quotation

2 The term of “Inclusive Recovery” is used in this paper as a synonym of “Inclusion for Resilient Recovery” used in the GFDRR (2019).

the discussion. Although IR is a new concept that has not been officially defined by UNDRR, IR requires that no one is left behind in recovery processes according to the Global Facility for Disaster Reduction and Recovery (GFDRR) (2019). In other words, it can be said that IR is a concept that puts particular focus on recovery processes but is unclear about what kind of results or outcomes of such recovery processes it needs to achieve, whereas BBB requires the reduction of the vulnerability of the whole society regardless of the differences in socio-economic status of the people involved. But, from the viewpoint of IR that puts particular focus on the participation of individual people and households, BBB recovery tends to be criticized as leaving people in the socially vulnerable groups behind that do not have sufficient resources for recovery. However, BBB and IR should be complementary by nature when implemented with proper consideration and arrangements.

The Nepal earthquake that occurred on April 25, 2015 with a magnitude of 7.8 Mw was centered in Gorkha district about 77km northwest of the capital city of Kathmandu and caused considerable damage to the country. Together with succeeding aftershocks, the earthquake left 8,790 people dead, more than 22,300 injured, about 500,000 houses completely destroyed, and about 260,000 houses partially destroyed (NPC 2015). The Nepal earthquake was the first major disaster in the world after the adoption of the SFDRR and the recovery work after the earthquake is of significant importance in developing an international consensus about the direction of disaster recovery in the future.

This paper first overviews the concepts and requirements of BBB and IR and their relationship in the housing reconstruction work during the disaster recovery from the earthquake and proposes a practical approach for achieving both BBB and IR. This paper argues that it is certainly possible to overcome the contradiction between BBB and IR, and that achieving both BBB and IR can lead to the most preferable disaster recovery that cannot be achieved by BBB or IR singly. Then, this paper refers to the reconstruction project implemented by the government of Nepal and

JICA to extract lessons learnt on how to practically achieve BBB and IR on the ground.

In addition to this section, this paper comprises the following sections. Section 2 reviews a framework called the MOVE (Method for the Improvement of Vulnerability Assessment in Europe) advocated by Birkmann et al (2013) to review the concepts of “disaster risk” and “vulnerability” which have been used differently depending on the academic fields and contexts. Section 3 looks into the subjects of “vulnerability.” While the framework of the MOVE only recognizes nations and communities as the subjects of vulnerability, this section explores the vulnerability of individuals and households. And it also discusses what would constitute a set of possible measures to alleviate the “vulnerability” associated with not only the vulnerability subjects but also different hazard types. Section 4 discusses how to achieve both BBB and IR, especially in the recovery from earthquake disasters and the difficulties associated with these. Section 5 chronologically overviews the progress of the housing reconstruction project in the areas supported by JICA after the Nepal earthquake. On the basis of the theoretical discussions in Sections 2 to 5, Section 6 overviews the desired approach to achieve both BBB and IR and evaluates the housing reconstruction project supported by JICA in Nepal from the viewpoint of the desired approach. Then, Section 7 summarizes all the discussions made in the previous sections.

2. The concepts of disaster risk and vulnerability on the basis of the MOVE Framework

UNDRR (2017) defines BBB as the increase in the resilience of nations and communities from integrating disaster risk reduction measures. In this paper, however, resilience is considered to be one of the risk factors of disasters on the basis of the concept advocated by Birkmann et al (2013). Resilience is not increased by disaster risk reduction. Instead, there is an inverse causal relation where disaster risks are reduced as a result of increasing resilience. That is, it can be

said that BBB is employed “to achieve a recovery state where the risks of nations and communities have been reduced through recovery processes.” Thus, in what follows, the discussion is made as to what are “disaster risks” in the definition of BBB and how reduction in these risks can be achieved.

2.1 The basic concept of disaster risks and components of vulnerability in the MOVE Framework

“Disaster risks (R)” and “vulnerability (V)” have been defined in many ways and in a broad or narrow sense. As one of the solutions for this issue, Birkmann et al (2013) advocated a framework called the MOVE which tries to facilitate a certain level of consensus about the vulnerability assessment. Specifically, the MOVE proposes to breakdown vulnerability (V) into three component factors: exposure (E); susceptibility (S); and lack of resilience which is also called response capacity (C); and additionally uses adaptation (A) as the fourth component factor affecting hazard (H) and vulnerability (V).

On the basis of the MOVE, the component factors of disaster risks are summarized in Table 1.

Hazard (H) is used to describe the potential occurrence of natural, socio-natural, or anthropogenic events that may have physical, social, economic, and environmental impact in a given area and over a given period of time. Exposure (E) describes the extent to which a unit of assessment falls within the geographical range of a hazard event. For example, spatial exposure can be reduced by limiting the in-migration to and encouraging relocation from the areas with high risk of disasters due to floods and landslides. Susceptibility (S) describes the predisposition of elements at risk (social and ecological) to suffer harm. Depending on communities and systems, the degrees of disaster damage (adverse direct effects or short-term effects after the occurrence of a hazard) vary even when exposed to the same hazard. Because hazards can cause diverse damage to communities and systems, Birkmann et al (2013) classifies susceptibility into six aspects depending on the type of damage experienced.

According to the MOVE, resilience has two aspects: one is passive capacity; and the other is the capacity to actively adjust to future changes. The former capacity

Table 1: Component factors of disaster risks on the basis of the MOVE Model

	Wisner (2004)	MOVE (Birkmann et al. 2013)	
		Component factor	Detailed description
Disaster Risk (R)	Hazard (H)	Hazard (H)	- Natural events - Socio-natural events
	Vulnerability (V)	Exposure (E)	- Temporal - Spatial
		Susceptibility (S)	- Physical - Economic - Social - Cultural - Ecological - Institutional
		Lack of Resilience / Response Capacity (C)	- Capacity to anticipate - Capacity to cope - Capacity to recover
		Adaptation (A)	- Hazard intervention - Vulnerability intervention, Exposure reduction, Susceptibility reduction, Resilience improvement

Table 2: Six aspects of susceptibility (S)
(based on Birkmann et al 2013)

Aspect of susceptibility	Content
Physical (S1)	Potential for damage to physical assets including built-up areas, infrastructure, and open spaces.
Economic (S2)	Propensity for loss of economic value from damage to physical assets and/or disruption of productive capacity.
Social (S3)	Propensity for human well-being to be damaged by disruption to individual (mental and physical health) and collective (health, education services, etc.) social systems and their characteristics (e.g. gender, marginalization of social groups).
Cultural (S4)	Potential for damage to intangible values including meanings placed on artefacts, customs, habitual practices and natural or urban landscapes.
Environmental (S5)	Potential for damage to all ecological and bio-physical systems and their different functions. This includes particular ecosystem functions and environmental services but excludes cultural values that might be attributed.
Institutional (S6)	Potential for damage to governance systems, organizational form, and function as well as guiding formal/legal and informal/customary rules—any of which may be forced to change the following weaknesses exposed by disaster and response.

comprises capacity to cope, capacity to recover and capacity to anticipate and the lack of these three types of passive capacity leads to vulnerability. The latter capacity, adaptation (A), is considered to include the capacity of communities and systems to learn from the experience of past disasters and improve existing methods in preparation for future disasters.

In this paper, the three types of capacity constituting resilience are collectively called response capacity (C), and response capacity (C) and adaptation (A) are collectively redefined as “Resilience (Re)” ($Re = C \times A$).³ That is, the situations with high risks of disasters are those high in hazard, exposure, and susceptibility and low in response capacity and adaptation. The numerical expression of what is discussed above can be as follows:

Disaster risk (R) = Hazard (H) x Vulnerability (V)
= Hazard (H) x Exposure (E) x Susceptibility (S) /
Response capacity (C) x Adaptation (A):

³ However, there have been considerably diverse discussions on the relation between response capacity (C) and adaptation (A) and, therefore, it should be noted that these two factors cannot be definitely said to be components of resilience in general.

$$C_d(T) = \frac{C_h(T)Z I}{R_g \Omega_u}$$

As stated above, on the basis of the concept that resilience is one of the risk factors in disasters advocated by Birkmann et al (2013), this paper supports the concept that disaster risks are reduced as a result of increasing resilience.

3. Measures to reduce disaster risks by subject of vulnerability and hazard type

Following the concept of MOVE, the discussion above has been made with social systems as the subject of vulnerability. This is considered important because in the field of disaster prevention research there is a tendency to discuss disaster risks as one of the problems of social systems as a whole. However, the factors causing vulnerability can be classified according to a variety of subjects (such as individuals and households) constituting a social system. Also, there are diverse types of natural hazards and the effectiveness of resilience against disasters is supposed to vary depending on the types of natural hazards.

3.1 Classification of measures to reduce disaster risks by subject of vulnerability and type of measure

According to Shimada (2009), natural hazards associated with physical shocks first undergo alleviation and attenuation by public infrastructures owned by social systems and then affect individuals and households. In contrast, economic, social, and political shocks do not have physical characteristics and these changes are considered to directly affect the smallest units of social systems such as individuals and households. Then, vulnerability can be classified by the types of subjects such as “(1) nations and communities” and “(2) individuals and households”; and the causes of vulnerability whether they are structural or non-structural. Accordingly, the measures to reduce disaster risks can be classified as shown in Table 3 and the items and actions that respective measures need to address, including infrastructures and social systems, may be summarized as in Table 4.

As an example, to reduce physical susceptibility (S1), both the improvement of individual houses, which are of course individual properties, and infrastructure which belongs to society are effective. Thus, for former physical private assets physical susceptibility varies depending on individuals even in identical societies. In contrast, for latter physical public assets infrastructure and social functions work to reduce disaster risks not

for individuals and households but for society. As to economic susceptibility (S3), the measures to reduce disaster risks for individuals and households need to address the susceptibility of respective occupations, but those for nations and communities need to focus on and address industrial structures or the susceptibility of each industry against external shocks.

3.2 Effective measures to reduce disaster risks for various types of hazards

What follows is an additional discussion about using structural and non-structural measures to reduce disaster risks. The first significant point about the structural measures is that the contents and the range of effects of the measures for “nations and communities” vary depending on the type of hazards. For example, in the case of hazards like floods and landslides, their source origins can be geographically limited and their generation mechanisms are often known and, therefore, it is highly likely that they can be prevented with physical infrastructure (such as dikes, retaining walls and dams). In contrast, it is difficult to control the generation or attenuate the magnitude of earthquakes. Thus, the role of structural measures to reduce disaster risks for “individuals and households” is larger for those hazards for which the effectiveness or disaster control capability of disaster prevention infrastructure is low. In the case of floods and landslides, such

Table 3: Classification of measures to reduce disaster risks by subject of vulnerability and type of measure

Disaster risk factor				Type of measure	Nations and communities	Individuals and households	
Disaster risk (R)	Vulnerability (V)	Hazard (H)		Structural measures	Reinforcement of disaster infrastructures and critical infrastructures	NA	
		Exposure (E)				Reinforcement of assets (houses, etc.)	
		Susceptibility (S)	Physical (S1)		Non-structural measures	Reinforcement of social systems	Reinforcement of capacity to cope
			Social (S2)				
			Economic (S3)				
			Cultural (S4)				
			Ecological (S5)				
			Institutional (S6)				
		Resilience (Re)	Response capacity (C)				
	Adaptation (A)						

Table 4: Items and actions that respective measures to reduce disaster risks need to address

			Nations and communities (Vx)	Individuals and households (Vy)
Disaster risk (R)	Hazard (H)		Hx: Disaster prevention infrastructures	
	Vulnerability (V)	Exposure (E)	Ex: Public evacuation and relocation	Ey: Voluntary evacuation and relocation
		Susceptibility (S)	Physical (S1)	S1x: Critical infrastructures (road, railroads, water and sewerage, power supply, schools, hospitals, etc.)
			Social (S2)	S2y: Personal assets (houses, etc.)
			Economic (S3)	S2y: Personal social capacity (education level, etc.)
			Cultural (S4)	S3y: Occupations, savings, incomes
			Ecological (S5)	S4y: Custom, tradition
			Institutional (S6)	
		Resilience (Re)	Response capacity (C)	S5x: Ecological systems
			Adaptation (A)	S6x: Government systems and social capital
			Cx: Government systems and social capital	Cy: Self-help capacity
			Ax: Government systems and social capital	Ay: Awareness and knowledge about disaster prevention and adaptation

disaster prevention infrastructures as the measures for nations and communities are effective but the measures for individuals and households are limited to the renovation to stilt houses using pilotis, or voluntary relocation to safer places, etc. In contrast, in the case of earthquakes, the quite effective and critical measures are those for individuals and households such as the earthquake retrofitting of houses.

The second significant point to be emphasized about the structural measures is the importance of reinforcing “critical infrastructures.” The “critical infrastructures” like lifelines including water supply networks, roads, and power supply networks as well as basic social service facilities including hospitals and schools, do not control hazards at the origin but

reinforcing those critical infrastructures allows them to play a protective role against hazards in terms of not only saving human lives but also helping to control the damage to social, economic, and administrative systems. Thus, “critical infrastructures” are indispensable for reducing disaster risks and vulnerability regardless of the nature of hazards.

The above discussion can be summed up in the important reinforcement points to be considered when establishing effective structural or non-structural measures to reduce disaster risks. These differ depending on the anticipated external shocks and whether the measures are for “(1) nations and communities” or “(2) individuals and households”, and can be classified as shown in Table 5.

Table 5: Difference in the effectiveness of measures to reduce disaster risks by the type of external shock

		Natural hazard			
		Controllable		Uncontrollable	
Structural measure	Nations and communities	○	Reinforcement of disaster prevention infrastructures	△	Reinforcement of disaster prevention infrastructures:
		○	Reinforcement of critical infrastructures	○	Reinforcement of critical infrastructures
	Individuals and households	○	Reinforcement of personal assets	○	Reinforcement of personal assets
Non-structural measure	Nations and communities	△	Reinforcement of social systems	○	Reinforcement of social systems
	Individuals and households	○	Reinforcement of capacity to cope	○	Reinforcement of capacity to cope

(where ○ means “very effective”, □ means “effective”, and △ means “not very effective”).

4. Achievement of both BBB and IR through housing reconstruction in the recovery from earthquake disasters

As previously mentioned, this paper redefines BBB as seeking “to achieve a recovery state where the risks of nations and communities have been reduced through recovery processes,” and shows that the main measures to reduce disaster risks differ depending on the controllability of natural disasters. This section discusses how to incorporate the concepts of BBB and IR in recovery work, with particular focus on that from earthquakes, as the basis to conduct the verification analysis of BBB and IR in the recovery from the Nepal earthquake. In the Nepal earthquake, private houses suffered the severest damage. About 80 percent of private houses were identified as being completely destroyed in the 14 districts designated as serious disaster areas (Nagami 2018). Thus, the fulfillment of the situations where the disaster risks of nations and communities have been reduced through recovery processes to reconstruct destroyed houses is set as the requirement to achieve BBB. It was anticipated that the particularly critical external shocks for each disaster-hit-area were also earthquakes even in the future. Because earthquakes are uncontrollable as previously mentioned, reconstructing destroyed houses into more earthquake resilient ones was the prioritized issue of the recovery work.

4.1 Difficulty in achieving BBB during recovery work after earthquakes

The fact that houses are the private assets of individuals and households makes achievement of BBB difficult. The first reason for the difficulty is the social and economic disparities between individuals and households as house owners. Such disparities result in large differences in the financial capacity to reconstruct earthquake resilient houses. Also, there exist different views and opinions with respect to their houses, and it is therefore difficult for nations and communities to set a uniform standard for the reconstruction of earthquake resilient houses.

The second reason for the difficulty is the problem with defining the “state fulfilling BBB.” When evaluating “vulnerability” or physical susceptibility (Sly) of housing, the simplest valuation is an average of the whole society and this can be defined as $S1y = \sum P_i = S1y_i/P$, where $S1y_i$ is the physical susceptibility of each household and P is the number of households in a social system. However, $S1y_i$ is randomly distributed and, when assuming that such distribution follows the normal distribution, it can be expressed as a blue line in the distribution map of Figure 1. Although “to achieve a recovery state where the risks of nations and communities have been reduced through recovery processes,” is required for achieving BBB, the problem here is that there has been no indication of the target level of disaster risks with which the achievement of BBB

is granted. Thus, when literally interpreting the definition of BBB, even slight improvements in vulnerability compared to previous situations can be considered as achievement of BBB. However, to prevent the recurrence of similar disasters, it is necessary not only to simply reduce disaster risks from the previous level but also to set a standard level of disaster risks enabling the vulnerability of individuals to be sufficiently reduced in consideration of potential hazards in the future. That is, the requirement to achieve BBB needs to be set so as to alleviate the vulnerability of disaster victims to the level that enables all disaster victims to be resilient to potential hazards and thereby improving the physical susceptibility (Sly) of society. Figure 1 illustrates how setting the requirement to achieve BBB works. Setting the requirement is to shift the distribution of Sly from the blue line to the green line throughout nations and communities.

However, it is highly likely that the population segment living in houses easily damaged by earthquakes actually overlaps with the socio-economically

vulnerable. Thus, implementing disaster restoration in a manner that uniformly applies support systems and standards throughout social systems may cause some population segments to be unable to carry through the reconstruction of earthquake resilient houses. Similarly, achieving BBB poses a dilemma as setting higher target levels for potential hazards may expand the population segments left behind.

Lastly, it should be noted that the discussions in this section have been made with a focus on the measures to secure the reduction in disaster risks in terms only of physical susceptibility and, as shown in Tables 3 and 4, there are many other measures contributing to the reduction in disaster risks. As previously mentioned, it is difficult to control the hazard at its origin in earthquakes and, therefore, reinforcing respective houses, personal assets, is inarguably an important measure to achieve BBB. The measures to reduce disaster risks through the reduction in the vulnerability of social systems (nations and communities) and individuals are summarized in Table 6. It is necessary to make it

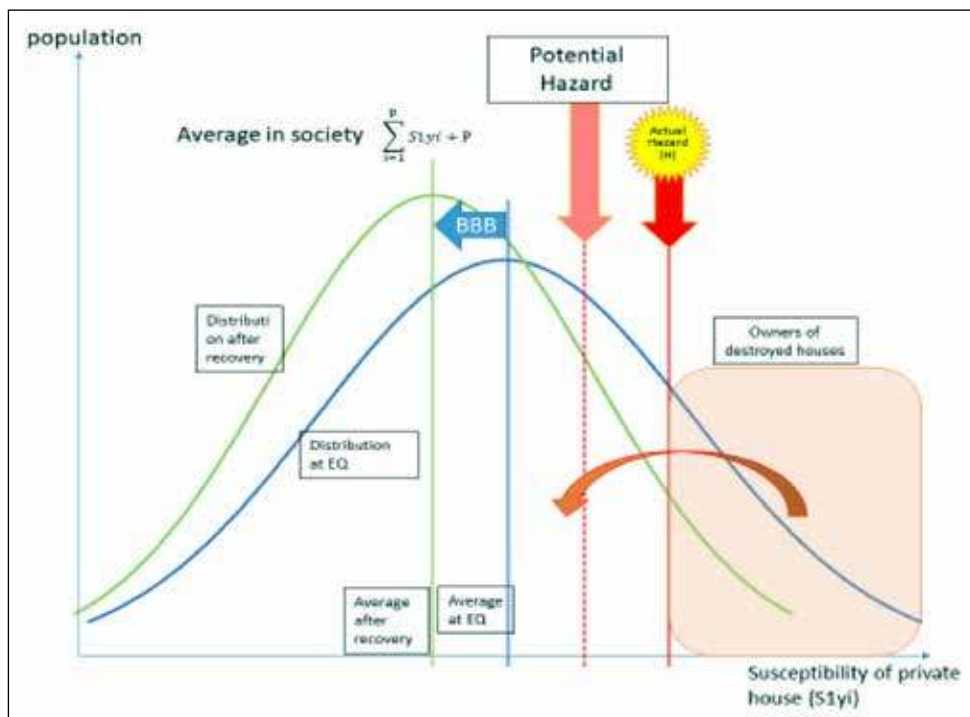


Figure 1: Approach to reinforce personal assets (ideal form)

Table 6: Specific measures to reduce disaster risks related to urgent housing reconstruction

	Nations and communities	Individuals and households
Hazard (H) prevention	Disaster preventive measures against hazard generation sources of landslide, floods, etc.	
Exposure (E) reduction	- Development of residential areas for relocation - Restriction of construction activities in dangerous areas	- Permanent voluntary relocation - Temporal voluntary relocation
Physical susceptibility (S1) reduction	- Development and reinforcement of critical infrastructures (roads, waterworks, power supply, schools, hospitals, health care centers, etc.) - Development of other infrastructures	- Redevelopment of safe personal assets (houses, etc.) - Reinforcement of safety at places to store assets (ground improvement, etc.)
Social susceptibility (S2) reduction	Reinforcement of social systems such as health care, medical and educational services in disaster areas and the reduction of physical susceptibility	Enhancement of social capability of individuals (education, health care, etc.)
Economic susceptibility (S3) reduction	Reduction of the physical susceptibility of production, processing, and logistic bases	- Reinforcement of occupational capability, occupational conversion, etc. - Relocation of agricultural land from hazard areas
Cultural susceptibility (S4) reduction	- Turning implicit knowledge on cultural activities into explicit knowledge - Recording of custom, tradition, etc. and dissemination as well as promotion of folklore - Reduction of physical susceptibility at cultural bases	Regeneration and maintenance of custom and tradition
Ecological susceptibility (S5) reduction	Conservation and reinforcement of ecological systems (afforestation, etc.)	
Institutional susceptibility (S6) reduction	- Improvement and reinforcement of intangible assets such as personnel structures of administrative organizations, personnel capability, legal structures, and regulations - Reduction of physical susceptibility at government administrative facilities	
Response capacity (C) enhancement	- Reinforcement of administrative systems - Reinforcement of emergency rescue systems - Reinforcement of mutual assistance - Dissemination of the awareness of disaster risks - Reinforcement of financial service	Reinforcement of self-help capability
Adaptation (A) enhancement	Reinforcement of disaster research functions	Enhancement of the awareness for disaster prevention

sure that physically safe housing reconstruction should be accompanied by the additional improvement of the items listed in Table 4 to the extent possible through the simultaneous implementation of the measures listed in Table 6 with the housing reconstruction. Or at least, the housing reconstruction should be made with full consideration not to produce adverse influences on the items listed in Table 4. That is, the achievement of BBB cannot be granted for the mere fulfillment of physically safe housing reconstruction.

4.2 How to ensure inclusiveness based on the IR concept

It is necessary to review the concept of IR in this section. Although the UNDRR has not given any official definition of IR, the GFDRR (2019) made the following statement about IR (Inclusive Recovery: Inclusion for resilient recovery):

Inclusion in disaster recovery and reconstruction is a key condition for the people's resilience. A more inclusive recovery fosters equal rights and opportunities, dignity, and diversity, guaranteeing that nobody from a community is left out because of their age, gender, disability, or other factors linked to ethnicity, religion, geography, economic status, political affiliation, health issues, or other life circumstances. The international frameworks set up by the Agenda 2030 for Sustainable Development Goals, the Sendai Framework for Disaster Risk Reduction, the Paris Agreement on Climate change all advocate for an increasing focus on resilience and inclusion.⁴

The point in the above statement is that IR is a concept designed to increase understanding of the conditions of "people;" that is individuals and households, not the average condition of society.

Recently, "Leave No One Behind (LNOB)" has often

been mentioned as the concept related to IR. In this paper, IR is considered to be the condition satisfying LNOB in recovery processes. The UNDP (2018) mentioned that people get left behind when they lack the choices and opportunities to participate in and benefit from development progress. All people living in extreme poverty can thus be considered 'left behind', as can those who endure disadvantages or deprivations that limit their choices and opportunities relative to others in society. Thus, it can be summarized that "the condition of being left behind" is the isolation of particular individuals or groups from society in a manner that keeps them from social systems and benefits because of their characteristics (such as personal capability, socio-economic statuses) and identities.

In addition, the UNDP (2018) advocated that empowering and enactment are necessary to satisfy LNOB. That is, IR is not simple inclusion of vulnerable people in recovery processes so as not to leave them behind but stepwise implementation of the identification of population segments with high risks of being left behind, enhancement of capability of such population segments and promotion of actual recovery processes. It is difficult to completely eliminate disadvantages rooted by the factors that people with high risks of being left behind have. Thus, what counts in satisfying LNOB is to prevent them from being overwhelmed by the hardships due to the characteristics and to enable them to cope with and eventually overcome such hardships. Thus, it is necessary to understand that LNOB and IR are not the concepts to advocate the necessity of humanitarian protection and rescue but the concepts to advocate the necessity of reducing vulnerability of individuals by empowering them. It is obvious that short-term assistance such as simple provision of monetary and physical supplies does not lead to fundamental solutions for LNOB and IR.

4.3 Simultaneous achievement of BBB and IR, a method for saving the underclass

When reinforcing personal assets, uniform support may be insufficient to enable houses of

4 Textual quotation

socio-economically vulnerable people to be reinforced against earthquakes. And setting higher safety targets has a risk of increasing the percentage of houses that cannot achieve the targets. Nonetheless, lowering the target level of vulnerability of society to a level appropriate for socio-economically vulnerable people lacking financial capability to reconstruct houses means the inclusion of the underclass at the cost of the vulnerability of society. Lowering the target level is also inappropriate in that it may deliver a wrong message to individuals and households that have excess capacity to further reduce vulnerability. In addition, discriminately setting low target levels only for the underclass is against the principle of IR since such a measure leaves the problems with the vulnerability of many households due to weak physical structure resistance to external shocks unsolved, which is one of the factors causing people to be left behind.

In summary, it is necessary to deliberate on the possibility of additional implementation of special assistance only for the underclass so as to encourage their self-help enhancement of capacity building without compromising on lowering the target level of the reduction of vulnerability of society. In extending additional assistance to the underclass, it is necessary to pay attention to the following two points: “fair and honest identification of people classified as the underclass”; and “appropriate provision of effective assistance to the disaster victims in the underclass.”

5. Outline of the housing reconstruction process in the recovery work after the Nepal Earthquake

The previous sections summarize the measures to achieve BBB taking into consideration IR on the basis of discussion results with respect to the inclusive assistance for housing reinforcement in the recovery process after earthquakes. What follows in this section is an evaluation of how efficient the Emergency Housing Reconstruction Project implemented jointly by the government of Nepal and JICA with the support

from the project management consultant was in terms of BBB and IR.⁵

In the recovery work after the Nepal earthquake, housing reconstruction was the biggest challenge in terms of the severity of damage to houses, and a great number of donor countries including emerging countries like India and China, international NGOs and private companies participated in housing reconstruction there. Housing reconstruction in Nepal was characterized by the implementation of the processes under a strictly unified mechanism, which was not the case in housing reconstruction after the Indian Ocean Tsunami. However, although the modalities of the housing reconstruction processes by a large number of participants were unified in a broad sense, the specific assistance extended to local people in respective areas largely varied depending on the donors and the consultants implementing on-site activities. Thus, it should be noted that what follows is applicable only to the housing reconstruction processes implemented in the areas supported by JICA.

5.1 Efforts in the Emergency Housing Reconstruction Project

As previously mentioned, the Nepal earthquake in 2015 left more than 750,000 houses completely or partially destroyed and caused particularly severe damage to private houses. Most private houses located in the hilly and mountainous areas were masonry ones constructed by piling pieces of shaped stones with mud mortar in between, and such masonry houses accounted for more than 90 percent of the houses completely or partially destroyed by the earthquake (Nagami 2018)). Being afraid that houses reconstructed with the same traditional masonry structure would be subject to similarly severe damage on the occurrence of major earthquakes in the future, the government of Nepal determined to introduce a Housing Reconstruction Program to promote the reconstruction of houses satisfying

5 Oriental Consultants Global Co., Ltd. was in charge of implementing the project.

certain seismic standards (which are defined as the Minimum Requirements) by granting the owners of houses completely or partially destroyed NRs. 300,000 on the condition of the compliance to the standards.⁶ The housing grant of NRs. 300,000 was disbursed in three tranches of NRs. 50,000, NRs. 150,000 and NRs. 100,000 according to the progress of the reconstruction. The housing grant program had been promoted on the basis of the principle of owner-driven housing reconstruction requiring owners of destroyed houses to be responsible for the reconstruction of their own houses into those resistant to earthquakes.

JICA's earthquake recovery assistance in the housing reconstruction field in Nepal comprises technical cooperation and financial assistance. The former of these was extended to the establishment of the Minimum Requirements for Housing Reconstruction and the training programs for house owners and masons. The latter was extended in the form of the Japanese Official Development Assistance (ODA) loan allocated to the part of the housing grant of the Nepal government for providing the housing grant and for hiring the project management consultant implementing the technical cooperation. For the implementation of the project, parts of Gorkha district and Sindhupalchowk district were assigned as the areas supported by JICA.

Figure 2 shows the progress of the housing reconstruction in the areas supported by JICA. Also, what follows summarizes the progress of the efforts by the government of Nepal and JICA, particularly on how the development of the housing reconstruction system and technical cooperation progressed chronologically.

First Year (April 2015 to March 2016): Program Deliberation Phase

Immediately after the earthquake, the government of Nepal and JICA jointly developed the Design Catalogue for houses to be reconstructed. Also, JICA started

Mason Training on the basis of the curriculum set by the Department of Urban Development and Building Construction of the Ministry of Urban Development, and House owner Training to enlighten house owners about the importance of building earthquake-resistant houses. Then, a Technical Working Group comprising the National Reconstruction Authority (NRA) newly established by the government of Nepal, JICA, and engineers of other donors and NGOs was organized in February 2016 and started the deliberation of the Minimum Requirements to be the condition for receiving grants for housing reconstruction. It was determined to establish the Minimum Requirements for BBB on the basis of the Nepal Building Codes (NBC) that have been adopted as the seismic standard in Nepal. In addition, the investigation of house damage was started from January 2016 and the first enrolment camp to participate in the Housing Reconstruction Program was held in March 2016 immediately before the first anniversary of the Nepal earthquake. Distribution of the housing grant was also started, although the specific systems or the Minimum Requirements had not then been established.

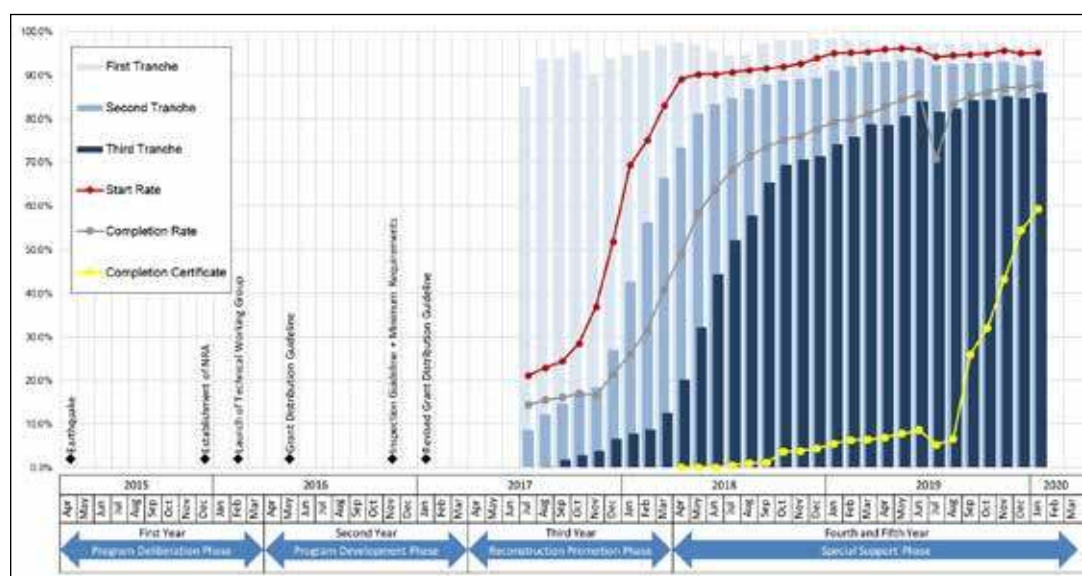
Second Year (April 2016 to March 2017): Program Development Phase

Mason Training and House Owner Training was conducted and the enrolment camps were held in rural districts. At the central level, the Grant Distribution Guideline and the Inspection Guideline for reconstructed houses including the inspection of compliance with the Minimum Requirements were established in May 2016 and November 2016, respectively. Inspection Training for house inspectors was also conducted on the basis of the Inspection Guidelines.

In January 2017, the Grant Distribution Guideline was revised and the amount of the housing grant was increased from NRs. 200,000 to NRs. 300,000. It can be said that the preparation for the Housing Reconstruction Program was completed at the same point of time as the housing reconstruction system and the Minimum Requirements were established, and Mason Training, House Owner Training and Inspection

⁶ Minimum Requirement is a set of technical features for seismic resilient houses. Only the house owners who reconstruct a house that has all the features defined in Minimum Requirement can receive the housing grant.

Figure 2:
Chronological
overview of
the progress
of housing
reconstruction
in the areas
supported by
JICA*



*The accuracy of data was temporarily reduced, when the areas supported by JICA were expanded in July 2019, because data on some households was not available.

Training were almost completed by this time. However, two years after the earthquake it had become evident that only using the uniform system provided by the government could not produce sufficient housing reconstruction progress. The reconstruction start rate as of March 2017 in the areas supported by JICA was 21.3 percent, which was much lower than what was expected.

Third Year (April 2017 to March 2018): Reconstruction Promotion Phase

The survey of the reasons for not commencing the reconstruction identified that the most common problem was “insufficient financial resources,” followed by “lack of masons,” “expensive building materials,” “lack of building materials” and “expensive labor cost for masons.” Some answers included a “wait-and-see attitude until confirming other beneficiary’s successful cases” and “ignorance about the Housing Reconstruction Program and the Minimum Requirements.” Based on the determination that these issues could be addressed to a large extent by the distribution of accurate information and the

promotion of mutual cooperation among beneficiaries, the Community Mobilization Program (CMP) was started to accelerate housing reconstruction.⁷ The CMP contributed to enhancing information sharing, identifying the issues of communities and solving the issues through collaborative efforts of communities having similar issues and thereby significantly increasing the reconstruction start rate. In particular, the reconstruction start rate was rapidly increased from 30 percent to 80 percent in the dry season from October 2017 to March 2018.

This drastic change could be explained as follows: those type of people who had already possessed capacity and been ready for starting housing reconstruction on the basis of public assistance (housing grant) and self-help capacity (personal funds and loans) but hesitated to start housing reconstruction were motivated

7 Not all the earthquake victims but only households whose houses were completely damaged can receive the housing grant on the condition that they reconstruct houses in align with Minimum Requirement. In this paper, we call such households who are entitled to receive the housing grant “beneficiaries” or “project beneficiaries.”

to do it through the mutual help (information sharing, collaborative efforts to solve issues and confidence building) among beneficiaries promoted by the CMP. Also, the Mobile Masons (skilled masons who travel around construction sites and provide technical assistance for house owners) was introduced as one of the components of the CMP. The Mobile Masons contributed to disseminating the Minimum Requirements into local construction sites, handholding support to the masons involved in reconstruction and thereby promoting the reconstruction of houses in compliance with the Minimum Requirements and accelerating the delivery of the housing grant to house owners.

Fourth Year and Fifth Year (from April 2018 onward): Special Support Phase

In contrast to the drastic increase in the reconstruction start rate owing to the CMP, it was identified that a considerable number of the project beneficiaries had not started housing reconstruction or had suspended ongoing reconstruction works. As a result of the monitoring survey, it was identified that there were people in the vulnerable groups who were left behind, while gender difference did not cause any difference in the speed of reconstruction.

In response to the survey results, the project started Special Support targeting the vulnerable households as part of the CMP. The Special Support comprises the following 3 main components:

1. Identification of “vulnerable” beneficiaries, in addition to “the vulnerable households”⁸ defined by the government (hereafter referred to as “government-defined vulnerable beneficiaries”), those who require additional support to complete the

reconstruction, as the recipients of the Special Support;

2. Extension of additional technical assistance by the Mobile Masons and labor supply in the form of collaborative work of community members to the households selected as the recipients of the Special Support; and
3. Extension of additional support related to building materials in terms of their preparation, procurement on credit, and transportation.

As a result of the Special Support, the completion rate in vulnerable beneficiaries was gradually increased to the level of the rate for non-vulnerable beneficiaries. In this project phase, along with the transition of the nation’s administrative system to a federal one, municipalities had started to be responsible for hous-

Table 7: Completion rates in the areas supported by JICA by vulnerable and non-vulnerable beneficiaries

	April 2018	April 2019	January 2020
Vulnerable beneficiaries	31.1%	71.5%	80.1%
Nonvulnerable beneficiaries	49.2%	82.9%	87.8%
Difference	18.1%	11.4%	7.7%

ing reconstruction and, accordingly, mayors and municipal officials had started to play important roles in accelerating the housing reconstruction. Figure 3 shows the trends of the reconstruction start rate and the completion rate in the areas supported by JICA. In these areas, the period required until the completion rate reached 55 percent was eight months shorter than the average of 11 districts⁹ that were not covered by the CMP. The data indicates the possibility that the CMP was indispensable for the promotion of the housing reconstruction in compliance with the

⁸ The government of Nepal defines the vulnerable beneficiaries among the recipients of the housing grant as: (1) households headed by women of 65 years old or higher, (2) households headed by elderly of 70 years old or higher, (3) households headed by orphans of less than 16 years old, and (4) households headed by government-authorized disabled people. These vulnerable beneficiaries can receive an additional grant of NRs. 50,000.

⁹ Eleven districts obtained by excluding three districts (Kathmandu, Lalitpur, and Bhaktapur) located in the Kathmandu Valley where the commencement of the Housing Reconstruction Program was delayed, from the 14 most affected districts.

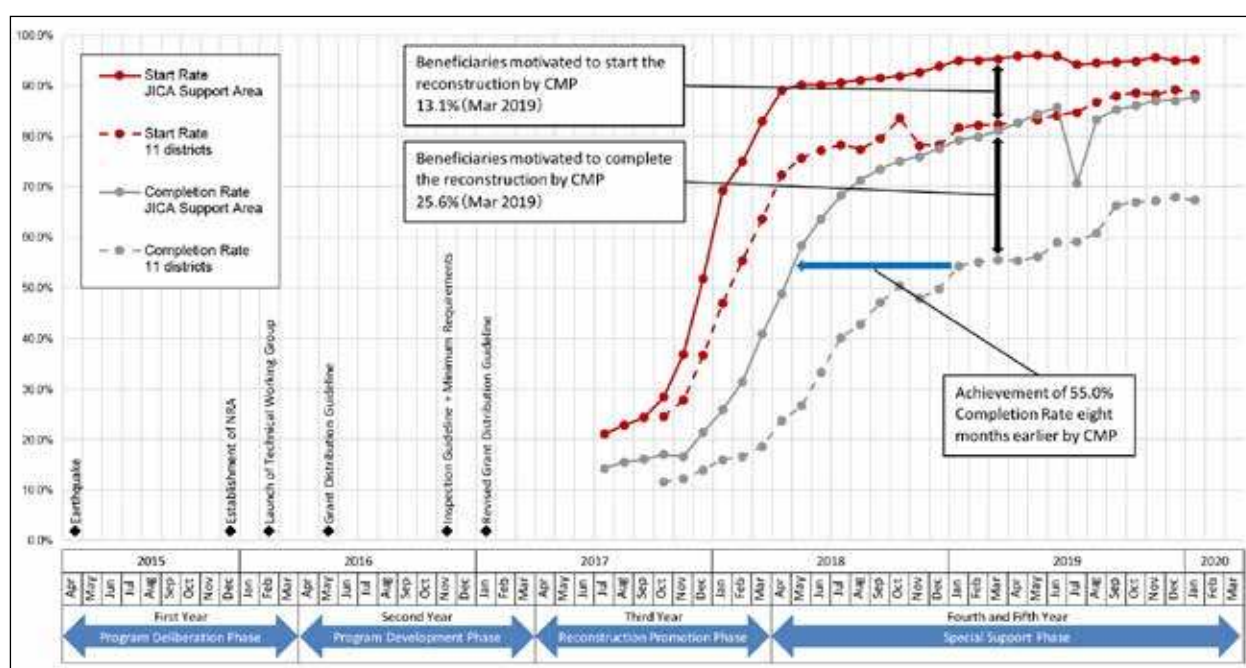


Figure 3: Comparison of the Reconstruction Start Rate and the Completion Rate between the Areas Supported by JICA and 11 Districts

Minimum Requirements. Also, it is considered that, in the four years after the earthquake, the CMP has produced effects on motivating the beneficiaries having the self-help capacity to start and to complete housing reconstruction. The gaps between the districts with and without CMP for the reconstruction start rate and the completion rate were 13.1 percent and 25.6 percent as of March 2019, respectively.¹⁰

In contrast, it gradually became evident that there were a certain number of beneficiaries who had not been able to commence or continue housing reconstruction only by the assistance of the original form of CMP which was for all community members. That is, the initial phase of CMP was not customized for the vulnerable beneficiaries unable to commence or continue housing reconstruction. However, the comprehensive assistance in the earlier stage of the CMP resulted in the identification of beneficiaries who need

additional support. That caused the CMP's purpose to be shifted from achieving BBB to achieving both BBB and IR.

6. Approaches for achieving BBB with Inclusive Recovery in housing reconstruction

6.1 Efforts considered to be effective for achieving both BBB and IR in the housing reinforcement

Based on what discussed in the previous sections, the assistance in housing reinforcement taking into consideration inclusiveness in the process of recovery from earthquake disasters needs to be implemented in stages as shown in Table 8.

First Stage: Setting of potential hazards level

It is extremely difficult to set potential hazard levels that will occur in the future with high reliability. It is particularly so when setting potential hazard levels concurrently with recovery work immediately after

¹⁰ This is merely a gap without controlling for any attributes of the target and control districts.

Table 8: Staged efforts considered to be effective for assistance in housing reinforcement taking into consideration inclusiveness in the process of recovery from earthquake disasters

	Name of stage	Content
First stage	Setting of potential hazards level	Setting of objective potential hazards with high reliability to the extent possible
Second stage	(1) Deliberation of Minimum Requirements	Setting of an adequate seismic standard to alleviate vulnerability to the level enabling houses to resist the potential hazards level
	(2) Identification of vulnerable groups	Identification of the population who are most vulnerable and are expected to have difficulty in achieving houses resistant to potential hazards level
Third stage	Deliberation of the contents of additional assistance	Determination of the contents of additional assistance
Fourth stage	Simultaneous initiation of all assistance programs	Implementation of disaster recovery programs universally across disaster victims
Fifth stage	Reinforcement of capacity to cope through housing reconstruction projects	Simultaneous reinforcement in every aspect, such as the administrative capability of government, the ability of local residents to cope with situations, and the capacity of economic as well as social systems through the housing reconstruction projects

disasters in the face of shortage in time and human resources. Accordingly, the severity of the hazards causing the existing disasters is often set as target levels of potential hazards in the future. That is, setting of potential hazards level is likely to be made on the basis of minimizing damage when facing the recurrence of disasters with severity equivalent to the latest one or the severity already considered in building standards. However, there are strong doubts about whether or not potential hazard levels set in these ways are appropriate for the prevention of damage due to the recurrence of disasters. Thus, it is ideally preferable to first develop consensus about potential hazard levels in normal time in preparation for major disasters and then set them on the basis of scientific evidence obtained through the verification, even simple ones, of past disasters.

During the setting of reliable potential hazards level after major disasters, the most important point is that governments of disaster affected countries take the initiative and responsibility for determining the potential hazards level. They should evaluate and finalize the future possible levels of hazards after building consensus. They need to answer whether or not it is appropriate and realistic to assume that a more severe disaster than the latest one will happen.

In the system deliberation phase, the first year after the Nepal earthquake, revising the NBC so as to renew the setting values of seismic force according to potential hazards was deliberated as an option but the final decision on the seismic force was made on the basis of NBC 105, the existing seismic standards in Nepal. As of the end of 2014, before the Nepal earthquake, only 26 municipalities were subject to the NBC throughout the country and, therefore, it is considered that most of the houses destroyed by the earthquake were not compliant with the NBC. Thus, it is considered to be a realistic decision to put a higher priority on the dissemination of the existing NBC and setting seismic force on the basis of NBC 105 without renewing potential hazards.

Second Stage (1): Deliberation of Minimum Requirements

The second stage is to technically standardize houses with sufficient resistance to potential hazards and establish the Minimum Requirements. Although such Minimum Requirements basically need to provide detailed specifications for respective technical elements centering on structural members, if the specifications are too complicated this would make house owners unable to comply with them and make house inspectors unable to confirm or inspect the compliance of a

reconstructed house. Also, in this stage of the deliberation of the Minimum Requirements, there may be cases where not only disaster victims but donors and NGOs supporting housing reconstruction put a higher priority on the speed of housing reconstruction. Hence, they insist on relaxing the Minimum Requirements by saying that “the technologies and materials required in the Minimum Requirements are too strict for house owners to follow.” It is necessary to pay attention to the fact that Minimum Requirements are likely to be subject to pressure on relaxing provisions.

In the system development phase, the second year after the Nepal earthquake, the Minimum Requirements for the Housing Reconstruction Program were established following the specified values of the NBC after verifying the safety of the masonry structures with cement mortar and mud mortar which have been commonly used in Nepal. The provisions in the Minimum Requirements have been directly used as inspection criteria. In the case of the masonry structure with mud mortar, the inspection criteria comprise 45 items in 10 categories. At the beginning, the inspection criteria included such unrealistic ones as the compressive strength of concrete and the bending strength of reinforcement, which are difficult to measure at housing construction sites in rural areas. Therefore, alternative criteria enabling the strength of concrete and reinforcement to be simply estimated have been introduced in “the Inspection Manual” established with the assistance of JICA.

In reality, however, there have been reports on cases where inspectors did not go through all the 45 criteria but passed houses, even when some criteria were left uninspected or confirmed to be non-conforming, on the basis of their determination of overall structural safety. Although unskilled inspectors were suspected to be the cause of improper inspection results, in the Emergency Housing Reconstruction Project, 311 inspection results by government inspectors were identified to be improper as of January 2020. The improper cases accounted for 0.3 percent of the total beneficiaries of the project in the areas supported by JICA.

Second Stage (2): Identification of vulnerable groups

In the second stage, it is necessary to identify the existence of vulnerable groups among the victims of the earthquake disaster in detail to the extent possible concurrently with “(1) Deliberation of Minimum Requirements.” However, it is practically difficult to select attributes to distinguish between vulnerable and non-vulnerable groups. Also, it is extremely difficult to set thresholds while ensuring equity among disaster victims so as to prevent disputes and criticisms in communities. The factors causing the issues of LNOB advocated by the UNDP seem to be useful for identifying “vulnerable groups” to some extent but again it is practically difficult to accurately define “vulnerable group” using appropriate attribute data at the site of implementing an actual policy.

Identification of vulnerable groups only becomes possible after accurately understanding the economic conditions of disaster victims, their statuses in communities and the cooperativeness of communities. However, in the areas supported by JICA, no investigation was conducted for such purposes before implementing the CMP.

Third Stage: Deliberation of the contents of additional assistance

The third stage is to deliberate what kind of additional assistance is required and how to extend such assistance to disaster victims. As previously mentioned, the UNDP (2018) advocated that empowering and enactment are necessary to satisfy LNOB. That is, what counts is not to temporarily save vulnerable groups from their hardship due to disasters but to enhance their capacity to overcome hardship without being overwhelmed by difficulties they have been facing. For performing this task, producing physical outcomes such as housing reconstruction for disaster victims is not sufficient. It is essential to enhance their capacity to cope with post-disaster difficulties including social and economic ones.

The government of Nepal decided to distribute an additional housing grant support of Rs. 50,000

equivalent to the government-defined vulnerable beneficiaries satisfying certain conditions defined by them. But as of January 2020, the number of those households classified as government-defined vulnerable beneficiaries in the areas supported by JICA was only 1,375 (1.5%) in contrast to the 11,580 households (12.3%) classified as vulnerable beneficiaries who could not complete housing reconstruction. Thus, it is considered that the government-defined vulnerable beneficiaries did not include the vulnerable households that actually need further special assistance. In addition, complicated application procedures prevented some households in the vulnerable groups from receiving the additional housing grant. In the areas supported by JICA, the scope of assistance was centered on the extension of intensive technical support by Mobile Masons and building material procurement support to the evidently vulnerable beneficiaries but did not include special assistance such as the distribution of grant money. Not extending the special assistance for the enhancement of the capacity of disaster victims to cope with socio-economic difficulties, the project still aimed at completing the housing reconstruction.

Fourth Stage: Simultaneous initiation of all assistance programs

The fourth stage is to universally extend assistance to all disaster victims regardless of their vulnerability. What counts in this stage is universality otherwise only the vulnerable groups are subject to prolonged hardship due to disasters and as a result being additionally subject to indirect damage associated with prolonged hardship.

Because the CMP was comprehensively implemented regardless of the vulnerability of beneficiaries, the existence of vulnerable beneficiaries that could not complete housing reconstruction only by CMP became evident.

Fifth Stage: Reinforcement of capacity to cope through the Emergency Housing Reconstruction Project

As summarized in Table 6, during the implementation

of the housing reconstruction project, the objects and items listed in Table 4 should be improved as much as reasonably possible. Otherwise, at least efforts to prevent housing reconstruction from causing adverse influences on disaster victims should be made.

The rapid increases in the reconstruction start rate and the completion rate as a result of CMP prove the effectiveness of mutual help in housing reconstruction. However, quantitative evaluation cannot be made for whether the capacity of beneficiaries and communities to cope with situations has been reinforced through the CMP. Still, it is considered that the CMP could reinforce the capacity of beneficiaries and communities to cope with disasters in the future at least in the form of accumulated knowledge on the importance of sharing accurate information and extending mutual help to promote recovery from disasters through their experience.

6.2 Summary

With respect to the practical approach for BBB with IR in the process of recovery from earthquake disasters, this paper systematically organized a variety of measures to reduce disaster risks from the viewpoints of the differences in the factors causing vulnerability, subjects of vulnerability and the types of hazards on the basis of the definition of BBB, and summarized the discussion results as “the staged efforts considered to be effective for assistance in housing reinforcement taking into consideration inclusiveness in the process of recovery from earthquake disasters” (Table 8).

In addition, this paper evaluated the implementation processes of the JICA's Emergency Housing Reconstruction Project in the recovery work from the Nepal earthquake from the viewpoint of the summarized staged efforts and evaluated whether or not the project simultaneously achieved BBB and IR. The evaluation result is summarized in Table 9.

In summary, the JICA's Emergency Housing Reconstruction Project could not fully go through the stages shown in Table 8 but could minimize the vulnerable beneficiaries who would have been gradually left

Table 9: Evaluation result of JICA's Emergency Housing Reconstruction Project

	Name of stage	Evaluation result of JICA's Emergency Housing Reconstruction Project	
First stage	Setting of potential hazards level	△ (Fair)	The project failed to deliberate on setting objective and reliable potential hazard levels in the real sense of the term but set the best potential hazards practically possible in the middle of the confusing period immediately after the earthquake for enhancing adherence to existing building standards.
Second stage	① Deliberation of Minimum Requirements	○ (Good)	The project established specific and detailed Minimum Requirements on the basis of scientific data and these were utilized as the standards for inspecting reconstructed houses with inspection errors in an allowably limited range.
	② Identification of vulnerable groups	× (Poor)	The project did not intend to disaggregate vulnerable beneficiaries from the initial stage but should have done it before starting the project.
Third stage	Deliberation of the contents of additional assistance	△ (Fair)	The project should have addressed this issue in its initial stage together with the identification of vulnerable beneficiaries but the implementation of the CMP can be regarded as ad hoc additional assistance.
Fourth stage	Universal implementation of all assistance programs	× (Poor)	The project took a long time until the identification of vulnerable beneficiaries in the end and failed to universally extend assistance across beneficiaries.
Fifth stage	Reinforcement of capacity to cope through housing reconstruction projects	△ (Fair)	Although the project paid attention to the reinforcement of capacity to cope in the course of its processes, that was not enough and the possibility to implement programs enabling beneficiaries and communities to enhance their capacity to cope and reinforce their social systems should have been intentionally implemented or deliberated.

behind in the recovery processes over time by implementing additional assistance at an appropriate time. In the recovery work from earthquake disasters in the future, it is preferable to intentionally plan assistance programs by introducing the staged implementation of assistance from the very beginning of commencing it and to implement such assistance according to the stages of a project. The CMP itself is a measure accelerating the recovery processes of disaster victims having self-help capacity and, therefore, is considered to be a necessary and effective approach to satisfy BBB in the proper sense of the word. That is, in housing reconstruction projects in the future, it is necessary to implement programs like the CMP that can enhance mutual help right from the beginning, thereby overcoming several socio-economic and technical issues that are very complex and embedded in the community. Also, it deserves special consideration that additional

assistance is still necessary as the preparation for the emergence of vulnerable groups who cannot catch up with recovery processes even with mutual help.

7. General overview

This paper defined vulnerability so that such a definition is considered to be adaptable to wide fields beyond the academic one, with the MOVE framework advocated by Birkmann et al as a base. Although the MOVE framework focuses more on the vulnerability of a social system as a whole, this paper pointed out the importance of reinforcing personal assets owned by individuals and households in the case of those types of disasters like earthquakes for which measures to work on the generating sources of disasters are quite limited. Then, this paper discussed the ideal form of BBB in the recovery from earthquake disasters, and the difficulty

as well as points of concern in achieving both BBB and IR. This paper introduced the JICA's Emergency Housing Reconstruction Project and evaluated it from the viewpoints of the ideal way of achieving both BBB and IR.

Based on the above considerations, this paper argues that BBB and IR are concepts that do not conflict with but complement each other. There has been no case of sacrificing one of the two concepts in exchange for the other. In the case of the approaches to assisting the vulnerable households, it is not appropriate to relax the target level of technical requirements, or Minimum Requirements in the context of Nepal. Instead of that, we have to effectively identify people who are likely to be left behind upfront, and extend additional necessary assistance intended to reinforce the capability of these people to reduce their own vulnerability. The measures considered to be effective for achieving both BBB and IR introduced in this paper were not taken in the JICA's Emergency Housing Reconstruction Project. This project could minimize the risks of the vulnerable households who would have been gradually left behind from the recovery processes over time by implementing additional assistance, key components of which were the CMP and additional support for vulnerable households. The CMP as the measure to reinforce the approach to disaster victims stimulated housing reconstruction by their self-help efforts.

However, the CMP is, by nature, a measure accelerating the recovery processes of disaster victims having self-help capacity and does not target vulnerable households. Thus, it is necessary to prepare additional assistance separately in anticipation of the emergence of vulnerable groups who cannot catch up with recovery processes even with mutual help. Ideally, such additional assistance should have been implemented concurrently with the main assistance project from the beginning.

References

- [1] Birkmann, J. et al. 2013. 'Framing vulnerability, risk, and societal responses: the MOVE framework.' *Natural Hazards*. 67(2): 192-211.
- [2] GFDRR, 2019. About WRC4: Inclusion for Resilient Recovery. <https://www.gfdrr.org/en/WRC4>.
- [3] Nagami, K., 2018. Basic research on the support model for establishing recovery policies and plans on the basis of the sectoral classification evaluation of disaster vulnerability, for the realization of Build Back Better (published in Japanese). *International Regional Development Studies*, 32663 A No. 434. Tokyo Repository for Academic Resources, Tokyo. <http://id.nii.ac.jp/1060/00010076>.
- [4] NPC, 2015. Nepal Earthquake 2015 Post Disaster Needs Assessment Vol. A: Key Findings. National Planning Commission, Kathmandu. http://www.npc.gov.np/images/category/PDNA_Volume_A.pdf
- [5] Shimada, S. 2009. Introduction to the Vulnerability analysis on African rural society (published in Japanese). *E-journal GEO* 3(2): 1-16. https://www.jstage.jst.go.jp/article/ejgeo/3/2/3_2_2_1/article/-char/ja.
- [6] UNDP, 2018. What does it mean to leave no one behind? Discussion Paper, July. United Nations Development Programme, New York. https://www.undp.org/content/dam/undp/library/Sustainable%20Development/2030%20Agenda/Discussion_Paper_LNOB_EN_lres.pdf.
- [7] UNDRR, 2015. Sendai Framework for Disaster Risk Reduction 2015 – 2030. United Nations Office for Disaster Risk Reduction, Geneva. <http://www.unisdr.org/we/inform/publications/43291>
- [8] UNDRR, 2017a. UNDRR Terminology. <http://preventionweb.net/go/51750>.
- [9] Wisner, B. et al., 2004. *At Risk: natural hazards, people's vulnerability, and disasters*, Second edition. Routledge, New York. http://www.preventionweb.net/files/670_72351.pdf.



Effectiveness of Holistic Socio-technical and Financial Support to Enable Socio-economic Vulnerable Households to Build Earthquake Resistant Houses

Manindra Malla^a, Ajay Kumar KC^b

Keywords: *Earthquake resistant, owner-driven approach, socio-technical assistance, vulnerable, build back better.*

Abstract

Caritas Nepal supported 4775 households in Dolakha, Sindhupalchowk, and Kavrepalanchowk districts with a holistic shelter package that included both socio-technical and financial support in accordance with the guidelines of the National Reconstruction Authority (NRA). This study reports on the intervention where 4631 house owners (97%) built their houses. Ninety-six percent of the surveyed households had reported earthquake damage to houses and of these households, 99 percent have re-built houses using locally available materials such as stone, mud, wood, and bricks. However, 89 percent of the households said the financial support was not sufficient for house re-construction and had generated additional resources by labor sharing, loans and household income. Similarly, 402 single woman-led households and 77 households with people with disabilities also built their houses. The research questions for the study included: (a) were house owners, including socio-economically vulnerable families, mobilized for house construction by providing socio-technical and financial support? And, (b) Did the support influence the households to pursue build back better techniques or not? The study found that the socio-technical and financial support had enabled rural households, including vulnerable households, to reconstruct houses in owner-driven ways. However, the financial support provided was inadequate and households and community institutions helped each other by labor sharing and accessing loans and other resources in a coordinated manner. Further, the local people adopted build back better techniques such as earthquake resistant designs and technologies and re-built houses using the new technologies, including Compressed Stabilized Earth Brick (CSEB).

1. Introduction

This study reviews the effectiveness of holistic socio-technical and financial support provided by

Caritas Nepal to earthquake-affected communities. It attempted to answer two research questions: (a). Were house owners, including socio-economically vulnerable families, mobilized for house construction

a Caritas Nepal, Dhobighat, Lalitpur, GPO 9571, Kathmandu, Nepal, mail: manindra@caritas.org.np and mallamani2020@gmail.com.

b Abhiyantra Consultancy Pvt. Ltd., Babarmahal, Kathmandu, Nepal.



Picture 1: Bir Bahadur Tamang and his wife built their house (in photo) in the first quarter of 2017. Photo: Caritas Nepal.

in a coordinated manner alongside the provision of timely socio-technical and financial support? And, (b). Whether or not the support influenced households to pursue build back better techniques?

The study has revealed evidence to suggest that socio-technical and financial support was provided effectively and on time and as result 99 percent of 96 percent of households whose houses had been destroyed by earthquake had built earthquake-resistant houses by August 2019. The 4631 households had built houses through the owner-driven approach. The socio-technical assistance included 4-6 targeted household visits during construction. This helped socially vulnerable households, including 382 households of Dalits, 142 households of Majhis or fisher folk, and 298 households of indigenous people known as Paharis to build houses. Further, 402 single woman-led households and 77 households with disability in the family had built houses.

The financial grant covered only part (40-60%) of the construction costs and households managed additional resources through labor sharing, loans and personal savings, etc. The surveyed households had rebuilt using local materials and earthquake-resistant technologies. Most households (89%) used two or more local materials and three percent of households had used CSEB blocks. Most households (97%) felt safer in the new houses.

The survey locations were project sites of the Nepal

Earthquake Recovery Program (NERP), a project of Caritas Nepal.

Caritas Nepal had provided earthquake recovery services at 15 locations (Table 1). The socio-technical support and housing grants were provided in six locations from June 2016, and only socio-technical assistance for shelter was provided in additional seven locations starting May 2017. No shelter sector support was provided in two locations in Sindhuli.

In addition to housing support, Caritas Nepal had also provided support in drinking water, sanitation hygiene (WASH); livelihoods; disaster risk reduction (DRR); protection and psychosocial support; and school building construction. The recovery program ended in November 2019 (Malla, 2019). Caritas Nepal had identified the following as vulnerable households: single women-led households; households with people with disabilities (mental or physical); and economically poor households with elderly members and of discriminated caste groups, indigenous groups, and ethnic groups.

2. Methodology

The study used both primary and secondary information. Primary data were collected through an end line household survey of 524 households from a total of 9,409 households. The survey had sought to capture the variations across a wide geographical area. The survey was planned with 95 percent level of confidence and a five percent margin of error. This significant sample size had captured different social categories effectively, including ethnic groups, gender, people of various ages, etc. The study also organized focus group discussions with people of various ethnicities, caste, economic backgrounds, occupations and gender to collect qualitative information. The method also included semi-structured interviews with key informants at the community level. The informants were local leaders, trained beneficiaries, project personnel, local government officials, NRA officials, Housing Reconstruction Recover Platform (HRRP) personnel, officials from Grant Management and Local Infrastructure (GMALI), etc. The secondary literature consulted included the

Table 1: Nepal Earthquake Recovery Program sites

Village, Rural Municipality / Municipality	District	Households	Population	Intervention: Socio-technical (ST) assistance, Financial grant (FG), no shelter sector intervention (NS)
Orang, Bigu-2	Dolakha	565	2801	ST & FG
Bulung, Bigu-3		759	3762	ST & FG
Sailung-6		550	2726	ST only
Sailung-7		580	2875	ST only
Kalika, Sunkoshi-3	Sindhu-palchowk	656	3252	ST & FG
Thokarpa, Sunkoshi-1 and 2		1178	5839	ST & FG by
Sunkhani, Sunkoshi-5		771	3822	ST only
Yamunadanda, Sunkoshi-4		473	2345	ST only
Chandenimandan, Mandan Deupur-10	Kavre-palanchowk	1065	5279	ST & FG
Balthali, Panauti-11		546	2706	ST & FG
Sanowanthali, Chaurideurali-1		277	1373	ST only
Nagregagarche, Chaurideurali-2		389	1928	ST only
Majhifeda, Chaurideurali-3		498	2469	ST only
Baseswar, Golanzer-6	Sindhuli	510	2528	NS
Hariharpur Gadhi, Hariharpur Gadhi-1		592	2935	NS
Total		9409	46640	

Note: The Government of Nepal had provided housing grants in locations where Caritas Nepal did not provide financial support or housing grants.

(Malla, 2019)

Post Disaster Needs Assessment report, mid-term evaluation reports with case studies, reports commissioned and generated by Caritas Nepal.

3. Literature review

A paper on Socio-technical module in assistance: Promoting resilient reconstruction in the wake of a disaster, argued that “availability of a comprehensive socio-technical assistance package has a direct positive influence in the overall progress of reconstruction and can expedite towards the construction completion” (Dhungal, 2019, p.141). The authors observed that it was more likely that the reconstruction was quicker alongside more compliance with earthquake-resistant technologies where socio-technical support was available. Similarly, training programs had helped motivate communities and increase recovery success, which was one lesson learned from earthquake reconstruction at

Yogyakarta, Indonesia (Guidance Notes on Recovery Shelter, 2010). Other lessons learned from Indonesia suggested that seasoned skill workers, when trained, could accelerate the safer re-construction processes, and households could be trained in groups to take the messages wider within short periods.

Community involvement remains central to reconstruction after disasters. A study on a British Red Cross post tsunami recovery program in Maldives said, community involvement in post disaster reconstruction was important to the overall success of housing and infrastructure redevelopment and recommended designing post disaster re-construction programs that promoted involvement of beneficiaries and communities, to the extent allowed by the scale and context of any given situation. (Lawther, 2009)

Housing costs are an important factor to consider during reconstruction as it affects household decisions. One study on the cost of house re-construction in 28

earthquake affected districts of Nepal had found that the average cost of NRs. 631,000 and an average duration of 10 months was required to build a one-story house with two rooms. It added that besides the housing grants of NRs. 300,000, on average of NRs. 331,000 and 2-3 building seasons were required to construct a small-sized house (Magar, 2020).

4. Result and discussions

4.1 Social and economic composition of respondents

This section presents an analysis of survey data of 524 households from all major social groups in Nepal. Most of the respondents belonged to ethnic groups (40%), followed by Chhetri (21%), Brahmin (18%), Dalit (17%) and other disadvantaged groups (4%). Fifty-percent respondents were male and 48 percent female. A majority of the respondents (39%) belonged to the

40-59 years age group, followed by 31 percent in the 20-39 age group (Table 2).

The NRA had identified 402 single woman-led households and 77 households with people with disabilities in the seven ward locations where Caritas Nepal provided both socio-technical assistance and financial grant.

The monthly incomes of the survey households ranged from NRs. 10,000 to NRs 50,000. According to the survey, the reported income of 20 percent households was up to NRs. 10,000, 38 percent NRs. 10,001-20,000, 23 percent NRs. 20,001 – 30,000, 12 percent NRs. 30,001-50,000, and six percent of respondents had monthly income of over NRs. 50,000. Further, 69 percent ethnic households and 65 percent Dalit households were economically vulnerable (Shrestha, 2018).

Among the households, 82 percent were engaged in agriculture and livestock raising activities and 32 percent relied on wage labor as the main sources of

Table 2: Demographic information of respondents

Location District R.M. or Mun.-Ward No.	No of Surveyed HH	Age group				Gender		Ethnicity				
		13-19	20-40	41-60	60+	F	M	B	C	D	E	O
Dolakha	158	1%	34%	41%	24%	49%	51%	8%	30%	18%	45%	0%
Bigu_2	73	1%	42%	36%	21%	44%	56%	0%	21%	15%	64%	0%
Bigu_3	74	1%	27%	46%	26%	53%	47%	16%	28%	23%	32%	0%
Sailung_6	11	0%	27%	36%	36%	64%	36%	0%	100%	0%	0%	0%
Kavrepalanchowk	149	0%	36%	43%	21%	46%	54%	16%	10%	6%	61%	7%
Mandan Deupur 10	88	0%	35%	43%	22%	39%	61%	19%	1%	9%	59%	11%
Panauti_11	61	0%	36%	43%	21%	56%	44%	11%	23%	2%	64%	0%
Sindhuli	70	1%	29%	47%	23%	50%	50%	20%	4%	39%	34%	3%
Golanzer_6	70	1%	29%	47%	23%	50%	50%	20%	4%	39%	34%	3%
Sindhupalchowk	147	3%	26%	47%	24%	46%	54%	32%	31%	16%	16%	5%
Sunkoshi_1	52	6%	27%	40%	27%	48%	52%	42%	17%	15%	25%	0%
Sunkoshi_2	35	3%	29%	40%	29%	34%	66%	20%	57%	23%	0%	0%
Sunkoshi_3	60	0%	23%	57%	20%	52%	48%	30%	27%	13%	18%	12%
Total	524	1%	31%	44%	23%	48%	52%	19%	21%	17%	40%	4%

Note: for tables 3 and 4: R.M. = Rural Municipality, Mun. = municipality, M = Male, F = female, B = Brahmin, C = Chhetri, D = Dalit, E = ethnic and O = others such as Muslims, etc. (KC, 2019)

Table 3: Education, household heads and decision making in survey households

Location District RM or M-Ward No	Education Level						Household Head		Decision Maker in the family		
	No Education	Informal	School	10+2 grade	Bachelors	Masters & higher	F	M	Both	F	M
Dolakha	5%	9%	52%	26%	8%	0%	15%	85%	42%	14%	44%
Bigu_2	7%	11%	56%	21%	5%	0%	15%	85%	36%	12%	52%
Bigu_3	4%	7%	53%	26%	11%	0%	14%	86%	47%	15%	38%
Sailung_6	0%	18%	18%	64%	0%	0%	18%	82%	45%	18%	36%
Kavrepalanchowk	23%	15%	31%	22%	9%	0%	19%	81%	42%	19%	38%
Mandan Deupur_10	26%	14%	26%	26%	8%	0%	17%	83%	51%	16%	33%
Panauti_11	18%	18%	38%	16%	10%	0%	23%	77%	30%	25%	46%
Sindhuli	17%	7%	36%	26%	11%	3%	21%	79%	67%	10%	23%
Golanzer_6	17%	7%	36%	26%	11%	3%	21%	79%	67%	10%	23%
Sindhupalchowk	4%	6%	34%	28%	17%	11%	17%	83%	64%	8%	28%
Sunkoshi_1	8%	10%	27%	27%	13%	15%	15%	85%	58%	8%	35%
Sunkoshi_2	3%	6%	40%	29%	14%	9%	17%	83%	69%	9%	23%
Sunkoshi_3	2%	3%	37%	28%	22%	8%	18%	82%	67%	8%	25%
Grand Total	11%	10%	39%	25%	11%	3%	18%	82%	52%	13%	35%

income. Many of the wage laborers were involved in construction work. The subsistence farming activities included growing paddy, maize, wheat, vegetables, and fruits. Livestock rearing included chicken, goat, cows, and buffalo (Shrestha, 2018).

4.2 Earthquake damage and a summary of support provided

According to the end line survey, 96 percent houses had been destroyed by the earthquake. After the disaster, 98 percent of the families had to stay in temporary shelters. Eighty-six percent households had obtained tarpaulin and 83 percent CGI sheets from Caritas Nepal. The households (96%) were provided other forms of shelter by Caritas Nepal in the relief/recovery phase, this included NRs. 300,000 as housing grants. The locations where the grants were provided are detailed in Table 1. In addition, Caritas Nepal had provided NRs. 50,000 each to households of Bigu 2 & 3 of Dolakha as transportation support (Malla, 2019).

4.3 Socio-technical services were crucial for reconstruction

There is evidence suggesting that a majority of households, including vulnerable households, developed both knowledge and confidence to build back better following orientations and technical guidance. For example, 48 percent respondents selected the house design themselves from among options in the Department of Urban Development and Building Construction Catalogue I. Another 48 percent had sought Caritas Nepal's advice to select house design, and four percent selected the design with the support of other people. Most respondents (96%) were satisfied with the earthquake-resistant designs.

A large proportion of respondents (75%) said orientation and trainings carried out during the recovery process had helped them to pursue earthquake-resistant house construction. Ninety-two percent households said the technical support was important for obtaining knowledge for building safer houses. Of

Table 4: Socio-technical support

Particulars	Number of households who received both socio-technical and financial support in 7 wards	Number of households who received only socio-technical assistance in 7 additional wards
Socio-technical assistance provided	4631 households	4088 households
Percentage of enrolled households as per the NRA list	97%	86%

(Malla, 2020)

these households, 45 percent said technicians had visited them for monitoring and supervision more than six times; 43 percent reported 4-5 visits; and 12 percent said they were visited 2-3 times. Local people trained and hired as social mobilizers by Caritas Nepal were knowledgeable of local geography and vulnerability of local households. They worked with engineering technicians to mobilize communities for reconstruction. Caritas Nepal employed 3-4 engineering technicians, five local social mobilizers and one village coordinator at each location. The socio-technical support included guidance on selecting house design, preparing layout, monitoring construction work, filling up grant application forms after various stages of construction, and guiding households to work collectively to address challenges.

Among beneficiaries, one said, “We have constructed an earthquake-resistant house... The house

has bands in the wall to make it stronger. After training, we were able to put to use ideas we had learnt. We cannot be dependent on others all the time. It is high time to do things by ourselves” (Personal interview: Ek Raj Thakuri of Orang, Bigu-2).

The socio-technical support enabled communities to address local challenges. These included improving road access, improving access to human resources, accessing materials and water for construction, accessing soft loans from cooperatives, and sharing labor for construction. A large proportion of households in Dolakha (66%), 31 percent in Sindhupalchowk, and three percent in Kavrepalanchowk said they had shared labor to offset costs. Labor sharing is a local practice where households work for each other for building houses, for planting or harvesting crops, and other types of local work.



Picture 2: Budha Maya Majhi in front of her new house at Chadeni Mandan, Mandan Deupur-10, Kavrepalanchowk. Photo: Caritas Nepal



Picture 3: A house owner in front of her reconstructed house, Bulung, Bigu 3, Dolakha. Photo: Caritas Nepal

4.4 Role of trained masons

The study found that trained masons led the reconstruction effort in the villages by providing the needed skills for earthquake-resistant construction and by organizing teams for the work. According to 54 percent of new house owners, the trained masons had helped them build their earthquake-resistant houses. Another 14 percent respondents said they were working as masons after being trained by Caritas Nepal. The organization had trained 758 masons, including 25 women, in 13 locations. Many of the masons came from low income and poverty-level households. A participant at a mason training program in Sunkhani, Sunkoshi-5 said, “We learned many new techniques on earthquake-safe construction such as size of foundation, band connection at damp proof, lintel and window sill levels, and roof detailing” (Personal interview: Jagat Bahadur Khatri of Sunkhani, Sunkoshi-5). With new knowledge and skill, this respondent’s wage had increased to NRs. 900 per day from NRs.600 before the earthquake. He had rebuilt around 60-70 houses at the time of the interview. The following paragraphs contain feedback received from trained masons.

Tek Bahadur Majhi, Chandanimandan: “I used to work as a helper in a bus before the earthquake and earned very little money. After developing skills and knowledge on masonry and plumbing through training from Caritas Nepal, I shifted my profession to the construction sector and now I am getting a better income. It has become a turning point in my life.” (Shrestha, 2019, Page 41)”

Raj Kumar Thakuri, Orang, Bigu-2: “After the masonry training, I worked in the construction of more than five dozen houses in this community and nearby villages, profiting about NRs.11,000 on an average from each house”. (Shrestha, 2019, Page 28)

Mrs. Swostika Khatri, Orang: “People are surprised that women can work as masons to build walls

and structures. I am very glad to have received the masonry training. I am an independent woman now and do not have to ask for money from my husband. ... I have become healthier after I started working as a mason”. (Malla et. al, 2019, Page 28)

4.5 Use of financial support and additional resources

Caritas Nepal provided shelter grants through NRA approved banks in market locations near the villages. Most of the beneficiaries could reach the bank and return to their homes on the same day. In case of residents of Orang, sometimes it took more than a day for grant recipients to return from the bank due to limited transportation services on the village road.

According to the end line survey, 99 percent of supported households in Kavrepalanchowk and Sindhupalchowk districts, and all supported households from Dolakha district had received the final installment of housing grant by August of 2019. This included 402 single woman-led households and 77 households that had people with disabilities. The grant disbursement was much higher than the aggregate data reported by the Housing Recovery and Reconstruction Platform (HRRP) on 31 August 2020. HRRP said, 88 percent of 18,505 NRA-identified vulnerable households, had received the first tranche, 64 percent the second tranche, and 55 percent the third tranche (HRRP, 2020).

In the project area, 52 percent of households had received the final payment within one month after the completion of construction, while 42 percent received it within two to three months of completion. The release of the final installment was delayed for six percent households due to challenges in the verification of completion and in obtaining approval of concerned authorities. In some cases, payment of the tranches was delayed by the absence of the head of household. The person whose name was in beneficiary card was out of district due to employment, and the grant was only paid to the person whose name was on the beneficiary card.

Caritas Nepal had agreed to provide NRs. 200,000

housing grant per household in 2016 and increased the amount to NRs. 300,000 per household in 2017 to comply to the change in the NRA's housing grant policy (Malla, 2020). In addition to housing grant, it had also provided transportation top-up support of NRs. 50,000 to 1413 households in Bigu-2 &3, and an additional toilet construction fund of Rs.25000 to 250 vulnerable households. It was found that the grants provided were not fully sufficient to rebuild houses and can therefore be considered partial support. Eighty-nine percent respondents said the grants were not sufficient for rebuilding houses. Drawing from studies, it can be estimated that grants of NRs. 300,000 to NRs. 350,000 covered about one-half of the average house building cost of NRs. 631,000 (Magar, 2020).

Households managed the deficit through various means: 47 percent had obtained additional fund themselves; 15 percent had obtained soft loans from cooperatives; and 15 percent had managed the costs through labor exchange. The labor exchange was widespread in Orang (Bigu-2) and Bulung (Bigu-3) of Dolakha, where 66 percent households had exchanged labor to support house construction.

Besides housing support, Caritas Nepal also provided livelihood grants of NRs. 22,000 to NRs. 35,000 to poverty level and low-income households. About 81 percent households said that their food security

had improved. Further, 47 percent households said they could invest in shelter reconstruction because of timely livelihood restoration (KC, 2019).

4.6 Time taken for house construction

A study undertaken in 28 out of the 32 earthquake-affected districts found that 70.25 percent households had completed reconstruction of houses in June 2020 (Magar, 2020). Compared to this general reconstruction status in June 2020, the reconstruction of 99 percent houses in the NERP project area was completed 10 months earlier in August of 2019. This indicates that the socio-technical assistance and financial support provided in the surveyed locations, had – among other factors – expedited the reconstruction process.

The average house re-construction period was 10 months for a one-story house (Magar, 2020). In the project areas surveyed, 63 percent households completed construction within three months and 18 percent within six months (figure 1).

The local people said timely construction of houses was possible because of additional investments made by Caritas Nepal to address limiting factors such as repair of access roads and support to communities to

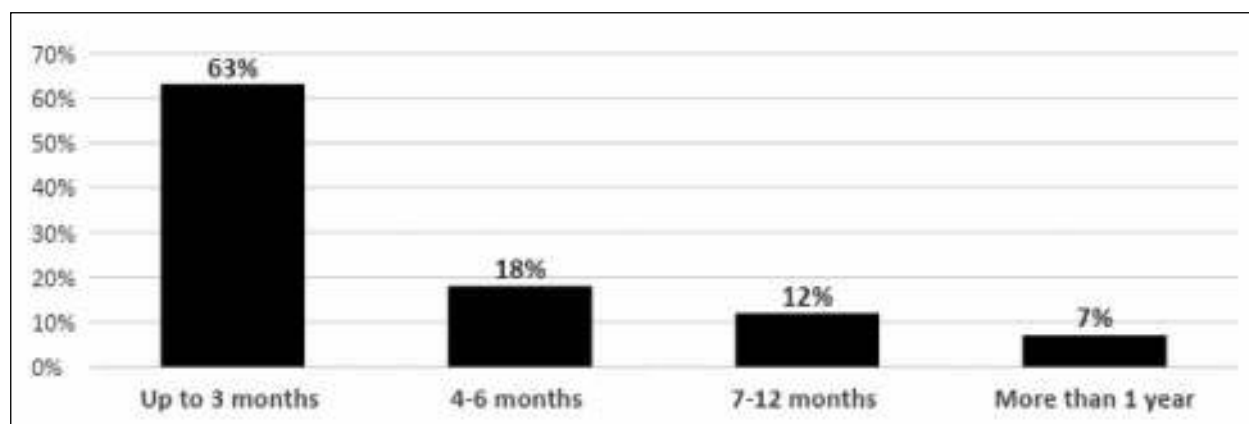


Figure 1: Time taken for house construction by households. (KC, 2019).

Picture 4: House of Maya Kanchi Tamang, Balthali, Panauti-11, Kavrepalanchowk. Photo: Caritas Nepal



access water for construction. According to Shrestha (2018), the improvement of water supply and distribution of storage tanks in some locations had helped reconstruction work. Further, improvement of access and roads through “cash for work” activities had also accelerated construction.

The local government at Orang or Bigu-2, Dolakha organized a “shelter construction completion ceremony” on May 13, 2018 to celebrate reconstruction of 560 of 565 houses enrolled for reconstruction support on the NRA list. The event was covered by a national newspaper as it was the first major report on house completion after the earthquake (Manandhar, 2018). The progress was notable because even in October 2018, the average percentage houses reconstructed in similar middle-hill locations of Nuwakot was 18 percent to 63 percent. (Dhungel, 2019) The reconstruction efforts in the surveyed villages were continued because NRA had identified additional beneficiaries after reviewing their grievance applications. Caritas Nepal ended its reconstruction effort in November 2019.

4.7 Houses built by economic and socially vulnerable households

In the surveyed villages, households belonging to socially vulnerable groups had built houses and 55.3 percent of the households who had rebuilt their houses, belonged to marginalized indigenous, ethnic and discriminated caste groups (figure 2).

Those completing house construction included all single woman-led households and all households with people with disability identified by NRA in the locations surveyed. There were 402 single women led households and 77 households with people with disabilities at the locations (Malla, 2020). (Table 5).

The vast majority of the surveyed households (92%) said they were able to build back better because of the socio-technical assistance that was provided. This indicated that the support was effective for mobilizing households to build houses despite their economic or social status. In the project areas, 58 percent households had monthly incomes of less than NRs. 20,000 in 2015 (Kumar, 2015) but all of them had rebuilt houses in August of 2019.

In Majhi Gaun of Chandanimandan Caritas Nepal

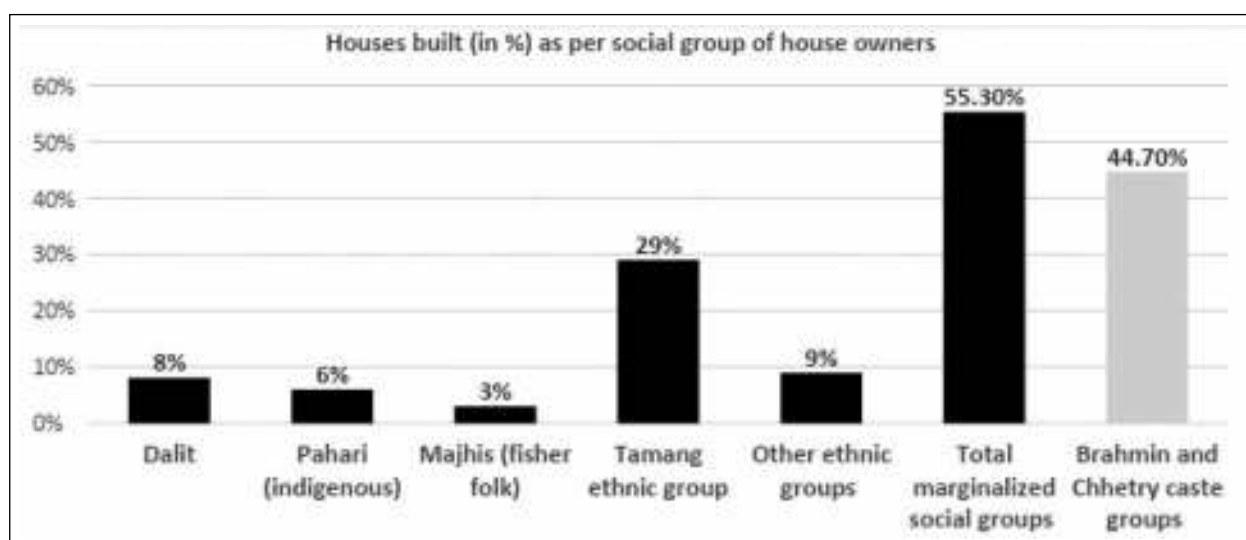


Figure 2: Houses built by different social groups (%)
(Malla, 2020)

Table 5: Number of houses built in terms of social group of house owners

S.N.	Social Group	No. of Houses
1	Dalit (marginalized caste group)	382
2	Pahari (indigenous group)	298
3	Majhis (fisher folk, indigenous group)	142
4	Tamang (ethnic group)	1324
5	Other ethnic groups (Magar, Newar – mainly Shrestha, Bhujel, etc.)	416
6	Total for Dalit, indigenous, ethnic households	2562
7	Brahmin and Chhetri caste groups	2069
8	Number of house owners who built houses with both financial and socio-technical support from Caritas Nepal	4631

(Malla, 2020)

provided additional support such as its truck for transporting construction materials purchased by the community, and a solar water pump to secure water for drinking and construction purposes.

A joint evaluation of the project by the Social Welfare Council, NRA and the Ministry of Women Children and Social Welfare reported on houses built by the most vulnerable households after receiving the reconstruction grant and socio-technical support. It also noted that Caritas Nepal had built model or demonstration houses for selected vulnerable households in the communities. In this way, 26 model houses

provided housing to the vulnerable households and also served as examples on the use of earthquake resistant technology.

4.8 Use of local materials and new technologies

People built back better by selecting earthquake-resistant designs while using local materials for construction. All (99%) households were approved to receive the final tranche of financial support based on field inspection of compliance to earthquake-resistant building designs and techniques. Almost all surveyed households (97%)

Table 6: Earthquake-resistant model houses built for vulnerable households

S.N.	Vulnerability criteria	Number of model houses/ beneficiaries' households
1	Widow with family	5
2	Single woman-parent led household	8
3	Households with people with mental and/or physical disability	3
4	Only child in household (supported by relatives)	2
5	Economically poor households (having elderly members)	8
6	Total	26

(Malla, 2020)



Picture 5: Model house constructed by Caritas Nepal for two widows. Location: Balthali, Panauti -11, Kavrepalanchowk. Photo: Caritas Nepal

said they felt safer in the new houses built by using local materials such as stone, wood, mud, and sand (figures 3 and 4).

4.8.1 Local materials used for reconstruction

The percentage of earthquake resistant houses built using locally available materials is presented in figure 3. Most houses (89%) were built by using two or more local materials.

Figure 4 shows a majority of houses built were of stone mud masonry (45%) and brick cement masonry (39%). These used two or more local materials.

HRRP reported that the median cost of stone masonry house was NRs. 550,000, brick masonry house NRs. 710,000 and that for reinforced concrete house was NRs. 2,050,000 for the different earthquake affected

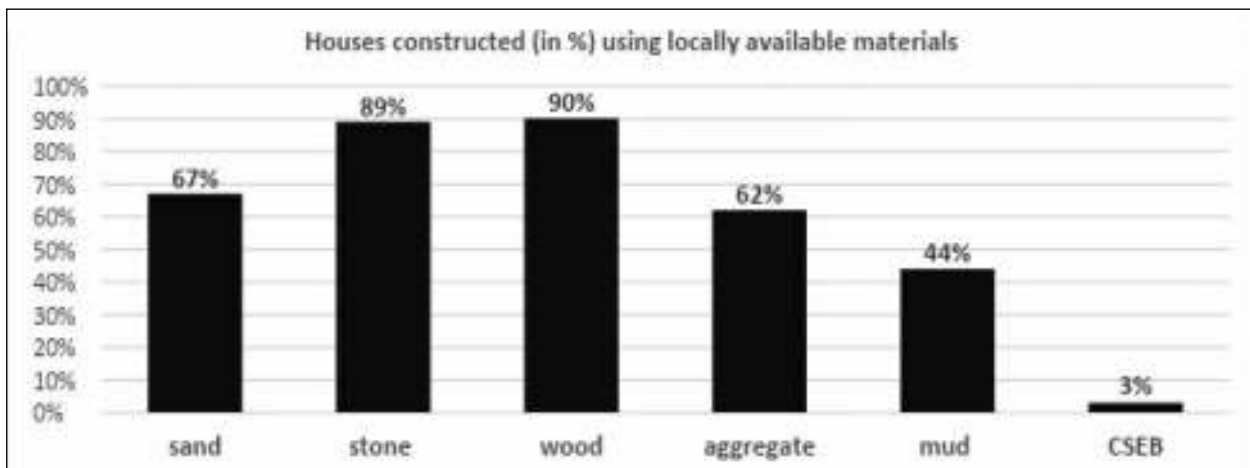


Figure 3: Houses constructed using locally available construction materials (KC, 2019)

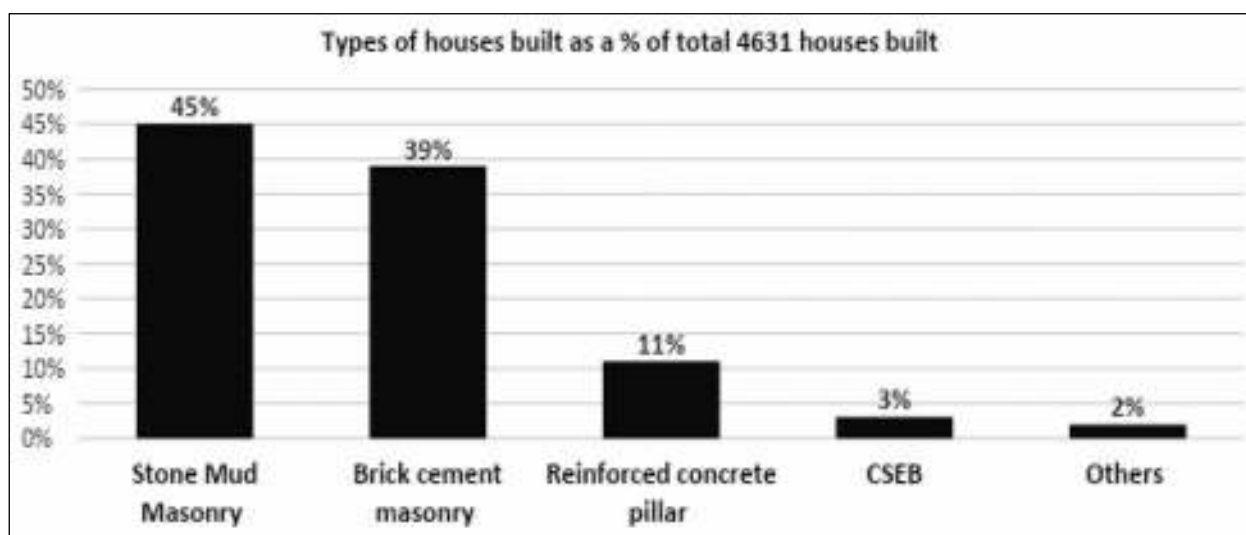


Figure 4: Types of houses built (%)
(Malla, 2020)

locations in Nepal (HRRP, 2018). In the project area, the people had built houses at 65 percent -73 percent lower cost if they chose stone mud masonry and brick cement masonry over concrete houses. Hence, it can be inferred that use of local materials helped the surveyed households to undertake cost-effective reconstruction.

4.8.2 Houses built using locally produced CSEB

In Thokarpa (Sunkoshi 1 & 2), Caritas Nepal provided three CSEB-making machines and trained communities to work together to produce bricks. In the end, 120 houses using CSEB were built by people from various social groups in Thokarpa (figure 5).

Thereafter, masons were trained to construct houses using CSEB that were much larger compared to earth bricks from kilns and required less mortar. Reinforcement of the walls with horizontal or vertical iron bars could also be done easily. CSEB technology was “highly efficient” in producing bricks locally in areas where brick supply was scarce (Caires, 2019). One Chitra Kumari Khanal had completed her house with NRs. 650,000. She said building house using CSEB was cost effective, climate responsive and looked nice. The bricks were also locally produced and easily available

(Shrestha, 2019). Shelter construction support provided helped in introducing CSEB for brick production and using them to build houses.

4.8.3 Perceptions of safety in new houses

Among the households surveyed, 97 percent said they felt their houses were safe because they had followed earthquake-resistant construction practices; 92 percent



Picture 6: Durga Devi in front of her CSEB house in Thokarpa, Sunkoshi.

Photo: Caritas Nepal

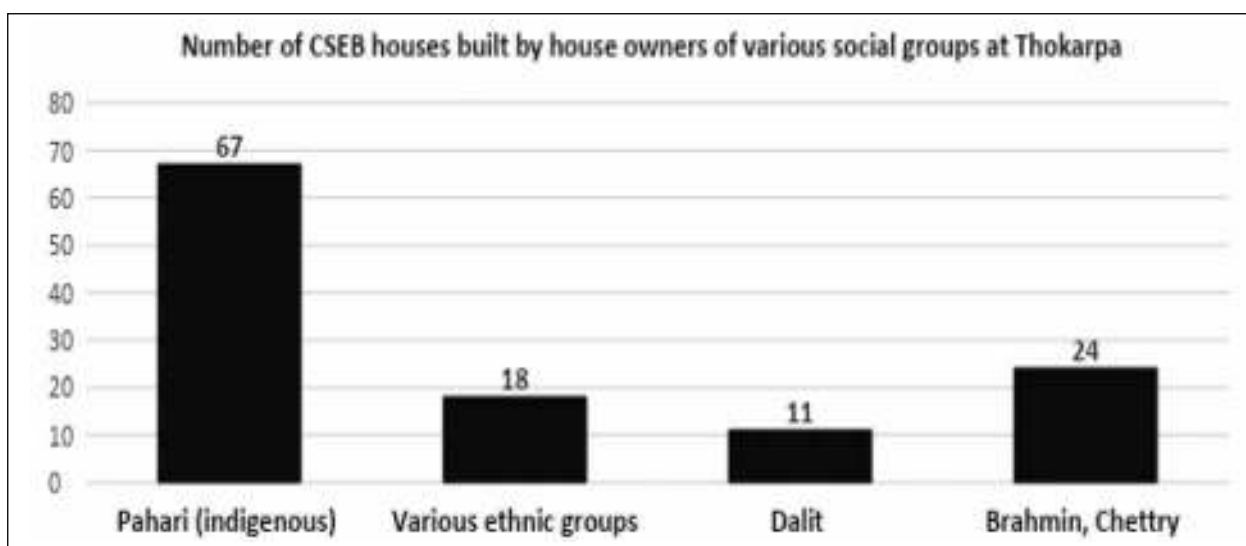


Figure 5: CSEB houses built by various social groups at Thokarpa (Malla, 2020)

households said good quality construction was assured by the presence of field level technical staff; 54 percent households said availability of trained masons made good quality construction possible; and 31 percent households said they were able to do quality construction because of training and orientation received.

4.8.4 Improved toilets

Almost all surveyed households had built new toilets and or improved existing toilets. The percentage of households reporting having toilets was: 99 percent in Dolakha, 100 percent in Sindhupalchowk, 100 percent in Sindhuli, and 91 percent in Kavrepalanchowk. The



Pictures 7 & 8: An elderly lady living all by herself has constructed a house and a toilet with septic tank, Bulung Bigu-3, Dolakha. Photo by: Caritas Nepal

few households without toilets used those of neighbors. A survey in six locations of Dolakha, Sindhupalchowk, and Kavrepalanchowk had said open defecation had increased after the earthquake had damaged more than 93 percent toilets in the villages (Kumar, 2015). The toilets were constructed next to the reconstructed houses. Many had a separate room with a pan and an external septic tank, while others had room with a pit toilet.

5. Conclusion and recommendations

There had not been a large-scale house reconstruction campaign in the middle hills of Nepal prior to the Gorkha earthquake (2015) recovery effort. It was a challenge for all agencies engaged in reconstruction to provide solutions for reconstructing safer houses in a timely manner. The end line survey undertaken in the NERP locations has made the following conclusions on the shelter reconstruction.

The survey found that Caritas Nepal had provided socio-technical and financial support as per the guidelines of NRA and this approach was effective in mobilizing households for re-building houses. Almost all supported households (99%) had rebuilt their houses by November 2019; 63 percent had built earthquake-resistant houses within three months.

All 402-single woman-led households and 77 households with people with disability listed by NRA in the project locations had built houses. The survey revealed that socio-technical assistance was done in a targeted manner and was an important factor contributing to timely completion. Eighty-eight percent households were visited at least 4-6 times by local socio-technical teams.

Another finding suggested that access to technology and use of locally available materials was important. The model houses used provided design options and local resources were also available. Most households (89%) used two or more local materials to construct houses. Although 96 percent households were satisfied with the house designs, many said the designs did not provide attic space for storage

This paper confirmed one main principle of disaster

risk reduction, i.e., disaster-affected people have an underlying capacity to contribute to reconstruction and recovery, and efforts have to be made to achieve high community participation. The socio-technical training and mobilization efforts had helped the project to tap into the underlying capacities. Not only did the 99 percent households build their own houses, but many (33%) also contributed labor to help others to build houses. The training of masons helped by providing individuals to lead the process as well as skilled labor. Local production of CSEB was a vital input for building 120 houses in Thokarpa. The communities had also jointly addressed challenges to reconstruction by working to ensure access to water, facilitate transport by repairing roads, etc.

The following are the recommendations of the study:

1. An integrated approach, involving socio-technical assistance, financial grants, and promoting owner-driven construction is suited for the middle hills of Nepal.
2. Social mobilization approaches applied for reconstruction should seek high participation of disaster-affected people. Such efforts need to focus on building local capacity and to organize the communities to address reconstruction challenges. The socio-technical assistance should be provided in a targeted manner to reach the vulnerable households.
3. Technical support strategies, including orientation of neighborhood groups, mason training, model house construction, and individual household level technical guidance need to be provided in locations where families cannot afford to hire engineers.
4. Earthquake-resistant house designs promoted should be based on local needs and should encourage use of local materials. Local governments need to develop suitable house designs as a pre-positioning activity taking into consideration people's need for living space, animal sheds, toilets, and common spaces.
5. Housing grants for locations with low incomes

and high poverty should cover at least of one-half of the cost of rebuilding a house. Additional provisions should be considered to help the communities to address limiting factors of shelter reconstruction. This may include additional support for transportation and soft loans for vulnerable households.

Acknowledgement

The authors thank members of earthquake-affected families for actively participating in the project's end line survey. The authors also thank local government leaders and officials at the NRA, Social Welfare Council, and the Ministry of Urban Development and Building Construction; and Caritas Nepal and Caritas International (Rome, Italy) for supporting the study.

References

- [1] Caires, F. et al., 2019. End of Programme Evaluation of Nepal Earthquake Recovery Programme of Caritas Nepal. Caritas Internationalis, Rome, Italy. <https://community.caritas.org>.
- [2] Dhungel. R. et al., 2019. Socio-technical module in assistance: Promoting resilient reconstruction in the wake of a disaster. Journal Nepal Geological Society. Volume 58, pp. 139-144. Kathmandu.
- [3] Guidance notes, 2010. Guidance notes on shelter. International Recovery Platform, Kobe, Japan.
- [4] Housing Typologies, 2018. Housing Typologies: Earthquake Affected Districts. HRRP, Lalitpur, Nepal.
- [5] HRRP, 2020. Housing Recovery and Reconstruction Platform. Bulletin 31 August 2020. HRRP Nepal, Lalitpur.
- [6] KC, A. et al., 2019. End of Project Evaluation Household Survey of Nepal Earthquake Recovery Programme (unpublished). Abhiyantra Consulting Pvt. Limited, Kathmandu.
- [7] Kumar, R., & Agrawal, S., 2015. Post Disaster Need Assessment Survey. Caritas Nepal (unpublished), Lalitpur.
- [8] Lawther, P.M., 2009. Community involvement in post disaster re-construction – Case Study of the British Red Cross Maldives Recovery Program. International Journal of Strategic Property Management. ISSN: 1648-9179. <https://doi.org/10.3846/1648-715X.2009.13.153-169>
- [9] Magar, M.T. et al., 2020. The Influence of Reconstruction Mandates and Affordability on Nepal's Post Earthquake Housing Reconstruction. National Reconstruction Authority Symposium, 24-27 August, (unpublished). Kathmandu.
- [10] Malla, M. et al., 2019. Achievement, Good Practices and Case Studies of Nepal Earthquake Recovery Programme. Caritas Nepal, Lalitpur.
- [11] Malla, M., & Karki, D., 2020. Report of Caritas Nepal on Nepal Earthquake Recovery (unpublished). Caritas Nepal, Lalitpur.
- [12] Manandhar, R., 2018. Uthyo Orang. Kathmandu Daily, page 2, May, 14. Kantipur Publications, Kathmandu.
- [13] Policy and Guideline, 2017. Policy and Guidelines. National Reconstruction Authority, Kathmandu.
- [14] Shrestha, B. et al., 2018. Monitoring and Evaluation Report -Shelter Construction Support to Earthquake Affected Households (unpublished). Caritas Nepal, Lalitpur.
- [15] Shrestha, B., 2019. Best Practices and Case Studies of Shelter Project in Nepal Earthquake Recovery Programme in Dolakha, Sindhupalchok and Kavrepalanchok Districts (unpublished), Caritas Nepal, Lalitpur.
- [16] Shrestha, E. et al., 2018. Development Phase Need assessment for Caritas Nepal Development Lalitpur (unpublished), Center for Development and Justice, Kathmandu.



The Influence of Reconstruction Mandates and Affordability on Nepal's Post-earthquake Housing Reconstruction

Minar Thapa Magar^a, Uttam Paudel^b, Sneha Malani^c

Key words: *Nepal earthquake, recovery, reconstruction, house size, tranche deadline, house extension, affordability, adequacy, reconstruction trends, housing finance, build back better*

Abstract

This paper analyses how the reconstruction mandates such as tranche deadlines have translated on the ground in terms of functionality, usage, and long-term resilience of reconstructed houses. As of June 2020, or more than five years after the 2015 earthquake, 70.25 percent of households had completed the reconstruction of their houses. However, we have no data on how many of these households live in newly constructed houses or continue to use their damaged homes. On average, the house size in Nepal has decreased from 51-75 m² to 26-50 m² from the pre- to post-earthquake periods, excluding verandahs. Adhering to the tranche deadlines of NRA's reconstruction grant, the affordability of beneficiaries and communication gap, rural reconstruction has witnessed a trend of building of one storied houses with 1 or 2 rooms. The study investigated this trend, and has concluded that the one or two-roomed houses do not serve the households' functional spatial needs, could face a long-term structural risk on future extension, and pose an increased level of risk to beneficiaries using their old damaged houses. By analyzing the gaps in the affordability and adequacy of reconstruction, the research advocates for effective policies and strategies for incorporation in the ongoing-recovery and resilience efforts and contributes to lessons that can be drawn from Nepal's experience.

1. Introduction

In Khotang district, a stone masonry house without earthquake-resistant elements that was built soon after the earthquake, stands behind the new house or *Bhukumpa Ghar* (earthquake house referring to the one rebuilt with government support). The house owner was building the new house in order to access the grant

as shown in the leftmost picture of Figure 1. Similarly, in Khiji Chandeshwari, Okhaldhunga, the homeowner had built a new house which has only a kitchen and one bedroom (on the right-hand side of middle photo). The family had continued using the damaged house (on the left-hand side of the middle photo) to store grains and belongings because the new one was not big enough.

a National Coordinator, HRRP, minar@hrrpnepal.org; minar.thapa23@gmail.com;

b Emergency and Recovery Manager, CRS Nepal, uttam.paudel@crs.org;

c Urban Recovery Advisor, HRRP, sneamalani@gmail.com;



Figure 1. The earthquake resilient small houses built in front of old damaged houses (Photo Credit BBC Media Action and DFID Nepal)

In Gatlang, Rasuwa, new one-roomed structures were being constructed to access the Government of Nepal (GoN) housing reconstruction grant. But the traditional houses, mostly reconstructed in 2015, did not comply with the building code and technical requirements under the grant process (NRA, 2017). Therefore, investment is required in research and testing to develop relevant corrections/ retrofitting measures so that the new traditional houses can be strengthened to reduce risk from future earthquakes (see: right most photo of Figure 1).

Owing to geography and climatic conditions, Nepal is one of the most disaster-prone countries in the world (ECHO, 2019). An earthquake of magnitude 7.8 on the Richter scale struck Nepal on 25 April 2015. The earthquake was followed by 300 aftershocks, out of which four were higher than magnitude 6 (PDNA Vol. B, 2015, p. 11). The earthquake and its aftershocks resulted in over 8,790 casualties and 22,300 injuries. According to the Post Disaster Needs Assessment (PDNA, 2015), it was estimated that the lives of more than eight million people, almost one-third of the population of Nepal, was impacted. Thirty-one of the country's 75 districts were affected, out of which 14 were declared 'crisis-hit' (PDNA Vol. B, 2015, p.11).

The 2015 Gorkha, Nepal earthquake and its aftershocks induced more than 13,000 landslides in earthquake-affected districts (Tsou, et al., 2018). A geohazard survey after the earthquake said that 4,067 households faced the hazard based on a survey conducted in 1,022 settlements by NRA (Durable Solutions, 2020). Every year, Nepal faces high human casualties

due to manmade or natural disasters.

1.1 Housing and house size in Nepal before earthquake

Through the early 2000s, the average number of rooms in Nepali houses increased from 3.7 (2003/4) to 4.6 (2010/11) and the average size of the dwelling increased from 531 sq. ft (2003/4) to 605 sq. ft. (2010/11) (NUDS B, 2017, p.27). The need for rooms and dwelling size increased every year as the existing dwelling was not adequate to accommodate people and their needs.

Approximately 85.6 percent of the households lived in their own house. In rural areas, 93.8 percent lived in their own houses compared to 75.3 percent in urban areas. In Nepal, 4.5 rooms are available for a household on average. The average size of a household in Nepal is 4.5 people, which is 4.3 in urban areas and 4.7 in rural areas. There are 16.9 percent nuclear households (with 1-2 members). Nearly half (47.1 %) of the household heads are in the age group 30 to 49 years and 24.8 percent households are headed by female members, which may be due to the high proportion of male labor out-migrants. (CBS & UNDP, 2015/16, p.3-14).

1.2 Nepal's recovery program

The Grant Management and Local Infrastructure (GMALI) Central Level Program Implementation Unit (CLPIU) reported that of 832,408 households eligible for the NRs. 300,000 (US\$ 2530) GoN reconstruction grant, 94.41 percent had signed the partnership agreement

with the GoN. The median cost to build a house is NRs. 650,000 (US\$ 5400). Costs range from NRs. 1,00,000 (US\$ 840) for stone masonry mortar (SMM) houses to NRs. 10,00,000 (US\$ 8400) for construction of RCC houses in Kathmandu and Lamjung (HRRP, 2020)

In May 2015, emergency shelter assistance was provided to more than 1.2 million households in the 14 most-affected districts. The GoN, through the National Reconstruction Authority (NRA), began planning the owner-driven housing reconstruction program in June 2015. The program included a housing reconstruction grant of NRs. 300,000 (US\$ 2530), provided in three tranches linked to compliant construction – NRs. 50,000 (US\$ 420) upon signing a partnership agreement, NRs. 150,000 (US\$ 1270) after completing the foundation, and NRs. 100,000 (US\$ 840) upon completing the walls. A retrofitting grant of NRs. 100,000 (US\$ 840) was also available to households whose homes had been partially damaged. This grant was provided in two tranches of NRs. 50,000 each (US\$ 420). In addition, the NRA and the Housing Recovery and Reconstruction Platform (HRRP) defined a core package of socio-technical assistance activities to complement the GoN financial assistance. (HRRP, 2019)

The objective of the Nepal Rural Housing Reconstruction program was to “ensure that houses destroyed in the most-affected districts of the country would be rebuilt using earthquake-safe building techniques through grants and technical assistance to eligible households from the Government of Nepal” (HRRP, 2017b).

Some of the key principles for reconstruction stated in the PDNA were:

- Reconstruction should empower communities to take control of their recovery facilitated through the Owner Driven Reconstruction (ODR) approach.
- Reconstruction should become a vehicle for building long-term community resilience. (PDNA Vol. B, 2015, p. 4)

The NRA's broad policy objectives were:

- To reconstruct, retrofit and restore the partially-and completely damaged residential, community and government buildings and heritage sites, to make them disaster resistant using local technologies as needed.
- To reconstruct damaged cities and ancient villages to their original form, while improving the resilience of the structures. (PDRF, 2016, p.6)

The NRA was established for a five-year period and its term was extended for one more year (until the end of 2021), during which all identified recovery and reconstruction activities are expected to be completed. The estimated budget solely for the housing sector is US\$ 3,278 million (PDRF, 2016, p. 44).

1.3 Progress of Nepal's recovery program

In June 2020, the GMALI reported that of 832,408 households eligible reconstruction grant, 94.41 percent had signed the partnership agreement with the GoN, 93.67 percent had received the first tranche, 77.99 percent the second tranche, and 70.24 had received the third tranche. Of the 78,031 households eligible for retrofitting grant, 63.24 percent had signed the partnership agreement, 62.57 percent had received the first tranche, and 0.21 percent households had received the second tranche. The GoN had disbursed more than US\$ 1.67 billion to earthquake affected households. In addition, more than US\$ 150 million had been invested by the GoN and Partner Organizations (POs) in socio-technical assistance (CLPIU GMALI, 2020).³

1.4 Objectives

As mentioned above, 70.24 percent of households (HH) enrolled in the reconstruction program had received

³ This data is dynamic and is updated daily. The data can be accessed online through reconstruction status dashboard in CLPIU GMALI Website or MoUD CLPIU website or HRRP Monthly Bulletins.

the third tranche and had thus completed the reconstruction (HHs that had received 3rd tranche were considered as “house completed”, GMAIL-CLPIU MIS, 29 June 2020). However, no data exists on how many of these households live in newly reconstructed houses or continue to use the damaged houses. There also is no data on houses that were either repaired or used in the same way. The damaged houses are those which were listed as not habitable during CBS damage assessment. The households were required to either demolish or retrofit based on the published repair and reconstruction beneficiaries lists. On an average, the house size in Nepal has decreased from 51-75 m² to 26-50 m² in the pre- to post-earthquake periods. Adhering to the tranche deadlines and the limited affordability of beneficiaries, rural reconstruction has witnessed a reduction in the house size. The shift has been from two story to one story and from four-roomed houses to 1 or 2-roomed houses, which do not serve the family needs functionally and could face a long-term structural risk when the houses are extended in future. Moreover, there is considerable risk associated with continuing to live in the house that was damaged in the earthquake.

Considering the quantitative progress in private housing reconstruction, this paper analyses the quality aspects of how the reconstruction mandates such as tranche deadlines have translated on the ground and the ability of beneficiaries to add to the government subsidy, along with the lack of communication that impacted the reconstruction in terms of functionality, usage and the long-term resilience of reconstructed houses. The earthquake resistant building standards following Nepal’s building code have not been discussed as this study only focuses on functionality and sufficient living space of reconstructed houses. The adequacy of appropriate construction is considered to assess and analyze the functionality of the house based on the need of living space by the people.

The research gap relates to the information on reasons why people built small houses inadequate for their required living space needs, thus contributing to an additional risk to people continuing to live in old houses and the increased structural vulnerability of

the houses due to unsafe modifications of new houses. The paper aims to suggest evidence-based recommendations for ensuring the adequacy and safety going forward.

The paper attempts to respond to the following research questions:

- Are the newly reconstructed houses adequate to meet the functional needs of the family?
- How have the reconstruction mandates (tranche deadlines and disbursal) affected the size and functionality of reconstructed houses?
- How has the affordability of people contributed to change in size and adequacy of reconstructed houses? and
- How have communication gaps impacted the adequacy and functionality of the reconstructed houses?

1.5 Post-earthquake reconstruction: New trends in housing

Visualizing the floor area data from the CBS damage assessment, just 0.7 percent of more than a million houses assessed were less than or equal to 13.4 m² (the minimum allowed size for a house). The average floor area by earthquake-affected districts is presented in Figure 2. The green line is the normal size of the single storied, two-rooms design that had become very prevalent in earthquake-affected areas (31.75 m²), and the orange line is the minimum size allowed for a one room, one story house (13.4 m²).

In this section data from the Central Bureau of Statistics (CBS) damage assessment (CBS, 2015) – conducted by GoN to determine eligibility for the housing reconstruction or retrofit grants – is compared with data from the analysis conducted by HRRP and the Inter-Agency Common Feedback Project (CFP) in May 2018. The analysis conducted by HRRP and CFP involved analyzing photos of more than 2700 completed houses by field staff. There are obvious issues in comparing this analysis with the CBS damage assessment due to differences in methodology and sample size, along with

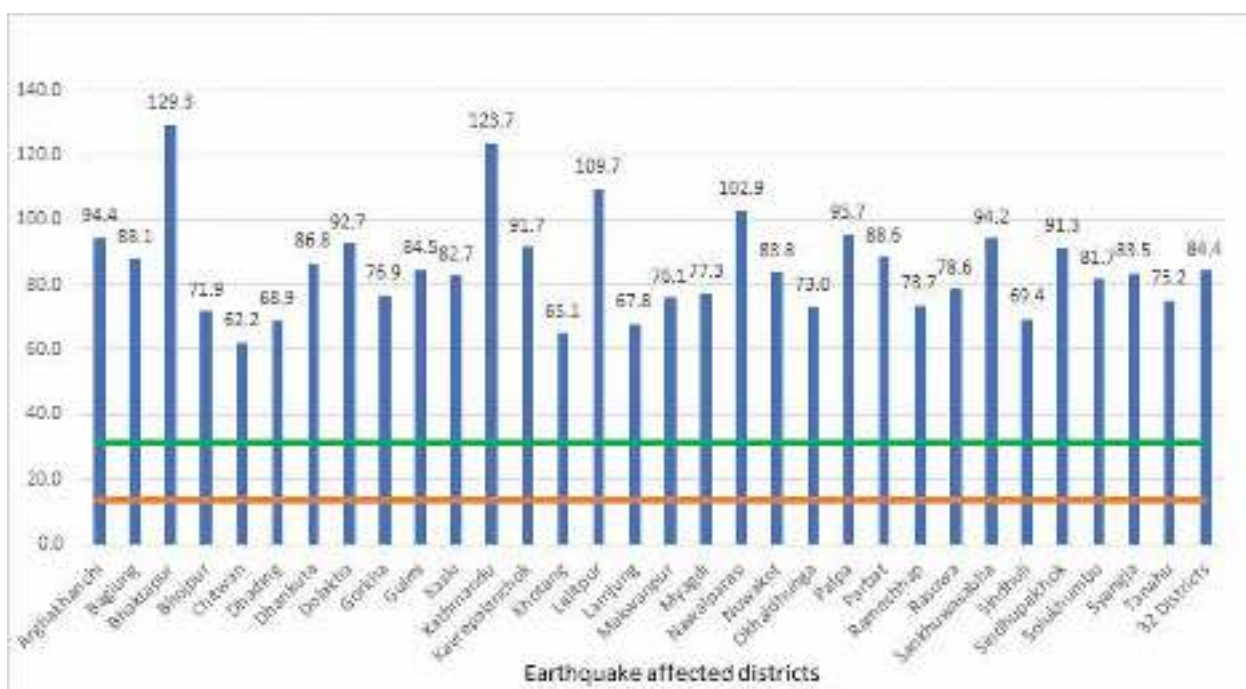


Figure 2: The Pre-EQ average floor area in sq. m. (CBS, 2015)

the 3-year time difference between both assessments. The inspection data collected by the GoN technical staff, would have been more appropriate for the comparison with the damage assessment data, but the data was not accessible for analysis (HRRP, 2019).

2. Methodology

The study uses data collected by HRRP and its partners. It has used data from both primary and secondary sources. The research was conducted using mixed methods, by collecting data and evidence from multiple sources and triangulating the information. The research uses primary data collected by HRRP and secondary data sources from past research and other external publications. The study focuses on analyzing the impact of the process and understanding the trend where the secondary data from responders plays a central role in terms of their experiences, and sharing knowledge from informed respondents at various levels. The secondary data and publications from

various partner organizations and HRRP itself contributed as the institutional memory of the process and where there was lack of evidence.

There was no marked difference in the coverage due to ethnicity, altitude, culture, tradition but remoteness may have had some level of influence in some locations. Primary data was collected by conducting household surveys during joint monitoring and other field visits. The scope of the assessment was to monitor the progress and assess the various aspects of construction in terms of adequate space, cost of construction, shape and size and various housing units like attic, toilets, kitchen, etc. The questionnaire was prepared by the HRRP team and it was administered in the districts and municipalities they visited. The data was collected in both urban and rural earthquake-affected areas in 28 districts through April 2019 to February 2020.

The survey was conducted with 568 respondents (0.068 % of total reconstruction beneficiaries) from 102 municipalities in 28 of 32 earthquake-affected districts as shown (figure 3). Most of the respondents were male

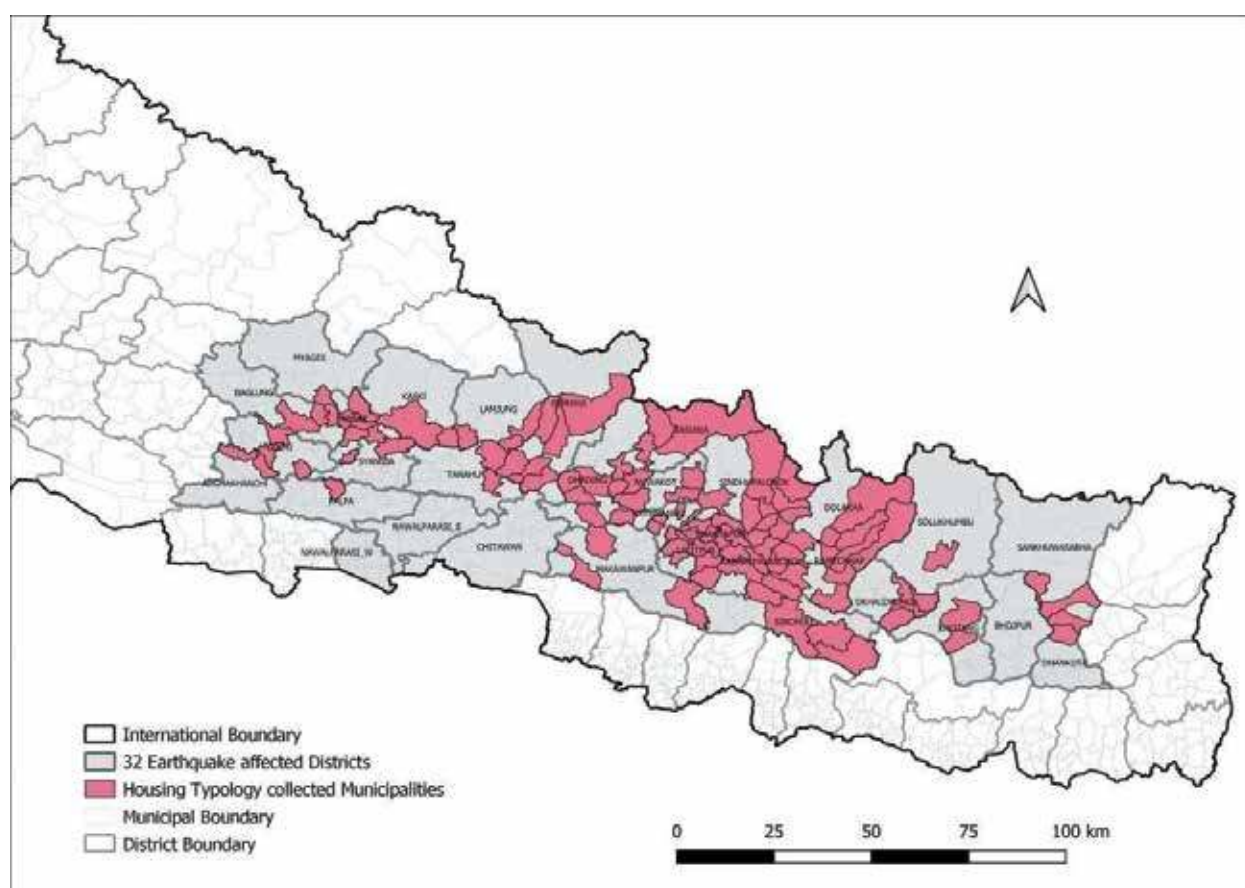


Figure 3: Map indicating municipalities covered under the household level survey

Source: HRRP, 2020

(80%) and 20 percent were female. The average family size was five.

According to the equations from Raosoft on determining the random sample size:

$$x = Z(c/100)2r(100-r), n = N x / ((N-1)E^2 + x), E = \sqrt{[(N - n)x/n(N-1)]}$$
 with the known total population size i.e., total number of reconstruction beneficiaries 823,385 and with confidence level 95 percent, margin of error five percent and response error 50 percent, the recommended sample size was 384. Considering the recommended sample as the minimum sample required, 586 samples were collected which is 52 percent more than the recommended number.

The secondary source of data was house size information of 42,266 households collected by HRRP partners, pre-earthquake house floor area from CBS damage grade assessment (CBS, 2016-2017) and data from other HRRP assessments. The NRA formal monitoring and inspection system has rich data but only the overall tranche status has been used due to limited access to data.

2.1 Limitations

The following is a list of limitations of the study.

- The data was collected in a 10-month timeframe where the response might be influenced by

- different seasons or time of the year
- The data is not stratified with altitude, remoteness and with socio-cultural aspects
- Findings and conclusions were drawn based on the sample data of 568 respondents from 28 districts by building on indirect linkages of the analysis based on response and other secondary evidence
- The data was collected from individual households and those in integrated settlement were not considered.
- Direct questions were not asked on household choice of building a small house, living in a structurally-compromised house and on not using the new house.
- Household economic situation and income were not considered during data collection.
- There was no access to detailed inspection data on tranche disbursement, shape and size and detailed construction that limited larger statistical analysis.

3. Findings

Various issues and processes influenced the trend of constructing small houses. Social, cultural and psychological issues were hard to diagnose and, in this paper, we have discussed the economic, governance and communication issues and processes. The study has discussed four major issues that contributed to this trend, i.e., tranche deadline, affordability, communication gap and adequacy of the new house.

3.1 Tranche disbursement deadline

Deadlines announced by the NRA for beneficiaries to sign agreements and receive all three tranches is referred to as tranche deadline. The CBS detailed damage assessment started eight months after the earthquake and the enrollment program, after 10 months. More than 1.5 years were required for NRA and the government to formulate the policy and kick off the disbursement process. In December 2016, almost 450,000 had received the first tranche after signing a participation agreement in 11 districts. There are two building seasons in Nepal with a six months of favorable construction time whereas at other times of the year, construction is affected by cold winter and the monsoon season. (HRRP, 2019) On top of these and other socio-political challenges, the NRA continued to face pressure to quickly complete the rural housing reconstruction program.

The NRA steering committee announced the first tranche deadline for disbursing housing reconstruction and retrofit grants in late July 2017 (*HRRP Bulletin*, July 2017), almost after eight months of its decision to increase the grant from NRs. 200,000 to NRs. 300,000 (HRRP, 2019, p.15).

After this announcement, the tranche deadlines were extended more than six times once about every six months, and a final tranche deadline extension was announced following the spread of coronavirus (COVID-19) in Nepal. The final extension was made on 28 June 2020 (NRA, 2020). With several extended tranche deadlines, there was an increasing rate of

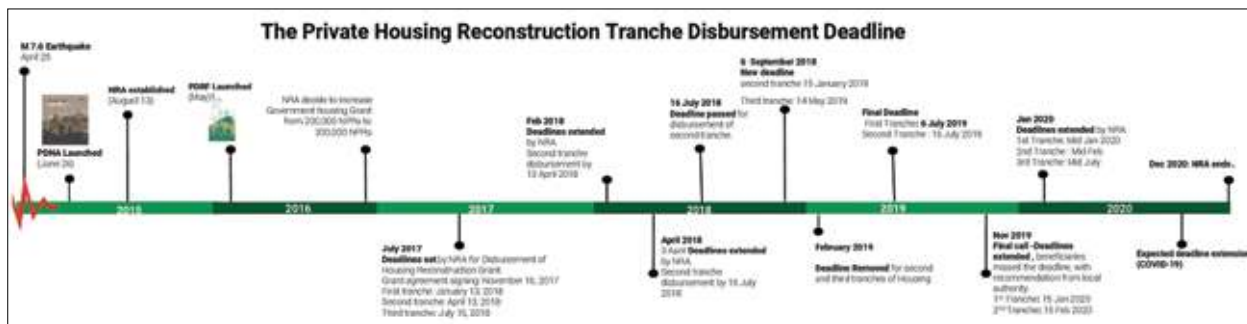


Figure 4: Timeline of the tranche disbursement deadline extensions

Source: Prepared by authors with data from HRRP, 2019; NRA Website

disbursement (see: figure 5). Further, the tranche deadlines have played a crucial role amongst other factors, in pushing the progress and maintaining the pace of reconstruction. Considering July 2017, when the first tranche disbursement deadline was set, the housing reconstruction pace increased and reached the peak in the second extension, in February 2018.

Further, there had been accelerated progress in housing recovery between 2016 and 2019. The number of people with housing damage who had done nothing to rebuild, decreased from 72 percent in 2016, to 56 percent in 2017 and 21 percent in October 2019. By late 2019, most people had fully repaired/ rebuilt (53%) or partially repaired/ rebuilt (26%). The majority had started rebuilding/ repairing in April 2016 – April 2018 (The Asia Foundation, 2020).

On 3 April 2018, the NRA Steering Committee agreed to extend the deadline for the disbursement of the second tranche to 16 July 2018 (*HRRP Bulletin*, 16 April 2018). The tranche deadlines represented an unrealistic and unplanned time frame for reconstruction for many households and proved to be counter-productive.

The HRRP together with other partners advocated for the deadlines to be extended to allow a realistic period for households to complete reconstruction. This was one reason why many households were building small houses to just get the grant for which they were borrowing at very high rates, increasing stress.

“Remove the tranche disbursement deadlines, or at least extend for the next two building seasons in rural areas and the next four in urban areas” (HRRP, 2018, p.3)

“The NRA deadline for earthquake victims to receive all grants for the reconstruction of private homes within the fiscal year 2017/18 (which ends in mid-July 2018) now has risks encouraging rushed reconstruction that does not meet building standards. Recommendation: The deadline for completing all household reconstruction by mid-2018 has the potential to create additional confusion and also impact building back better negatively. Develop and communicate flexible

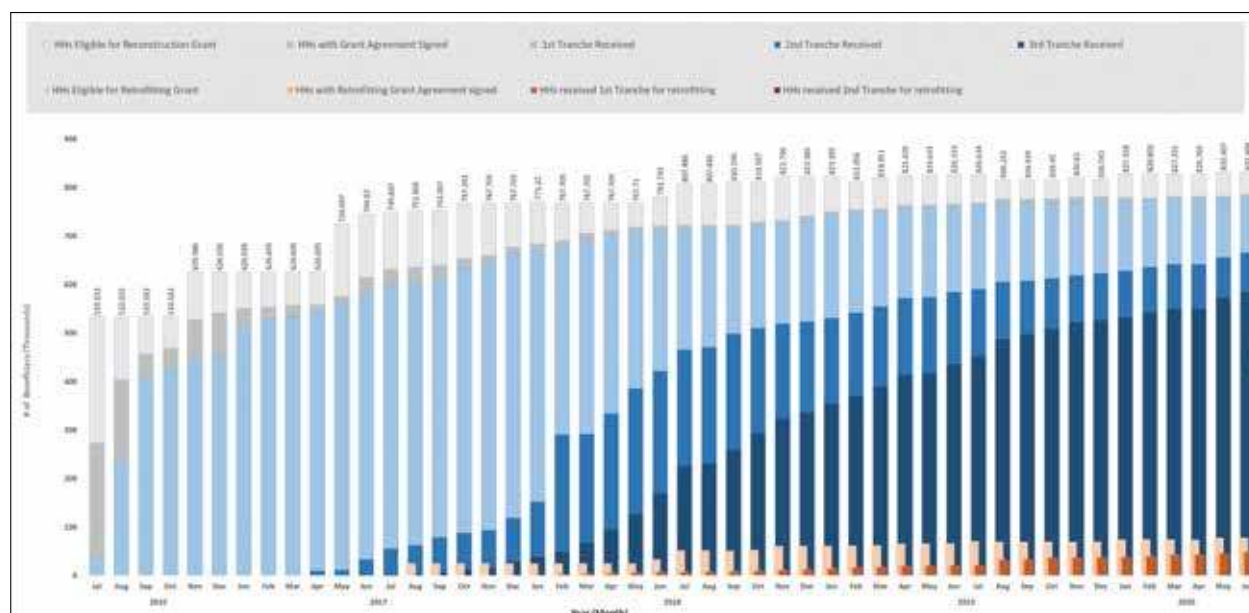


Figure 5: Reconstruction and retrofitting monthly tranche disbursement status

Source: HRRP Bulletin, 29 June 2020

plans for households who may miss the deadline”
(The Asia Foundation, 2017).

3.2 Affordability

The government provided reconstruction grants of roughly US\$ 2,530 to households that complied with earthquake-resilient building codes. Retrofitting assistance of US\$ 840 per household was introduced later in the reconstruction process. The government also made some low-interest loans available through the banking system, but access was extremely limited, and most earthquake-affected borrowers have had to find other sources, often at high-interest rates. The IRM (Independent Impacts and Recovery Monitoring) project found that the number of new loans, the amounts borrowed, and total household indebtedness had all increased significantly since the earthquakes. Facing this rising debt burden, a small but growing number of households have had to sell land and other assets. How this will affect their long-term resilience is not yet fully understood (Michaels, 2020).

The median cost to build a house is NRs. 650,000 NPR (US\$ 5400). Costs range from NRs. 1,00,000 (US\$ 840) for SMM houses to NRs. 10,00,000 (US\$ 8400) for building RCC houses in Kathmandu and Lamjung (HRRP, 2020). In terms of accessing finance, the annual interest decreased from 23 percent (2017) to 20.45 percent (2020) as analyzed in the cost of construction study, ranging from 0 percent, where two respondents

had taken interest-free loans from either their friends/ relatives/ neighbors, to 43 percent also from friends/ relatives/ neighbors (HRRP, 2017a & 2020). This showed that the access to loans from financial institutions was still challenging due to extensive documentation and collateral required.

In May 2018, the CFP community perception survey (CFP, 2018) had asked 2580 households “have you taken a loan to finance your reconstruction?” to which 55 percent respondents had said they had and the average interest rate was found to be 24 percent per annum (almost exactly the same as the HRRP data from October 2017, which was 23 percent per annum on average). The difference by housing status was striking, with respondents who had not yet started reconstruction begin much less likely to have taken a loan.

Among respondents to this study 21.8 percent of 568 households surveyed had taken loans to finance the reconstruction of their homes at an average interest rate of about 23 percent and a maximum rate of 36 percent from friends and relatives as shown in figures 6.1 and 6.2. The median cost of building a new house was NRs. 600,000 (US\$ 5000), with NRs. 100,000 (US\$ 840) as the minimum cost of construction of in Stone Mud Mortar Masonry (SMM) and hybrid structures in 3 districts (Kavrepalanchowk, Sindhuli and Tanahun districts). The cost of construction depended on the typology chosen and the district location.

The cheapest house constructed was in SMM and the expensive type was of reinforced cement concrete

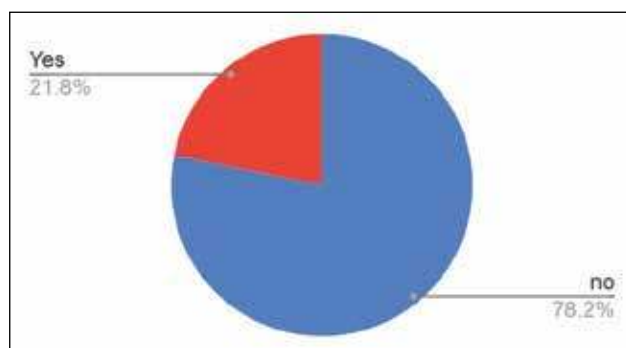


Figure 6.1: Loan status of respondents

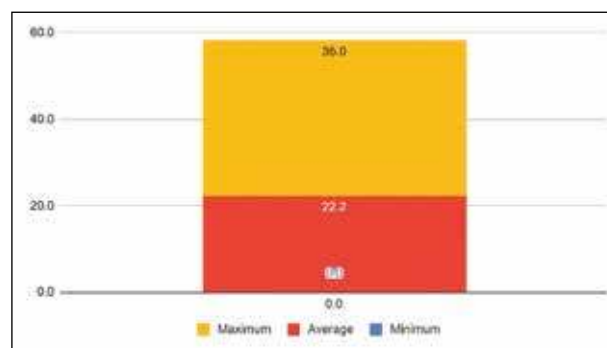


Figure 6.2: Minimum, average and maximum interest rate of loan taken by respondents

(RCC). The cost of house construction was higher within the Kathmandu Valley compared to other earthquake-affected districts. Based on our assessment, the average time taken for construction was 10 months with a maximum of 48 months including planning and management of the construction and grant process up to receipt of third tranche. This clearly illustrated that even with access to finance, it was very challenging to construct the house within one tranche deadline period of about 6 months. Though the government grant was a subsidy to contribute to the owner-driven reconstruction process, people did not have adequate savings or access to finance, and also time required to plan and construct an adequate house.

In Table 1 below, the data of various typologies of newly constructed houses with one story and two rooms has been analyzed, indicating the average cost in thousands and average reconstruction duration in months. The average cost of NRs. 631,000 (US\$ 5260) and the average duration of 10 months was required to construct one story house with two rooms, where NRs. 331,000 (US\$ 2760) additional investment and two to three building seasons were required to build a small house.

As of June 2020, 832,408 households were eligible for the GoN housing grant. If 50 percent of these households had taken loans of US\$ 3,250 (estimated amount as the additional investment required to top-up government subsidy) to construct a one story, two-roomed

house, that added up to more than US\$ 1.3 billion in debt. At an average interest rate of 23 percent per annum, the annual interest payment would be more than US\$ 300 million. At a household level, if a family was paying 23 percent as interest, it would pay almost US\$ 750 in interest annually on a US\$ 3,250 loan. If the same loan had a two percent interest rate, it would have paid US\$ 65 in interest annually. Over the course of a five-year loan period (likely a conservative estimate), the difference in the amount paid in interest comes to US\$ 3,425 (US\$ 3,750 for loan at 23% and US\$ 325 for a loan at two percent interest). Given the scale of the debt, livelihoods programs intended to improve household income, and in turn assist households to pay off debt. It would have been potentially cheaper, and more effective, for donors / GoN to look at options for clearing the debt and / or making the expected subsidized loans a reality.

3.3. Communication gap: Blacklist/ promotion of small-sized house

Mass communications campaigns are required to address confusion, misinformation, and rumors, some examples of which are listed below:

- “Blacklist” and impact of not meeting tranche disbursement deadlines: many people said they

Table 1: Comparison of number of stories and rooms; cost and duration of construction across dominant housing typologies. Source: Data analyzed from the households’ survey

New typology	No. of Story	No. of Room	Average construction cost (in thousand NRs.)	Average construction duration(months)
BMC (Brick in Cement Mortar)	1	2	656	9
BMM (Brick in Mud Mortar)	1	2	1000	4
HCB (Hollow Concrete Blocks)	1	2	850	9
Hybrid	1	2	1200	12
RCC (Reinforced Cement Concrete)	1	2	1333	4
SMC (Stone in Cement Mortar)	1	2	569	12
SMM (Stone in Mud Mortar)	1	2	514	11
Steel Frame	1	2	500	10
Grand Total	1	2	631	10

feared missing the tranche as they had heard that if the deadlines were missed, they would will lose their social security payments or their children would not be able to get citizenship certificates.

- Seventeen designs from DUDBC catalogue volume 1. The preface of the catalogue stated, "it is not mandatory for households to select a design from this catalogue, and they are free to prepare house designs outside of the catalogue but these designs must comply with the National Building Code" (DUDBC 2015). One design for SMC houses is given in figure 7.

However, this message was lost and distorted and many reconstruction actors (NRA, Building DLPIU

engineers, field staff, etc.) had been informing households saying that they could only rebuild using one of prescribed designs. Reconstruction actors at all levels consistently misunderstood the intention of the catalogue and considered the designs to be a mandatory part of the grant process. This was the information shared with households by GoN and implementing agency staff working at the local level.

- One room house: In some areas, there was a misconception that the only way to have an earthquake-resistant house, that was eligible for the reconstruction grant, was to build a one-storied, one-roomed house.

It is important to reflect on the lessons learned where the partner organizations and donors have promoted

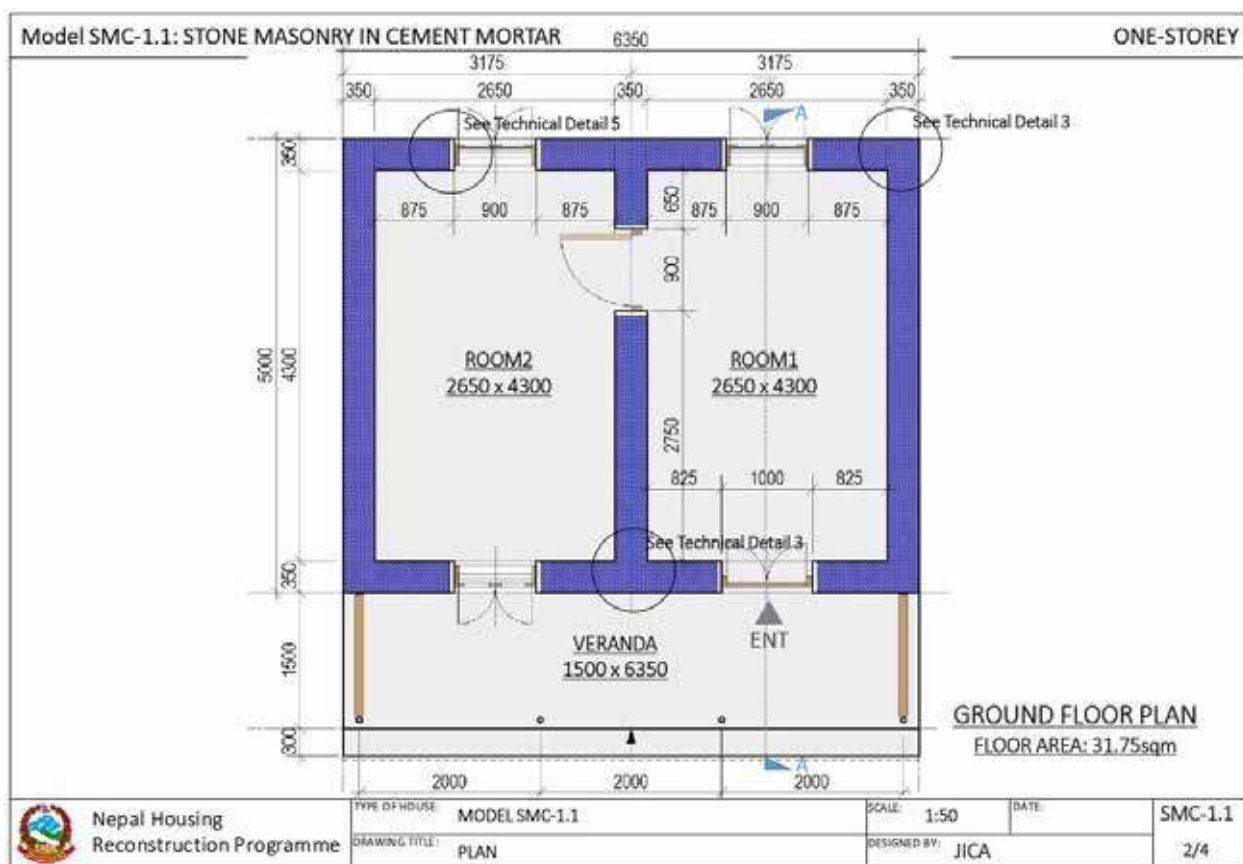


Figure 7: Plan of a SMC house from the Design Catalogue
 Source: DUDBC, Oct 2015, p.15

small-sized houses (one or two rooms) without considering the people's requirements, and choices. There are two significant examples of this; first, the "10 key messages" developed under the Shelter Cluster, and second, the demonstration house design and size that partner organizations (POs) and donors constructed and promoted (HRRP Bulletin).

1. The "10 key messages" was a leaflet developed through a working group under the Shelter Cluster over the course of several months in the second half of 2015. The leaflet was intended to provide information to support recovery and reconstruction and the eight messages of the were "build a strong shape" as seen in figure 8 (Shelter Cluster, 2015).

Whilst the message regarding shape was valid, the oversimplification of the issues around the number of stories was potentially misleading; stone and cement mortar masonry buildings could be constructed up to two stories under the Nepal National Building Code, but stone and mud mortar masonry was limited to one story plus attic under the NRA inspection manual. It may have been more useful to facilitate or advocate for increased investment in research and development of solutions for stone and mud mortar masonry buildings of more than 1.5 stories, brick and mud mortar masonry buildings, hollow concrete block structures, etc.

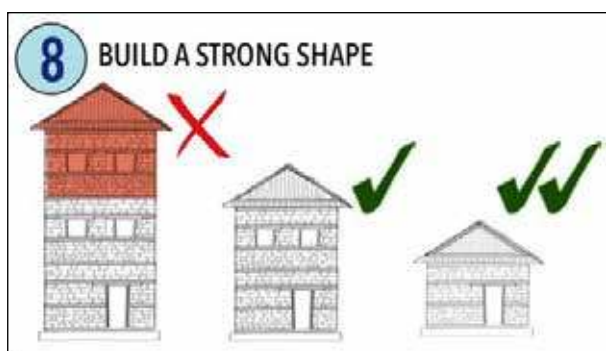


Figure 8: Excerpt of visual communication materials for households

Source: Shelter Cluster, 2015

The two-roomed house which is now ubiquitous across earthquake-affected areas, has been described as alien addition to the villages. This type of building was promoted by many implementing agencies and donors through the development of designs and construction of demonstration houses, etc. (Baniya, 2018).

2. Most of the demonstration houses/models constructed by partner organizations were one/two room houses and change in house size was an impact of replication.

3.4 Adequacy

"Adequate shelter means more than a roof over one's head: It also means adequate privacy; adequate space; physical accessibility; adequate security; adequate lighting, heating and ventilation; adequate basic infrastructure, all of which should be available at an affordable cost" (High Level Task Force, 2008). Some aspects of adequacy like structural safety (compliance to National Building Codes) and availability of toilets were well covered and was the focus of housing recovery policies, technical advice, and financial assistance. Considering the impact of mandates, affordability and communication gap in the house size and space adequacy are focused in this paper. In this research, adequacy of housing has been understood as usable house area in the context of Nepal's average family size and requirement.

3.4.1 House size

According to The Asia Foundation's Independent Recovery Monitoring Study in 2019 covering 5857 respondents, most households had built two-roomed houses (45%) and one-roomed houses (19%). Further, 31 percent had built three-roomed houses and 11 percent had built houses with four or more rooms. Approximately one-fifth of the respondents planned to extend the house incrementally in the future (The Asia Foundation, 2020).

The pre-earthquake house size data has been



Figure 9: Left: demonstration house in Aru Pokhari, Gorkha supported by an INGO working in the area. Right: a house constructed as part of on-the-job training for masons in Kavrepalanchok supported by an INGO. Source: HRRP, 2020

analyzed using the CBS damage grade assessment survey data and house size data from HRRP and POs with N=86,000 analyzed on 15 April, 2019. The graph (figure 10) clearly indicates that house sizes were generally becoming smaller after reconstruction. Based on the house size analysis, on average, the house size in Nepal has decreased from 51-75 m² to 26-50 m² in the pre- to post-earthquake period (HRRP, 2019).

Even for smaller families or single individuals, cramming a kitchen, bedroom, storage space, living area, space for work / business / agriculture, etc., into 13.4 m² (the minimum allowed size for a one-roomed house (119 NRA Executive Committee Meeting minutes, Decision 8), although there are houses smaller than this), is not something that would be an obvious choice. More so in the context of larger house sizes prevalent in Nepal. To put the 13.4 m² into context, the Shelter Cluster REACH survey conducted in November 2015 found that in their temporary shelter, people had on average 13 m² living space per person – far exceeding the Sphere Standards minimum of 3.5 m² per person (Shelter

Cluster Nepal, 2015, p. 38). Sphere and UNHCR standards for minimum space are explained in Table 2.

3.4.2 Attic

The attic is a very important component of the house in rural areas. It is used to store food and grains and also as living space in some circumstances. Low Strength Masonry (LSM) buildings were required to conform to this standard and not exceed two stories in height with

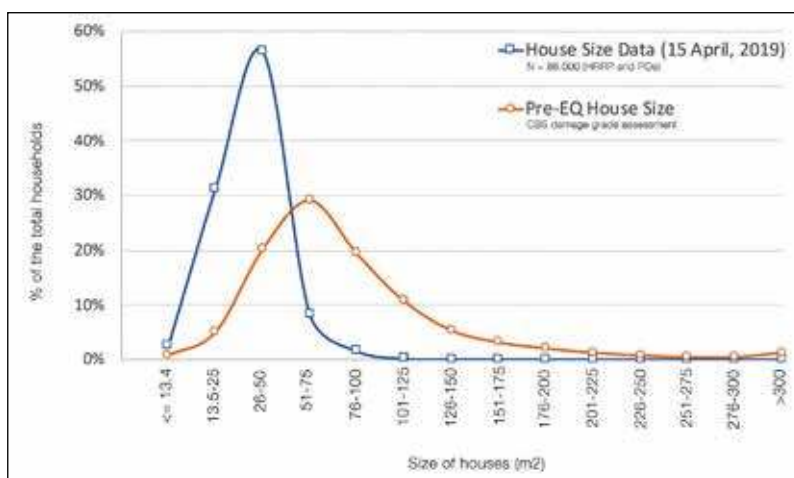


Figure 10: Comparison of housing size before and after the earthquake
Source: HRRP, 2019

Table 2: Minimum space requirements per person (camp vs settlement and shelter standards)

Space required	The Sphere project (2004)	UNHCR (2007)
Minimum surface area of camp per person	45 m2, including infrastructure	45 m2 per person recommended
Minimum covered floor area per person	3.5 – 4.5 m2	3.5 m2 in warm climate 4.5 – 5.5 m2 in cold climate or urban area

Source: Shelter Cluster Standards

an additional attic floor (NBC 203, 2015). Though Nepal National Building Code permits construction of attic for SMM and other typologies, the data showed that 77 percent respondents had an attic before the earthquake (figure 11.1) and only 30 percent had rebuilt houses with attic (figure 11.2). Or, more than half of the new houses didn't have an attic though we know it is very important for storing grains and for general storage. This suggested a decreasing trend in attic construction after the earthquake.

3.4.3 Story

Comparatively, more single-story houses have been built after the earthquake. As seen in figure 12, two story houses were more prevalent (54.4 percent) before the earthquake, which decreased after the earthquake (25 percent).

3.4.4 Room

Similarly, there has been an increase in the reconstruction of two room houses, where 38 percent of houses rebuilt had two rooms, where the average family size

was 4.6 (CBS & UNDP, 2015/2016). However, there has been a decrease in the construction of four-room houses after the earthquake (figure 13).

3.4.5 Enough living space

While most families had built houses, 15 percent considered that their houses had insufficient space for family members. Most houses built were single story and two-roomed, while the average family size was five. Thus, insufficient space in the new house was reason why some people had been using the old damaged houses as kitchen, storage and even for residential purposes. About 42.7 percent people didn't respond to this question as they were not sure about the space because they had not started construction and/or had just started or not completed construction.

The housing typology survey also showed that the average number of rooms rebuilt was three for families with an average of five members. This indicated that family members were required to adjust within the room and had no separate common room, kitchen, etc. The average family size of the households with such houses was five and their house had three and two rooms.

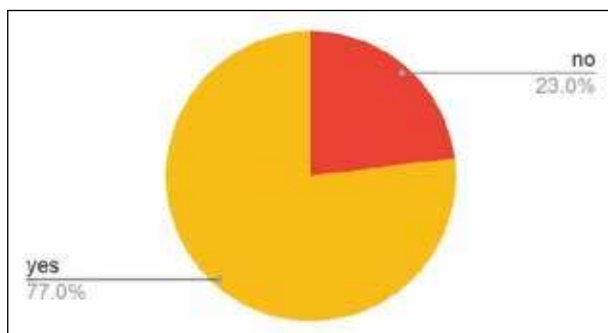


Figure 11.1: Households with attic before the 2015 earthquake

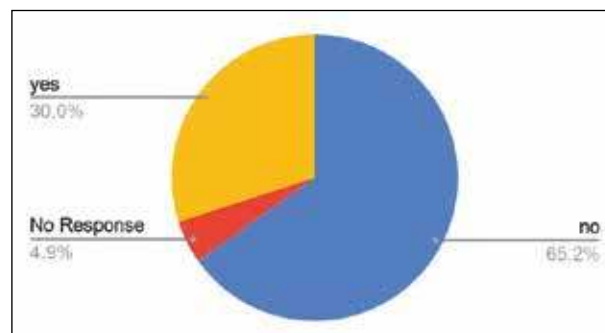


Figure 11.2: Households that constructed attics after the 2015 earthquake



Figure 12: Comparison number of stories built before and after the earthquake (%).

Source: Authors

The respondents who had built one-roomed houses (81%) did not believe that the space was sufficient for their needs and were planning to use the old structure, or continue to use their temporary structure, to supplement the deficit. Seven households said they had no plan to live in the one-roomed structure. (Rapid Assessment –Housing Reconstruction Progress in Gajuri wards 2, 5, and 6.

3.4.6 Occupancy of old damaged house

Reconstruction beneficiaries (66%) had demolished their old houses including houses that had collapsed in the earthquake while 20 percent were still residing in their old houses, using them as kitchen and for storage. Only 0.9 percent said they had not demolished the old houses and were also not using them (figure 15).

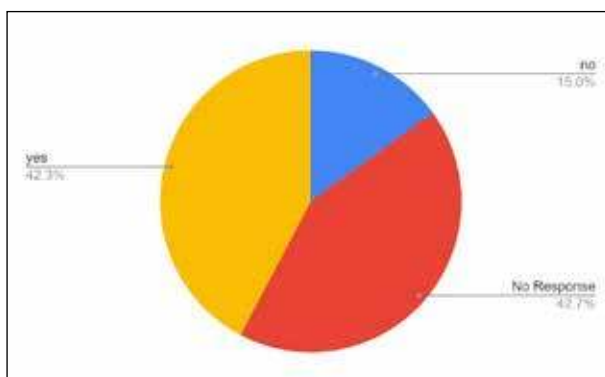


Figure 14: % of HHs living in new house have enough space

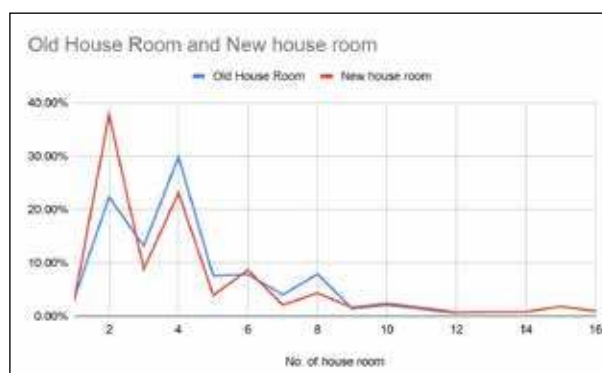


Figure 13: Number of rooms compared, before and after the earthquake (%)

Source: Authors

The main reason for not demolishing the old house was the high cost associated with the process, and the family's historical sentiments also played a role in decision-making.

Respondents who had not demolished the old house said the old houses were being used for residential (9.26%), as kitchen (5.56%) and storage (4.63%) purposes. This indicated that almost 20 percent families were still spending time in the damaged houses that increased the risk for those families. Not only the old houses were vulnerable but could also endanger other nearby structures.

The preliminary findings of the Independent Recovery and Monitoring Study, 2020 (The Asia Foundation, 2020), suggested that half of the people reporting some level of housing damage had not demolished their pre-earthquake houses – primarily those

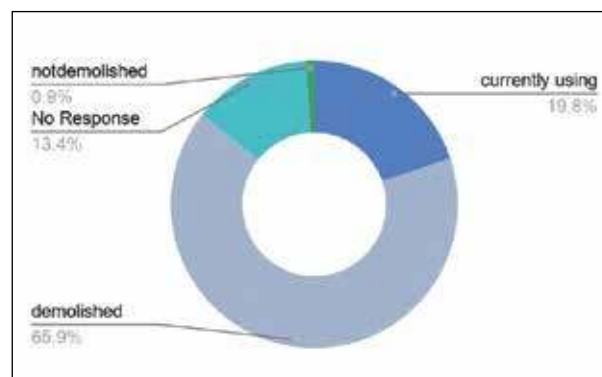


Figure 15: Occupancy of old damaged houses (%)

with low damages in districts that were not highly affected, and in urban areas. They were still using the damaged houses for multiple purposes, including to sleep in (85%), for storage (55%), and for livestock (11%). Houses with extensive damages in severely hit districts were more likely to have been demolished. Overall, 32 percent households reporting housing damages were currently living in a partially (10%) or fully (22%) repaired house i.e. repair or maintenance of the non-structural component of the house, while only three percent lived in a pre-earthquake house without any repairs. The results suggested that most of those who lived in pre-earthquake houses had done at least some repairs.

3.4.7 Occupancy in new house

Ninety-three percent of respondents reported living in their reconstructed house, whereas seven percent were not living in their new houses even after completion (Figure 16). They had continued living in temporary shelters, old houses, rented houses and in houses of relatives. (Figure 17)

3.4.8 Possible modification/ extension

Almost seven percent respondents had plans for the horizontal extension (figure 18) of the house, which points to the additional need for technical assistance and solutions to safely extend the new house in compliance with government standards and building code.

3.4.9 Availability of kitchen and toilets in new houses

New house

The new construction trends showed that kitchen space was not planned and prioritized during the reconstruction in rural areas. Twenty-eight percent respondents said they do not have kitchens and 30 percent did not have toilets in newly built houses (figures 20.1, 20.2). The government grant disbursement guidelines had mandated construction of toilets alongside each new house in order to be eligible for the third tranche. But

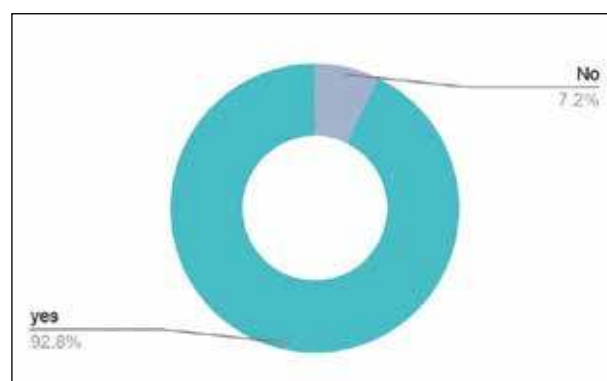


Figure 16: HHs living in newly constructed houses (%)

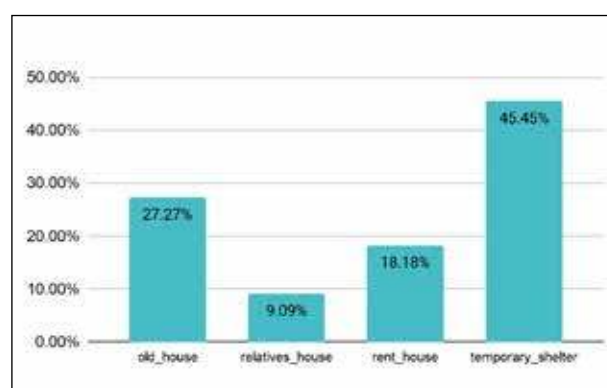


Figure 17: Living status of households not living in their reconstructed house

in the later stages of the reconstruction process, this requirement was not considered during inspection to recommend the third tranche. The grant disbursement procedures for private houses required construction

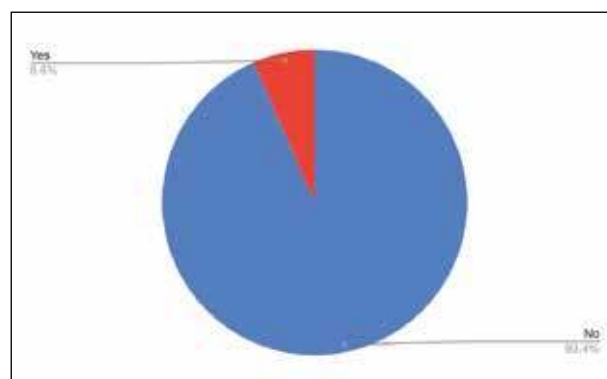


Figure 18: People planning to extend/modify new houses (%)



Figure 19.1: ASF-Nepal, SMM: Extension with earthquake resilient elements after receiving third tranche.



Figure 19.2: ASF-Nepal, RCC house: Extension after receiving a third tranche.

of a toilet or the installation of solar power, biogas or any other source of alternative energy, in order to qualify for the third tranche. Of the NRs 100,000 (US\$ 830) provided in the third tranche, NRs 75,000 (USD 625) was allocated for completion of reconstruction,

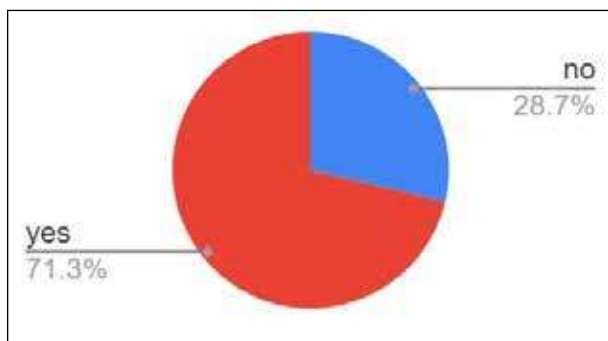


Fig 20.1: Reconstructed houses having a kitchen (%)

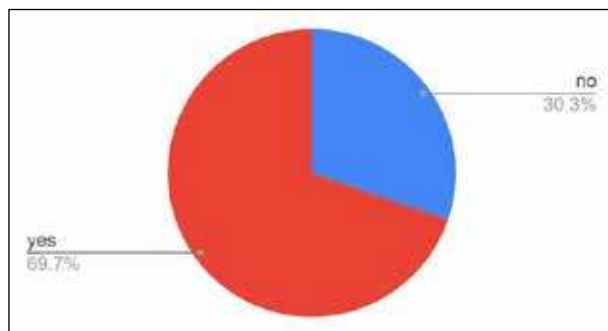


Fig 20.2: Reconstructed houses having a toilet (%)

and NRs 25,000 (US\$ 205) building a toilet or installing an alternative energy source, with payment being contingent on fulfilment of the latter criterion (Limbu et al, 2019)

In Dhading, the foremost cause of dissatisfaction was the size of the one-roomed house, which was simply too small to be livable. As one respondent said, “If you place two beds inside, where will you make the kitchen? Where to sleep? Where to keep other things?” (Limbu et al, 2019, p. 24).

4. Discussion

The earthquake house Bhukampa Ghar resulted from a series of factors and an interlinked web of decision-making in the reconstruction process. To understand this further, it is important to reflect on people’s choices and requirements. The significance of this research is in its inquiry of private housing reconstruction in terms of the quality of building back better with adequate and safe living space. These were missing from the largely “quantitative” approach to rush for number of houses built, which effectively took a building back in a “something better than nothing” direction. The following section synthesizes the findings in terms of spatial, temporal, economical and communication parameters.

4.1 Spatial aspects

The shape and size of newly constructed houses were reduced compared to pre-earthquake houses. With the reduced size, the new houses did not meet their spatial requirements as almost half of the respondents did not have attic, kitchen and toilets. This indicated that not only were living space and rooms short, but also other essential components of the house were still missing or incomplete. The one- and two-roomed new houses cannot accommodate five family members but such houses were rebuilt in both rural and urban areas. The Urban Recovery Technical Working Group, facilitated by HRRP, conducted a qualitative study to prioritize urban recovery issues and the findings suggested that the issue of building one- or two-roomed houses was one among the top 10 issues in urban recovery as well. Though, all new houses have followed government building standards, expansion either vertically or horizontally for additional living space will increase the risk of the families and also make the houses non-compliant to the building code.

One third of the surveyed households had indicated that they would either live in or continue using the old damaged structure or extend the newly constructed houses, which could increase structural vulnerability. Current housing reconstruction procedures and technical assistance need to be re-examined, considering the practice of building the house with incremental construction or financing. Historically, incremental development has been a part of the Nepali building culture. In the Kathmandu Valley, until the 1950s, when the dominant typology was brick and mud mortar, sloping roofs were added to prevent monsoon damage. Due to this and the easier land availability, extensions were usually horizontal, undertaken make space for expanding families (Shah, 2009-10). There is a gap in technical guidelines and assistance for incremental housing construction, though a large percentage of houses have been built in this manner through generations. There are no clear regulations or policy to guide incremental housing construction in both rural and urban areas.

The high proportion of households using the damaged houses, also indicated that retrofitting could be a potential solution. Retrofitting has the potential of addressing the requirement of affordability, safety and adequacy. While the uptake for retrofitting has been low so far, both awareness and interest have been increasing. The initial construction cost of stone buildings with weak mortar and local construction materials is low. “The appropriate retrofit strategy for a specific building depends on the socio-economic constraints, and a number of technical issues, including the structural system, construction materials, quality of construction, building condition, site conditions and constraints” (Bothara & Brzev, 2011).

4.2 Temporal aspects

As mentioned, during the five-year period of reconstruction program, the tranche deadline was extended six times after the first announcement in July 2017. The deadline pressure assisted completion of 70 percent of reconstruction of private houses in July 2020. But the quality of the construction remains to be evaluated.

Government housing reconstruction programs often have a limited timeframe and there is high political and international community pressure to complete reconstruction within a short period of time, on average five years. The five-year time frame for the earthquake recovery is not sufficient when the average earthquake recovery period – looking at different disasters – is 12 years with no difference between high income or low-income countries. (Adapted from Platt, 2017)

This might have caused Nepal think of building the core house rather than considering complete construction within the reconstruction timeline, in the anticipation there could be further guidance and control from the local authorities for vertical or horizontal expansion. Globally, starting in the 1950s, “The original intentions of core housing, were (thus) motivated by a vision of the marriage of the formal and informal processes” (Napier, 2002). The whole design and process could have been considering supporting owner-driven reconstruction with the core building

and the system and technical process to be monitored or handed over to the local authorities tied up with the local building bylaws and national building codes. The Government of Gujarat undertook a reconstruction program with a policy of providing core housing such that each affected beneficiary received at least a “minimum safe shelter”, which could be expanded incrementally. Different core shelter grant amounts were given for rural and urban housing. (Trohanis et al, 2010).

4.3 Economic aspects

Housing recovery affordability depends on two key factors: 1) housing costs, and 2) household ability to pay including from savings, grants, income and credit (Stephenson, 2020). As seen above, affordability is a major factor to consider for quality and adequate housing reconstruction. The government reconstruction grant intended to subsidize and motivate people to construct as per government standards and building code, where households were expected to contribute almost NRs. 350,000 (US\$ 3250) on average, to construct one-story houses with two rooms. This task took 10 months on average, or tranche deadline periods. This showed that the people could build only small houses in the time frame and support provided unless they had additional financial capacity, stable incomes or were confident to take loans.

On 29 June 2020, there were 832,408 households who were eligible for the housing reconstruction grant. If 50 percent of these households had taken a loan of US\$ 3,250 (estimated amount as the additional investment required from households on top-up government subsidy to build one story 2-room houses), the resulting debt would be US\$ 1.3 billion. At an average interest rate of 23 percent per annum, the annual interest payment alone would add up to more than US\$ 300 million.

Access to housing finance for low-income communities was an issue even prior to the earthquake, with these communities excluded from accessing formal bank loans that require large collateral. They mostly relied on savings or informal loans from within their

community and relatives, which is more appropriate for incremental building (UN Habitat, 2010).

4.4 Communication aspects

The government programs and mandates were not clearly communicated with the households and the Partnership Agreement between the government and households was used as the base document to release the tranche amount, with inadequate efforts and means to regularly engage with households. The deadlines and rumors about “blacklisting” people not meeting them had resulted in stress for households.

Building back better messaging, various types of designs, and demonstration models promoted small size structures as safe without additional communication effort on building traditions based on needs and requirements, which influenced household decisions to build existing structures. Further, a trend was also noticed of “replicating” the first housing initiative in an area. “The lesson is that, after an earthquake, it is best to build some model houses at prominent locations with appropriate techniques before anyone else starts with wrong practices that will be replicated by the community” (Bothara, et al, 2016).

5. Conclusion

People’s affordability, a short reconstruction time frame, strict mandates, and communication gaps resulted in a change in the house size after the earthquake. These houses have inadequate living space and increase the risk of unsafe extension and that stemming from continued use of the damaged structure. Although the reconstruction process resulted in achievements in terms of number of houses built, the qualitative outcomes remain questionable. Households had to invest additional money equivalent to government subsidy to build a one story two-room house, which has increased indebtedness. The new houses were smaller than the previous structures in length, breadth and height and are inadequate to fulfill the need for living space.

More information is required on the social and cultural impacts of this undertaking. Are there more houses being built, representing a move away from joint family living? Are there any changes occurring in how houses are used or designed? If so, what information will those building houses need to have to ensure that any extension does not impact earthquake safety?

There is some ongoing research on the debt crisis, in general, economic impact of reconstruction efforts and housing finance for urban areas, in particular, but there is a research gap on the use of old damaged houses and potential extension of new houses without technical assistance and mechanisms for compliance with building standards. This study highlights the need for identifying the actual caseloads for extension and available technical solutions for a safe extension.

Overlooking safe extension of new houses and retrofitting of old damaged houses during the reconstruction time frame will further contribute to structural vulnerability, which contributes to negative impact on building back better and disaster-resilient reconstruction.

6. Recommendations

The resulting inadequate living space of one and two-roomed reconstructed houses has led to the use of old damaged structures that has increased the risk of unsafe extension. The case load verification of the use of old damaged houses and small reconstructed houses with the potential incremental expansion, is recommended as the first step to identify the size and nature of the problem, to further design culturally appropriate, affordable, replicable and scalable solutions. There is a clear gap in the required policy, provisions, and technical guidelines to support households for safe extension. Government efforts

to continue technical assistance through local and permanent systems is very important for ensuring safe extension and promoting retrofitting of old damaged structures.

The household's additional investment in rebuilding houses can contribute to a debt crisis if 50 percent households borrow money for housing reconstruction. As part of GoN's longer term vision of affordable housing for all, the government can influence subsidized loan schemes for incremental housing connected with other employment opportunities and livelihoods programs, together with the private sector, with the government as enabler rather than provider.

Two-way communication between the authorities, facilitators and the people is the key to inform all of existing risks and to jointly address the problems. A clear and flexible communication plan is required, involving media as the key partner at the national and local level.

The National Reconstruction Authority (NRA) should work with other government agencies such as the National Disaster Risk Reduction and Management Authority (NDRRMA), Ministry of Urban Development (MoUD) and the municipalities that will take over its tasks to explore solutions for safe extension and retrofitting. This can include offer of free socio-technical assistance by developing the household level extension/ retrofitting plan monitored and supported by municipal or even ward level authorities. This process should be institutionalized through the NRA exit strategy.

Finally, a sustainable building culture should be encouraged through the institutionalization of the housing reconstruction experiences by local authorities to create a system to track, monitor and provide continuous support and assistance to ensure the safety of people as well the structures.

References

- [1] Baniya, J., 2018. Rebuilding 'Homes' or 'Houses'? SOAS. University College of London. Retrieved from <https://blogs.soas.ac.uk/violentsway/2018/03/14/rebuilding-homes-or-houses-by-jeevan-baniya>.
- [2] Bothara, J., & Brzev, S., 2011. A Tutorial: Improving the Seismic Performance of Stone Masonry Buildings. Earthquake Engineering Research Institute. Retrived from <https://www.traditional-is-modern.net/NEPAL/EERI-WHE-Tutorials/EERI-WHE-StoneTutorial.pdf>.
- [3] Bothara, J. et al., 2016. The Challenges of Housing Reconstruction after the April 2015 Gorkha, Nepal Earthquake. Nepal Engineers' Association – Technical Journal. XLIII. 121-134.
- [4] CBS, 2015. Nepal - Household Registration for Housing Reconstruction Survey 2016-2017. Central Bureau of Statistics. Retrieved from <https://nada.cbs.gov.np/index.php/catalog/69/study-description>.
- [5] CBS, 2016-17. Nepal - Household Registration for Housing Reconstruction Survey 2016-2017. Central Bureau of Statistics. Retrieved from https://nada.cbs.gov.np/index.php/catalog/69/data_dictionary.
- [6] CBS & UNDP, 2015/16. Annual Household Survey. Central Bureau of Statistics & UNDP. Retrieved from https://reliefweb.int/sites/reliefweb.int/files/resources/Annual%20Household%20Survey%202015_16_Major%20findings.pdf.
- [7] CLPIU GMALI, 2020. Reconstruction Update. Central Level Project Implementation Unit. Retrieved from <http://www.clpiugmali.gov.np/reconstruction-update>.
- [8] CFP, 2018. Community Perception Report - Reconstruction, Food Security & Livelihood and Protection. The Inter-Agency Common Feedback Project. Retrieved from <https://reliefweb.int/report/nepal/inter-agency-common-feedback-project-community-perception-report-reconstruction-food>.
- [9] Durable Solutions, 2020. Dashboard. Durable Solutions. Retrieved from <https://www.durablesolutionsnepal.org>.
- [10] DUDBC, Design Catalogue for Reconstruction of Earthquake Resistant Houses, Volume I. DUDBC. Retrieved from <https://reliefweb.int/report/nepal/design-catalogue-reconstruction-earthquake-resistant-houses-volume-i>.
- [11] ECHO, 2019. ECHO Factsheet – Nepal – May 2019. ECHO. Retrieved from <https://reliefweb.int/report/nepal/echo-factsheet-nepal-may-2019#:~:text=According%20to%20the%20United%20Nations,affected%20more%20than%201.7%20million>.
- [12] GoN, 2015. Design catalogue for reconstruction of earthquake resistant houses, volume I. Government of Nepal. Retrieved from <https://reliefweb.int/report/nepal/design-catalogue-reconstruction-earthquake-resistant-houses-volume-i>.
- [13] HRRP, 2017a. Cost of Construction. HRRP. Retrieved from https://www.hrrpnepal.org/uploads/media/VEcWsqlBkOwoAgUQ2Sbj_2017_12_04.pdf
- [14] HRRP, 2017b. Nepal Rural Housing Reconstruction Program. HRRP. Retrieved from https://www.hrrpnepal.org/uploads/media/QcKmiCB2UWlzXuvsP9JS_2017_02_22.pdf.
- [15] HRRP, 2017c. Core Socio-Technical Assistance. HRRP. Retrieved from https://www.hrrpnepal.org/uploads/media/6lpmjTYZ5Rc9BQFioLJx_2017_11_15.pdf.
- [16] HRRP Bulletin, 2017. Weekly Bulletin, July 27. HRRP. Retrieved from https://www.hrrpnepal.org/uploads/media/XSd3TlqZ5NWkBECjyJiF_2017_07_24.pdf.
- [17] HRRP Bulletin, 2018. HRRP Bulletin, April 16. HRRP. Retrieved from https://www.hrrpnepal.org/uploads/media/U6VdOKNobBXFpkSTIPhr_2018_04_17.pdf.
- [18] HRRP, 2018. Points for WB Stakeholder Consultation. HRRP. Retrieved from [https://www.hrrpnepal.org/uploads/media/PointsforWBStakeholderConsultation-HRRP-ForSharing\(newlayout\)-180802_20190204142451.pdf](https://www.hrrpnepal.org/uploads/media/PointsforWBStakeholderConsultation-HRRP-ForSharing(newlayout)-180802_20190204142451.pdf).
- [19] HRRP, 2019. The Path to Housing Recovery. HRRP. Retrieved from https://www.hrrpnepal.org/uploads/media/HRRPtimelinebooklet-April2019_20190425195635.pdf.
- [20] HRRP, 2020. Cost of Construction, unpublished. HRRP. <https://drive.google.com/file/d/1r7QDhtX-b00o8FnDWQ4JHphL1hVOZQRbt/view?usp=sharing>
- [21] Limbu, B. et al., 2019. Reconstructing Nepal: Post-Earthquake Experiences from Bhaktapur, Dhading and

- Sindhupalchowk. Social Science Baha. Retrieved from <https://soscbaha.org/wp-content/uploads/2019/11/reconstructing-nepal.pdf>.
- [22] Michaels, L., 2020. Still Recovering from the Earthquake, Nepal Faces Covid-19. The Asia Foundation. Retrieved from <https://asiafoundation.org/2020/04/15/still-recovering-from-the-earthquake-nepal-faces-covid-19>.
- [23] Napier, M., 2002. The Origins and Spread of Core Housing. Retrieved from <http://web.mit.edu/incrementalhousing/articlesPhotographs/pdfs/Origins-Spread-CoreHousing.pdf>
- [24] NBC 203., 2015. Nepal National Building Code. Department of Urban Development and Building Construction. Retrieved from <https://www.dudbc.gov.np/uploads/default/files/b8e8f70594055e66f43b739e-d48ae057.pdf>
- [25] NRA, 2017. Correction/Exception Manual for Masonry Structure.
- [26] NRA, 2020. Decisions of the 133rd meeting of the Executive Committee. NRA. Retrieved from http://www.nra.gov.np/np/resources/details/Or9y22CA16krqyxze_VHZDIKYvr_OC69kYUKRf3u6Nk.
- [27] NUDS B, 2017. National Urban Development Strategy. Ministry of Urban Development, p.27. Retrieved from http://www.moud.gov.np/images/category/NUDS_PART_B.pdf.
- [28] PDNA B, 2015. Post Disaster Needs Assessment. Government of Nepal. Retrieved from https://www.npc.gov.np/images/category/PDNA_volume_BFinalVersion.pdf.
- [29] PDRF, 2016. Post Disaster Recovery Framework. Government of Nepal. Retrieved from https://www.recoveryplatform.org/assets/publication/PDNA/RecoveryFrameworks/Nepal_Earthquake_2016_PDRF.pdf.
- [30] Platt, Stephen., 2018. Factors Affecting the Speed and Quality of Post-Disaster Recovery and Resilience. 10.1007/978-3-319-62099-2_19.
- [31] https://www.researchgate.net/publication/321707006_Factors_Affecting_the_Speed_and_Quality_of_Post-Disaster_Recovery_and_Resilience.
- [32] Rai, A., 2018. Building homes on a deadline. Nepali Times, July 13. Retrieved from <https://www.nepalitimes.com/here-now/building-homes-on-a-deadline/>
- [33] Rapid Assessment –Housing Reconstruction Progress in Gajuri wds 2, 5, and 6. Unpublished. Retrieved from <https://drive.google.com/file/d/1eYBQchsu63ljns7mCOVv1EpXeXH3vnII/view?usp=sharing>
- [34] Shah, B., 2009-10. A Brief Overview of Incremental Housing Construction in Kathmandu Valley, Nepal. Retrieved from <http://web.mit.edu/incrementalhousing/articlesPhotographs/nepalKarthmanduValley.html>.
- [35] Shelter Cluster, 2015. 10 Key Messages. Shelter Cluster Retrieved from https://www.sheltercluster.org/sites/default/files/docs/english_151124_10_key_messages_0.pdf
- [36] Shelter Cluster Nepal, 2015. Nepal Earthquake Recovery Monitoring
- [37] Assessment. Shelter Cluster Nepal. Retrieved from https://www.impact-repository.org/document/reach/9c64cf74/reach_npl_report_shelter_recovery_monitoring_assessment_nov2015.pdf
- [38] Shelter Report, 2014. Step by Step: Supporting Incremental Building Through Housing Microfinance. Habitat for Humanity. Retrieved from https://www.sheltercluster.org/sites/default/files/docs/49_hfh-step-by-step-supporting-incremental-building-through-housing-microfinance-oct-2013.pdf
- [39] Stephenson, M., 2020. 4 Lessons from the 2015 Nepal Earthquake Housing Recovery. Habitat for Humanity.
- [40] FOUR LESSONS FROM THE 2015 NEPAL EARTHQUAKE HOUSING RECOVERY, April 2020
- [41] The Asia Foundation, 2017. Aid and Recovery in Post-Earthquake Nepal Independent Impacts and Recovery Monitoring Phase 4 Qualitative Field Monitoring: The Asia Foundation. Retrieved from <https://asiafoundation.org/wp-content/uploads/2017/10/Aid-and-Recovery-in-Post-Earthquake-Nepal-Qualitative-Field-Monitoring-April-2017.pdf>.
- [42] The Asia Foundation, 2020. Independent Impacts and Recovery Monitoring (IRM) Project Nepal Early Findings from Round 5. Retrieved from https://asiafoundation.org/wp-content/uploads/2020/03/IRM-Round-5-Early-Findings-Brief_3.24.20.pdf.

- [43] Trohanis, Z., & Read, G., 2010. EAP DRM Knowledge Notes. World Bank. Working Paper Series No. 9. Retrieved from <http://documents1.worldbank.org/curated/en/837891468027852896/pdf/529450BRI0RE-VI10BOX353820B01PUBLIC1.pdf>.
- [44] Tsou, C. et al., 2018. Topographic characteristics of landslides induced by the 2015 Gorkha earthquake, Nepal. *Journal of Nepal Geological Society*. 55. 10.3126/jngs.v55i1.22792.
- [45] UN-Habitat, 2010. Urban Housing Sector Profile. Retrieved from <http://unhabitat.org.np/?publications=nepal-urban-housing-sector-profile>.



Urban Regeneration of Dwalkha: Prospects and Challenges

Surya Bhakta Sangachhe^a, Aditi Dhakal^b

Keyword: Earthquake; urban regeneration; cultural heritage; conservation

Abstract

Dwalkha, a heritage settlement of values of tradition, culture, architecture, religion, and tourism in Dolakha District was heavily damaged by the 2015 Gorkha, Nepal earthquake. Since the early 1970s, there has been a trend of migration of people from Dwalkha to Kathmandu and abroad and very few residents remained to nurture its essence. Some residents began replacing vernacular architectural forms with modern concrete buildings. The remaining vernacular buildings struggled to recover from the significant impacts of the earthquake during which nearly 90 percent of houses and many monuments were heavily damaged. Following the 2015 Gorkha, Nepal earthquake, Dwalkha developed a five-year Urban Regeneration Plan in 2017. The proposed plan aimed to promote conservation and utilization of public spaces for community services. Additionally, it aimed to stimulate the local economy by promoting heritage conservation, entrepreneurship development, retail commercial activities, and tourism that are compatible with heritage conservation. Further, the plan targeted to strengthen the capacity of municipality and community groups in managing urban growth and conservation of tangible and intangible cultural heritages. However, the plan remained only on paper. The main objective of this paper is to discuss the development and some major elements of the “Urban Regeneration Plan of Dwalkha” and the prospects and challenges of its implementation. The authors explored these issues in Dwalkha through a mix of field investigation, interviews, focus group discussions, and literature reviews. One major finding of this paper is that Dwalkha, a historic settlement damaged by earthquake, requires urban regeneration. However, there are governance, physical and social challenges in the implementation of the regeneration plan.

1. Introduction

Urban Regeneration is a process of bringing life into a deteriorating city thus growing its potential for development (Boussaa, 2017). The degrading essence of historical town due to urbanization and industrialization together with out-migration of skilled professionals and lack of economic potential can be protected by encouraging traditional professions,

generating economic activities, conserving cultural infrastructures, promoting tourism, and upgrading capacity/skills of inhabitants (Parlewar, 2006). The Urban Regeneration Plan of Dwalkha prepared in 2017 incorporated all these aspects.

The main objective of this paper is to discuss the development and some major elements of the urban regeneration plan. Additionally, it also discusses the prospects and challenges of implementing the plan,

especially as it relates to the preservation of heritage urban forms.

The process of urban regeneration is not easy. It has many challenges: social, financial, economic, physical, political, etc. (Roberts & Sykes, 2000). Despite conservation, modernization is prioritized at the cost of cultural heritage (Chan, 2016; Boussaa, 2017). Economic schemes most often erase the identity of a historic place. As a result, gentrification, population density, and urban slums increase and bring an irreversible change (Boussaa, 2017), (Chan, 2016). Cities can prepare plans to address such issues, specific to their needs and for heritage areas, conservation should be a major part of urban regeneration.

Conservation areas are always special because of their architectural and historical identity, (Mceldowney, 2006). Heritage conserved will preserve the entire essence of authenticity. Authenticity is the original architectural and historical identity of a city, which can just be revealed, but additional elements cannot be added to it (Assi, 2014). However, studies reveal that urban regeneration and conservation have become a worldwide challenge (Mansour, 2015) (Yaldız, Aydın, & Sıramkaya, 2014; Roberts & Sykes, 2000).

1.1 Gorkha earthquake and its subsequent effects

A 7.6 magnitude earthquake hit Nepal on 25 April 2015 at 11:56 am local time with Barpak, in Gorkha district, as its epicenter. This catastrophic earthquake, followed by more than 300 aftershocks, resulted in 22,300 injuries and 8,790 casualties. The lives of approximately eight million people, almost one-third of the population of Nepal, was affected. The earthquake affected 31 of the country's seventy-five districts. Many private, government, and heritage buildings, educational institutions, hospitals, and infrastructures such as rural roads, bridges, water supply systems, and even historic towns and settlements, as well as agricultural land, were fully or partially damaged (GoN, 2015) (NRA, 2016).

Following the earthquake, the Government of Nepal prioritized reconstruction and revival of

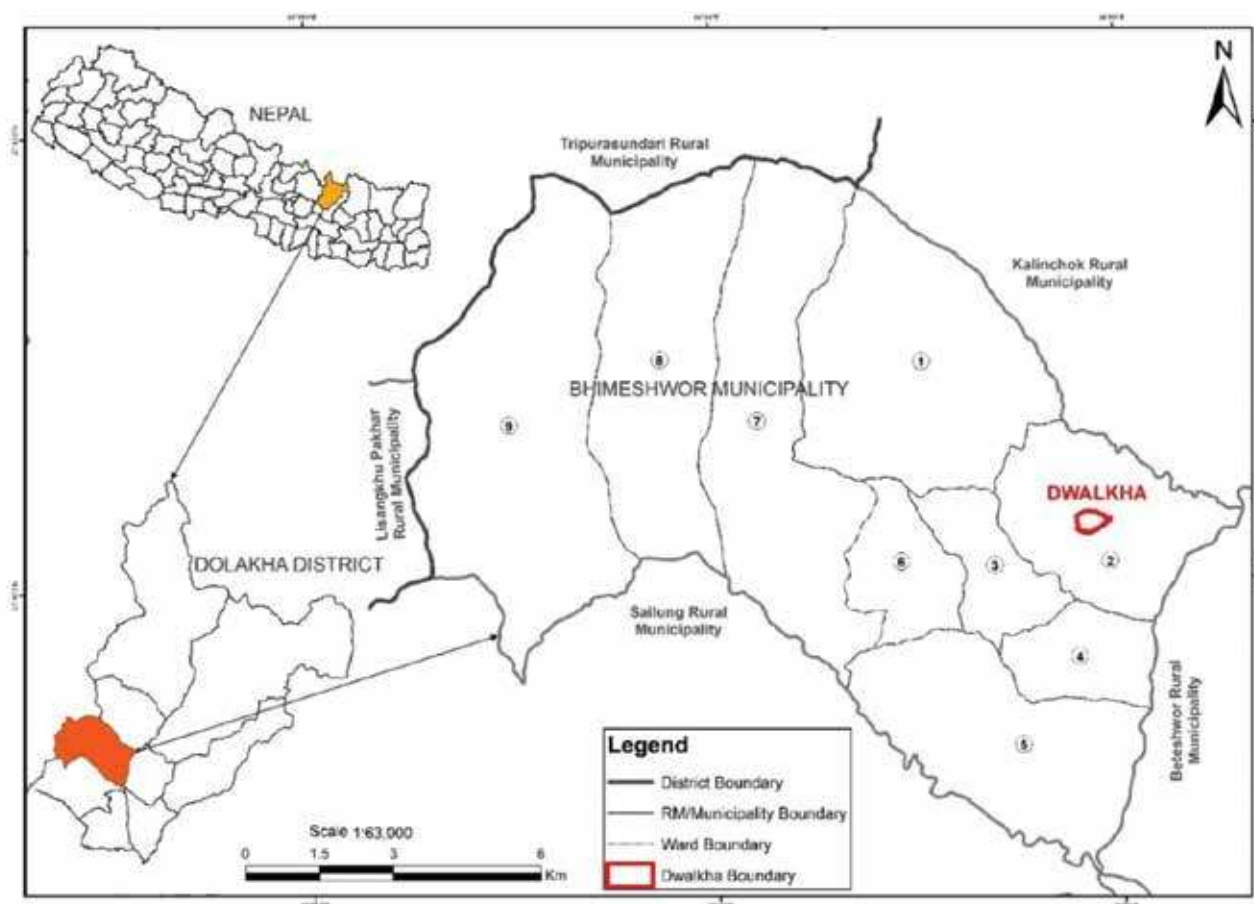
historic settlements. National Reconstruction and Rehabilitation Policy, 2015 had, "Use of local materials, knowledge, skills, and labor will be prioritized during reconstruction" as one of its guiding principles. One of the six stated objectives of the policy was to "Reconstruct old settlements by maintaining their traditional characteristics and improving them" (NRA, 2016). The Post Disaster Recovery Framework published by the government prioritized the restoration of heritage settlements (NRA, 2016).

1.2 Impact of the earthquake in Dwalkha

Dwalkha, a historic settlement predominantly of the Newar community, lies in a mountainous region of Dolakha district, Bagmati Province of Nepal. It is believed to have been founded in the 14th century. Dwalkha lies in Bhimeshwor Municipality, about 183 km east of Kathmandu. Dwalkha is famous for its cultural heritage, particularly the Dolakha Bhimsen temple and its historic heritage settlements. Starting in early 1970, its population started migrating to Kathmandu and abroad for education and better economic opportunities. Interviews showed that the unavailability of higher education and job opportunities in Dwalkha were the major reasons behind outmigration. Very few residents remained to nurture the essence of the settlement. According to the 2011 census, the population of Dwalkha was around 1,690 in about 338 households.

The vernacular buildings struggled to recover from the impacts of the Gorkha earthquake during which nearly 90 percent of its houses and many monuments had been damaged. Some residents had begun replacing vernacular building forms with modern concrete buildings in the 1990s. The continuation of the trend in building construction during post-earthquake recovery, could cause the vernacular architecture of Dwalkha to be lost. Thus, ahead lay an enormous task ahead of rebuilding, regenerating, and conserving the heritage settlement.

People of Dwalkha had started expressing their desire to conserve the heritage settlement even before the earthquake. They had requested Bhimeshwor



Map 1: Geographical location of Dwalkha

Source: NSET

Municipality and the Department of Archeology for a study of the history of Dwalkha and had urged for enlisting Dwalkha as a UNESCO World Heritage Site (Bhadgaule, 2009; Tumbahang, 2013; Shrestha, 2014). They had also requested assistance from Bhimeswor Municipality for developing Urban Regeneration Plan for Dwalkha following which the municipality requested technical assistance from the National Society for Earthquake Technology-Nepal (NSET). Formulation of urban regeneration plan started in May 2016 with the participation of locals, technical support of NSET, and Bhimeswor Municipality.

This paper discusses the development of the urban regeneration plan and its prospects and challenges in implementation.

2. Literature review

Literature reviews were done to understand the urban regeneration process, its prospects, and challenges.

2.1 Urban regeneration definition and principle

Urban regeneration is a strategic process or art of managing decisions using strategic alternatives to revitalize an urban area (Roberts & Sykes, 2000). According to Roberts and Sykes, this process should emphasize the specific need of an area to draw a clear picture for deriving the required outcome. Urban regeneration deals with many issues such as financial, economic, physical, social (employment, education),

and infrastructural. Comprehensive action that leads to solving urban problems and developing financial, economic, physical, social, and infrastructural aspects of an urban area is urban regeneration (Roberts & Sykes, 2000). According to the Handbook of Urban Regeneration (Roberts & Sykes, 2000), Principles of urban regeneration are:

- Urban regeneration should be based upon a detailed study of an area.
- The timely adaptation of physical, social, financial, environmental, and economic issues is a prerequisite.
- An area-specific comprehensive strategy should be developed.
- This strategy should agree with the goals of sustainable development.
- Objectives of the strategy should be measurable.
- Urban regeneration should focus on the use of indigenous material, technology, and human resource.
- Urban Regeneration should ensure consensus through the participation of all interested stakeholders.
- It should monitor the achievement of the specified objectives.
- The objectives should be revised as or if required.
- The objectives of the strategy progress at different speeds: redirection of resources or revision in the strategy may be required.

An urban regeneration plan formulation should incorporate all these principles.

2.2 History, mythology, and beliefs of Dwalkha

The history of Dwalkha is yet to be studied. It is believed to have been founded in the 14th century. Some historians and intellectuals of Dwalkha believe that the ancient settlement is older than Kathmandu (Bhadgaule, 2009; Tumbahang, 2013; Shrestha, 2014). An article entitled “Coinage of Nepal” published in London in 1989 shows that the first coin of Nepal was

issued by King Jayaindra Singh who ruled Dwalkha in 1535-1549 A.D. (Shrestha, 2014).

There are various mythologies behind the naming of the settlement:

- In Chinese, Dwalkha means a city of stone idols (Shrestha, 2014).
- Some locals say that “Do” means two and “lakha” means lakh (hundred-thousand) in Nepali. Do and lakh together mean two hundred thousand. It is believed that a saint once circumambulated Dwalkha for 200,000 times and hence the city got its name as Dwalkha.
- Some locals say that someone in the past sacrificed 200,000 due to which Dwalkha got its name, and
- The name Dolakha came from the Sherpa community. In Sherpa’s language “Do” means stone, “LA” means in, and “KHA” means face, collectively meaning “Face in stone” (Wikipedia, 2021).

Most of the myths suggest the connection of the city to temples, idols, and its culture.

Cultural beliefs are also connected to Dwalkha. At times, there is news in newspapers about the “perspiration” of Dwalkha Bhimsen’s stone idol. This perspiration is believed to be a bad omen for the country and is believed to cause something inauspicious to the rulers and prevailing political system. To overcome anything inauspicious happening, there is a custom of conducting an atonement worship (*Chhyama puja*) at state expense. These aspects signify the intangible heritage of Dwalkha (Khatiwada, 2020; Himalayan, 2017).

2.3 Case study of Bhaktapur

The German Government-supported Bhaktapur Development Project was carried out from 1974 to 1986. The project targeted to conserve and restore the historic environment of Bhaktapur keeping its urban fabric intact (Parajuli, 1992). Bhaktapur is the smallest city of Kathmandu Valley. It lies in a former trade

route between India and Tibet. The majority of buildings in Bhaktapur are built in vernacular Newari style (Parajuli, 1992).

The Bhaktapur Development Project envisioned improving the living condition of its inhabitants, enhancing their skills, and conserving the heritage values of Bhaktapur. The overall impact due to physical improvement was positive. However, the social aspects such as people's priorities, perspectives, and needs were not fully addressed (Haaland, 1982).

Under the project, land-use plans, and design standards were developed. The project tried to build the capacity of house owners, masons, carpenters, artisans, and technicians. The project also provided financial and technical assistance to house owners in the conservation area of Bhaktapur to maintain architectural features while constructing a house (Parajuli, 1992). Even though the North East quarter of Bhaktapur was developed, the overall outcome was not as expected (Dorji, 2019). Several violations of land-use and design standards were observed. People of Bhaktapur did not see the various strategies proposed by the project from the same perception as the planners. They felt some restrictions in their freedom of construction. Additionally, concerned stakeholders were also blamed for not maintaining their professional ethics. Implementing mechanisms and legal instruments were also found insufficient and the bureaucratic procedures were lengthy (Parajuli, 1992).

Lessons learned from Bhaktapur Development Project are as follows:

- Rules and regulations should be designed, imposed, and implemented by respective stakeholders.
- Strategies should focus on modern demand and requirements.
- All stakeholders should remain within their professional ethics (Parajuli, 1992).
- People should be involved in the planning and overall process with their consent (Parajuli, 1992) (Dorji, 2019).
- Implementers should be well experienced in

incorporating social aspects together with technical aspects (Haaland, 1982).

2.4 Pro-poor urban regeneration pilot project in Lalitpur Metropolitan City

Pro-poor Urban Regeneration Pilot Project was a project funded by Japan Social Development Fund (JSDF) and administered by the World Bank. The objective of the project was to improve the living conditions of poor and vulnerable households in selected wards of the historic core of Lalitpur Metropolitan City through urban regeneration. The urban regeneration activities included improvement of infrastructure and services, conservation of local cultural heritage, and improvement of livelihood (LMC, 2017).

The project had four components: Component 1: preparation of a 3-year participatory action plan that includes improvement of local infrastructure and services, heritage conservation, cultural industries, local environmental protection, social development, and disaster risk management. Component 2: Grant facility that funded small infrastructure projects, and supported community-based initiatives and small businesses. Component 3: Community awareness and local capacity building that funded community awareness-raising initiatives and local capacity building. Component 4: Participatory monitoring and evaluation, knowledge dissemination, project management, and administration (LMC, 2017).

As per the information published on LMC's official website in May 2017, almost 76 percent of the project had been completed. The project had faced various problems in its implementation: such as delay in signing the MoU with the Government of Nepal, delay in budget management, delay due to the 2015 earthquake and blockade of supplies, and delay due to local-level restructuring. Despite all these delays, the World Bank and the consumers of the project appreciated the overall progress. This project was popular because the beneficiary demands and ideas had been addressed (LMC, 2017).

2.5 Bandipur Eco-Cultural Tourism Project (BECTP)

The Bandipur Village Development Committee, along with residents, project partners from Greece and Italy, and financial support from the European Commission, initiated the Bandipur Eco-Cultural Tourism Project for the conservation of its urban fabric and tourism promotion in 2005-2006 (Dorji, 2019).

Bandipur is located 143 km west of Kathmandu in Tanahun District. It is a hilltop settlement with a beautiful view of the Annapurna Range and Dhaulagiri peaks. Bandipur is rich in its cultural heritage and Newari architecture. In the 1970s, after the construction of the Kathmandu-Pokhara highway, the district headquarters of Tanahun shifted from Bandipur to Damauli resulting in a loss of identity, importance, and accessibility. As result, people started migrating that caused a decline in the commercial trade and administrative activities in Bandipur.

The BECTP emphasized community participation, interaction, and discussion with various stakeholders due to which, residents felt a sense of responsibility. The project focused on conservation, tourism, training, publication, and promotion. The implementation of the project was also done by the respective local committee under the supervision of the project team (Dorji, 2019).

Learnings from BECPT are as follows: The project emphasized the importance of meetings and discussions among the partners and the local community. It also showed that training and awareness campaigns were needed for the project to be successful.

3. Methodology

The technical team of NSET prepared the Urban Regeneration Plan of Dwalkha under the Building Code Implementation Program in Municipalities of Nepal with the financial assistance of the United States Agency for International Development/Office of U.S. Foreign Disaster Assistance (USAID/OFDA) in 2017 AD. The plan comprised of urban regeneration of the historic settlement through

conservation, reconstruction, capacity building, and institutionalization.

For the preparation of the plan, the authors of this paper along with associated engineers at NSET collected data through a census survey of households and buildings. The survey was conducted in two phases. The first phase consisted of data collection during the countrywide Detail Damage Assessment (DDA) conducted two months after the 2015 Gorkha, Nepal earthquake. A second phase consisted of data collection for the urban regeneration plan in 2016. Data from both surveys were used in formulating the plan.

Bhimeshwor municipality invited NSET to perform the required tasks for DDA and urban regeneration. The authors of this paper and the associated engineers, trained by NSET especially for DDA conducted the field survey. Bhimeshwor Municipality authorized the surveyors to conduct field surveys, organize meetings, and focus group discussions (FGD).

In the first phase, a census survey was conducted using a structured questionnaire of DDA. Questions were asked to house owners, family members, relatives, or neighbors (whoever was available during the survey). GPS coordinates and pictures of the houses were taken. Detailed survey consisted of physical and technical details of the residential buildings.

During the second phase of the survey, a mixed methodology was used to gather information, and a survey of infrastructure and monuments was performed. The mixed methodology consisted of a structured questionnaire (minor modification in the questionnaire of the first phase) for infrastructure and monuments, informal interviews with locals, meetings, and FGD with municipal officers, local reconstruction assistance committee, and residents of Dwalkha. Streetscapes were drawn with reference to the photos taken during the field survey. Social, cultural, and economic information of the area were obtained through meetings and FGDs. Secondary data (inventory made by some local intellectuals) and door-to-door surveys helped to identify socio-economic trends in Dwalkha.

The first FGD was held in May 2016. Following it, a local reconstruction assistance committee was formed

among the locals, who participated in all steps of planning and supported the technical team of NSET with necessary data. This committee stressed the need for urban regeneration and facilitated the finalization of the boundary of the urban regeneration area. Some of them had already studied the history of Dwalkha and made an inventory of existing monuments. The objectives of the urban regeneration plan were discussed in the FGDs. Finalized objectives included all suggestions from locals. Missing data and information were collected and verified at the FGDs. During FGDs participants (municipal officers, local reconstruction assistance committee, and residents of Dwalkha) interacted on the draft plan, and reviewed it for acceptance. In this way, the residents had participated at each stage of the planning process.

As per the principles of urban regeneration, field surveys were conducted to fully understand the community and infrastructure of Dwalkha. During interviews and FGDs, all required social and economic data were also collected. An area-specific and measurable objective was set and further elaborated in the plan. This plan focused on the use of indigenous material, technology, and human resource.

NSET submitted the final draft of the plan to Bhimeshwor Municipality incorporating all the

reasonable comments, and suggestions accumulated during the meetings and FGDs in 2017, two years after the earthquake. However, the implementation of the plan has remained almost unnoticeable and people had been building houses they desired irrespective of the provisions of the plan.

This study further focuses on the prospects and challenges of the implementation of the urban regeneration plan based on the data collected before the formulation of the plan and after observations of the situation in terms of implementation over a period of five years (2015-2020).

4. Findings

The mix-methods survey of Dwalkha helped to establish a clear understanding of its land use, architecture, and cultural practices. Analysis of the building survey found that 30 percent of Dwalkha was built-up and the remaining area was occupied by farmlands, forests, and open spaces. Ninety-five percent of all the 338 houses surveyed were built following the vernacular Newari architectural style. Most houses, 90 percent, were constructed using stone and mud. Only around six percent of the houses were built using reinforced concrete. Among all, 95 percent of houses, were completely



Picture 1: Vernacular Newari architecture of Dwalkha threatened by modernization



Picture 2: Reconstruction of a house after the 2015 earthquake

residential. Of 338 houses, 168 had been newly built within a period of 10 years (2005-2015) and around 50 percent of the total houses were more than 50 years old. The vernacular Newari architecture predominated the built-up area, and this fact highlighted the importance of conservation of vernacular architecture to be considered in the urban regeneration plan. The few reinforced concrete constructions already threatened conservation of the architecture of the settlement as highlighted in the picture 1 above.

Besides houses, the survey documented an extensive number of heritage and cultural sites. Dwalkha had 63 heritage infrastructure including temples, monuments, *chaityas*, *bihars*, wells, etc. of cultural importance. Nine of them were completely damaged, eight required retrofitting and others required minor repair and maintenance.

During the survey, it was also observed that some temples such as the Narayan temple and Pashupati temple were already being reconstructed without

following the principles of conservation as shown in pictures 3, 4, 5, and 6 below.

Dwalkha is rich in intangible heritage. It celebrates many historical feasts and festivals: Khadga Jatra, Balachaturdashi Jatra, Sahashra Jatra, Holi Jatra, Macchhindranath Jatra, Bhairavkumari, and Twakhalpyakhal Jatra. The main streets of Dwalkha are not just used for the movement of people and goods but also used for chariot processions during festivals making them heritage routes. Chariots have special wheels made on purpose to move along the stone stairs and stone-paved streets. Hence, conservation of both the heritage buildings, annual festivals, and routes needed consideration in the urban regeneration plan to conserve both the tangible and intangible heritages.

The DDA showed the impacts of the Gorkha earthquake on the settlement. Nearly all, 95 percent, of the houses were damaged by the earthquake and needed repair and reconstruction (pictures 7 and 8). Most of the buildings were more than 50 years old. Some of

Table 1: Inventory of heritage Infrastructures of Dwalkha

Dolakha Bhimsen Temple	Bajrayogini Stupa	Taksar
Manjushree Temple	Swayambhu Stupa	Nyaya Magne Dhunga
Tripura Sundari Temple	Simbuthan Buddha Stupa	Bheem Pustakalaya
Pashupati Temple	Dungalsen Stupa	Rajhiti Stone Spout
Shiva Temple	Sano Korchhe Stupa	Dhunga Deuta
Baranasi	Korchhe Stupa	Pwatanga Stone Spout
Balkumari Temple	Dwaku Guthi	Bal Sangathan
Shyam Narayan Temple	Harisiddhi Stupa	Bajrawati Dhara
Machhindranath Temple	Faleti Spout	Namkai Madau
Harisiddhi Temple	Ganesh idol	Chherpwale
Dhungeshwor Mahadev	Natyeshwor Dabali	Bhandar Chhe
Kulen Temple	Bhrameshwor	Hipathami Chhe
Narayan Temples	Kumari House	Dungal Pati
Saraswoti Temples	Buddha Idol	Kanji House
Ganesh Temple	Bhimsen Dabali	Kumari House
Kali Temple	Pingal Dabali	Mahata Pati
Narayan Temple	Religious pond	Puranche building
Taleju Temple	Chakra Dabali	Bahatada Pati
Guru Natyeshwor Temple	Champuja park	Dwakulunga
Narayan Temple	Deepkar Buddha	Bhimeshwor Cultural Building



Picture 3: Narayan Temple after Gorkha Earthquake 2015



Picture 4: Narayan Temple after reconstruction



Picture 5: Pashupati Temple after Gorkha Earthquake 2015



Picture 6: Re-constructed Pashupati Temple

these buildings were left empty and timely repair and maintenance was lacking. Thus repair, maintenance, and restoration were other factors that should be considered.

Secondary survey data showed that more than 72 percent of families of Dwalkha had migrated to Kathmandu and abroad. Most of the remaining residents were economically weak. The informal interviews with the locals suggested that the community seemed divided among those living in Dwalkha and

those living in Kathmandu. It reflected the differences in financial status, which resulted in a difference in the determination regarding reconstruction.

From interviews with house owners and municipal leaders, it was clear that some traditional professions and activities were declining, which was one of the main reasons why inhabitants were migrating. Interviews also clarified that lack of infrastructure for economic activities, and lack of educational institutions were other significant reasons for out-migration.



Picture 7: Houses damaged by 2015 earthquake



Picture 8: Houses damaged by 2015 earthquake

From the literature reviews, it was found that a properly documented system for the institutionalization of urban regeneration did not exist.

5. Urban regeneration plan of Dwalkha

The Urban Regeneration Plan of Dwalkha was prepared by Bhimeswor Municipality with technical support from NSET. The plan was prepared to demonstrate revival of historic settlement Dwalkha through a “people’s process” while conserving the heritage values, stimulating economic growth, and improving quality of life. A series of FGDs among NSET, municipal officers, local reconstruction assistance committee members, and residents of Dwalkha were organized to include the locals in urban regeneration planning process. A field survey was conducted to obtain primary information from the locals.

Objectives of the urban regeneration plan of Dwalkha were:

1. Support rebuilding the historic settlement of Dwalkha damaged by the earthquake in a planned and participatory manner keeping the urban fabric intact.
2. Support the rebuilding of vernacular houses to make them safe and convenient while conserving local heritage.

3. Promote conservation and utilization of public spaces for community services.
4. Stimulate the local economy by promoting entrepreneurship, tourism, and retail commercial activities that are compatible with heritage conservation.
5. Strengthen the local capacity of municipality and community groups in managing urban growth and conserving heritage in the context of a historic town.

The cost of Dwalkha urban regeneration was estimated at US\$ 3.73 million based on the construction rate of the fiscal year 2015/16. This total did not include the cost borne by local people to rebuild their houses or the cost of reconstruction projects undertaken by development partners, such as the Swiss Agency for Development and Cooperation, which was rebuilding several temples, stupas, and pedestrian paths.

Bhimeswor Municipality and the community were supposed to take lead in the implementation of the plan, under the guidance and support from National Reconstruction Authority (NRA), Ministry of Urban Development (MoUD), and Ministry of Federal Affairs and Local Development (MoFALD), and other development partners. For policy support and guidance, it was envisioned to create a project steering committee comprised of NRA, representatives of respective Central

Level Project Implementation Units (CLPIU) of MoUD, MoFALD, and Ministry of Culture, Tourism and Civil Aviation (MoCTCA), and Bhimeshwor Municipality.

As planned in 2017, the project implementation period was five years. The first six months were for preparatory works, including the formulation of steering and management teams, mobilization of local communities, and consultation with local stakeholders to finalize details of the project. The second six months were for focusing on the preparation of reconstruction and recovery plans including housing reconstruction, neighborhood development, socio-economic development, and capacity development. The remaining three and half years was for implementing the plans and regularly monitoring the progress. The final six months of the project were to focus on evaluating and disseminating the findings of the project. The complete Urban Regeneration Plan of Dwalkha is available at Bhimeshwor Municipality.

6. Prospects and challenges for implementing the urban regeneration plan

The Dwalkha Urban Regeneration plan detailed out information on objectives, expected outcome, human resources, and estimation of time and financial resources to bring back life into a deteriorating town to enhance its potential of development as suggested by Boussaa and Parlewar (Boussaa, 2017; Parlewar, 2006). This plan was submitted to Bhimeshwor Municipality in 2017 but had not been implemented at the time of writing.

As stated by Robert and Skyes, urban regeneration is not an easy task. It depends on various factors and brings together many challenges. Some of the challenges that made implementation of the Urban Regeneration Plan difficult are:

Governance factor: One factor inhibiting implementation was the lack of a formal process for the urban regeneration plan. There are no recorded urban regeneration projects in Nepal to date and therefore lacking is a properly documented system for institutionalization.

Social factor: The household survey showed the pronounced difference between people living in and out of Dwalkha, which often translated to differences in financial status, and differences in the determination/commitment towards reconstruction. Locals urged for faster reconstruction whereas people living outside were more relaxed.

Physical factor: The extensive deterioration of the built environment also made implementation of a regeneration plan difficult. The tremor of April 2015 and following aftershocks damaged 95 percent of the vernacular buildings. They were not maintained and were in a dilapidated condition as shown in Pictures 7, 8, and 9. Most of the concrete structures recently built were intact or slightly damaged. Many residents interpreted this damage pattern to mean concrete was stronger and better construction material compared to bricks or stone masonry and timber. If this misconception prevails, there is a possibility that the vernacular houses will be replaced by concrete buildings.

Architectural trend: Another factor was modernization that was competing with vernacular architecture (Picture 10). As also noticed by Chan and Boussa, modernization was prioritized at the cost of cultural heritage. There is a desire among some people to modernize the settlement with wider roads, more commercial buildings and change the land use to convert the settlement into a commercial center. Therefore, there is an urgent need to not only support the people who have lost their houses in the earthquake to build back better, but also to raise awareness regarding the values and associated benefits historic settlement have. There is an urgent need to provide residents with necessary support to build their communities and make them prosperous while conserving the vernacular architecture and cultural heritage sites, and building livable and safer settlements.

Awareness: Lack of awareness of the concept of conservation was another factor. For Dwalkha, conservation is one of the major aspects of urban regeneration and locals wanted the town to be a heritage settlement. But some of them are not aware of conserving its authentic architecture forms. The construction of



Picture 9: Vernacular buildings of Dwalkha damaged by the earthquake



Picture 10: Vernacular essence being engulfed by RCC construction

modern RCC buildings in Dwalkha showed that some locals lacked a concept of conserving their settlement as a heritage settlement. Meanwhile, the municipality was aware about Dwalkha losing its vernacular architectural forms but had not made strict rules and regulations to stop the unplanned construction of RCC buildings and reconstruction of temples. The reconstruction of few temples had not followed conservation practices, an issue that was addressed in the regeneration plan, which, however, remained to be implemented. Pictures above (3, 4, 5, and 6) show Narayan temple and Pashupati temple immediately after the earthquake 2015 and after reconstruction.

Social capacity: A final consideration affecting implementation could have been community capacity. It could have resulted from either lack of capacity of local authorities to deliver quality control services or that the artisans were not qualified enough to construct safe earthquake resistant buildings in vernacular architecture. Interviews with locals suggested that in the last 50 years the trend of passing on the artistic professional qualities to future generations had been reduced significantly.

7. Conclusions

The proposed five-year urban regeneration plan aimed to promote conservation and utilization of public spaces for community services. It also aimed to stimulate the local economy by promoting heritage conservation and entrepreneurship development, tourism, and retail commercial activities compatible with heritage conservation. Further, the proposed plan targeted to strengthen the capacity of municipality and community groups in managing urban growth and conservation of tangible and intangible cultural heritages.

For effective implementation, urban regeneration needs to be institutionalized. As the Local Government Operation Act 2017 provides authority to the municipalities to formulate and implement development plans, Bhimeshwor Municipality should launch an urban regeneration plan as soon as possible.

People's participation would be a must in any urban regeneration project as was observed in the cases of Bhaktapur and Bandipur. For this, residents of Dwalkha need to develop notions of solidarity, pride, and identity to unite them and to find effective ways for implementing the urban regeneration plan.

Even though reconstruction in vernacular architecture is not very expensive, people should be encouraged

by providing them incentives for reconstructing in safe vernacular architecture.

The survey showed that unoccupied and poorly maintained houses were more vulnerable to earthquake damage. The local government should therefore have a policy to encourage the maintenance of vernacular buildings and discourage house owners to let the building go unattended.

As some residents of Dwalkha misinterpreted the large damage of stone, and mud masonry houses to mean concrete was stronger and a better construction material as compared to stone masonry. This misconception needs to be corrected quickly to conserve the vernacular buildings of Dwalkha.

Dwalkha is a heritage settlement, and therefore modernization should not be allowed to take over its vernacular architecture. All municipal officers, political leaders, and the local people should be made knowledgeable about conservation and for promoting the reconstruction of earthquake-safe vernacular architecture.

As the trend of passing on the artistic professional qualities from one generation to another has been significantly reduced, the municipality should take a lead to assess the need and take necessary measures to enhance the capacity of required professionals.

8. Recommendation

Institutionalization of the urban regeneration plan is very essential for its effective implementation. The municipality should launch the program to develop the technical and managerial capacity. Similarly, the Ministry of Urban Development (MoUD) should define urban regeneration, formulate policies, and develop guidelines for implementation. As discussed in the Bhaktapur Development Project, the institutional measures should be taken while conservation measures must be strengthened, and the urban regeneration strategies should be supported by political will.

From the literature reviews, it is clear that people's participation is essential in any urban regeneration effort. Hence, Bhimeshwor Municipality should

conduct activities to engender a sense of belonging and partnership among the people. Also, as learned from the Bhaktapur Development Project, social aspects of regeneration should also be considered together with the technical aspects.

As poorly maintained and unoccupied houses are more vulnerable to earthquakes, income generation activities such as homestay or small cottage industries should be encouraged in the heritage area to ensure that no house remained unoccupied and unmaintained.

To increase income generation activities, private investors could be encouraged to rebuild the houses (in a partnership or lease) and generate business so that both the house owner and investor can benefit from, as is the case with some heritage buildings in Malaysia (City, 2020).

The misconception that concrete is stronger and a better construction material compared to bricks or stone masonry, should be corrected. Brick/stone masonry structures can also be made earthquake resistant with the use of proper technology (like the use of horizontal and vertical bands). Municipalities should take a lead partnering with NGOs to conduct awareness campaigns for disseminating the importance of earthquake resistant vernacular construction techniques and material for conservation. These campaigns should focus on prosperity through conservation. It is also very essential to make house owners aware of the importance of timely repair and maintenance of houses.

Modernization should not be allowed to take over vernacular architecture. The municipality should conduct awareness campaigns to disseminate the benefits of conservation of vernacular architecture. The municipality should produce architectural model plans/ type designs that provide ideas for modernizing without losing heritage values. These model designs should comply with building bye-laws in protected monument zone. Model plans or type designs can serve as templates of readymade house plans to use as it is or with minor non-structural modifications.

The concept of conservation should be explained to all municipal officers, political leaders, and the locals

to ensure uniform understanding. Both the conservation of tangible and intangible heritage should be prioritized. For this, the municipality should seek and accept the technical assistance of NGOs or academic institutions. Study tours to the conserved towns can also impart visual knowledge.

Training to enhance the capacity of masons for earthquake resistant and safer vernacular construction techniques should be conducted. The municipality should take a lead and promote partnership with NGOs/ academicians to enhance the skills of artisans and craftsmen and promote vernacular architecture.

References

- [1] Assi, E., 2014. Searching for the Concept of Authenticity: Implementation Guidelines. *Journal of Architectural Conservation*, 69.
- [2] Bhadgaule, A., 2009. Search of Old Newari Settlement. *Nagarik Shanivar, Nagarik*, August 29, Kathmandu.
- [3] Boussaa, D., 2017. Urban Regeneration and the Search for Identity in Historic Cities. MDPI, Qatar University, 16.
- [4] Chan, K.D., 2016. Planning for Heritage Conservation and Community Development : Study of Historic Town 'Thimi' of Kathmandu Valley. *Research Gate*, 78.
- [5] City, T., 2020. Think City. Retrieved from <https://think-city.com.my/conservation/>
- [6] Dorji, W., 2019. Sustainability of Urban Renewal Projects: Lessons from Bhaktapur and Bandipur Projects. *Journal of Urban and Landscape Planning*, 27.
- [7] GoN., 2015. Post Disaster Need Assesment. GoN, National Planning Commission.
- [8] Haaland, A., 1982. *Bhaktapur – A Town Changing*. Frankfurt, Germany: Craftsman Press, Bangkok.
- [9] Himalayan, T., 2017. Atonement worship at Bhimeshwor Temple, Prasad to be sent to Prez. Retrieved from *The Himalayan*. <https://thehimalayantimes.com/kathmandu/atonement-worship-bhimeshwor-temple-prasad-sent-prez>
- [10] Khatiwada, R., 2020. Bhimsen idol 'perspires', Prez to send Puja materials for atonement worship. Retrieved from *My Republica*. <https://myrepublica.nagariknetwork.com/news/bhimsen-idol-perspires-prez-to-send-puja-materials-for-atonement-worship>.
- [11] LMC. 2017, Progress of PURPP (Pro-Poor Urban Regeneration Pilot Project). Retrieved from *lalitpurmun.gov.np*, May 12. <https://lalitpurmun.gov.np/en/content/progress-purpp-pro-poor-urban-regeneration-pilot-project>,
- [12] Mansour, H., 2015. The lost Identity of the City: The case of Damascus. *CITTA 8Th Annual Conference on Planning Research*, p. 20.
- [13] Mceldowney, N.G., 2006. Place and Special Places: Innovations in Conservation Practice in Northern Ireland. *Planning Theory and Practice*, 420.
- [14] NRA., 2016. Government of Nepal, Kathmandu.
- [15] Parajuli, Y.K., 1992. The Lessons of Bhaktapur. Retrieved from *Himal*, January 1. <https://www.himalmag.com/the-lessons-of-bhaktapur>.
- [16] Parlewar, F.A., 2006. *The Sustainable City IV : Urban Regeneration and Sustainability*. UK: Athenaem Press Ltd., Gateshead. Retrieved April 5, 2020. https://books.google.com.np/books?hl=en&lr=&id=LW7P8B-UzLkC&oi=fnd&pg=PA209&dq=india+%22historic+settlement%22&ots=GUpYK-cKkK0&sig=n8tsTt1tLVvj8i7rCsZ2s3Px-byk&redir_esc=y#v=onepage&q=urban%20regeneration&f=false
- [17] Roberts, P., & Sykes, H., 2000. *Urban Regeneration- A Handbook*. London: Sage Publications Ltd.
- [18] Shrestha, S.K., 2014. *Traditional and Ancient Settlement Dwalkha (Pauranik tatha Prachin Nagari Dwalkha)*, unpublished. Dolkha.
- [19] Tumbahang, D.G., 2013. Which One is Ancient (Ko Purano?). *Kantipur*, April 4. Kathmandu, Nepal.
- [20] Wikipedia. 2021. Dolakha District. Retrieved from *Wikipedia*, 2 1) https://en.wikipedia.org/wiki/Dolakha_District
- [21] Yaldız, E. et al., 2014. *Loss Of City Identities In The Process of Change: The City of Konya-Turkey*. Elsevier Ltd., 233.

Contributors

Editorial Board:

Editor in Chief	Tara Nidhi Bhattarai, Professor of Geology, Tribhuvan University, Nepal
Editor	Basu Dev Sharma, Joint Secretary, National Planning Commission
Editor	Jitendra Bothara, Earthquake Engineering Expert, CDPMP/UNDP - Nepal, New Zealand
Editor	Nigel Fisher, World Bank Consultant on Disaster Management, Canada
Editor	Ram Manohar Shrestha, Emeritus Professor, Asian Institute of Technology, Klong Luang, Pathumthani, Thailand.

Organizing Committee:

1. Sushil Gyewali, Chief Executive Officer (CEO), National Reconstruction Authority (NRA)	Chairperson
2. Sushil Chandra Tiwari, Secretary, NRA	Member
3. Baikuntha Aryal, Office of the Prime Minister and Council of Ministers (OPMCM)	Member
4. Dhruva Prasad Sharma, Executive Committee Member, NRA	Member
5. Chandra Bahadur Shrestha, Executive Committee Member, NRA	Member
6. Bishnu Bahadur Bhandari, Executive Committee Member, NRA	Member
7. Hariram Parajuli, Executive Committee Member, NRA	Member
8. Anil Pokhrel, CEO, NDRRMA	Member
9. Jeevan Sitaula, Joint Secretary, NRA	Member
10. Bharat Prasad Aryal, Joint Secretary, NRA	Member
11. Yamuna Pradhan, Joint Secretary, NRA	Member
12. Padma Mainalee, Joint Secretary, NRA	Member
13. Ganesh Raj Osti, Project Director, CLPIU (GMALI)	Member
14. Shyam Kishor Singh, Project Director, CLPIU (Building)	Member
15. Ramsharan Sapkota, Project Director, CLPIU (Education)	Member
16. Damodar Gautam, Director General, Department of Archeology	Member
17. Joint Secretary, Ministry of Finance	Member
18. Joint Secretary, Ministry of Home	Member
19. Joint Secretary, OPMCM	Member
20. Joint Secretary, Ministry of Federal Affairs and General Administration	Member
21. Joint Secretary, Ministry of Foreign Affairs	Member

22. Joint Secretary, Ministry of Urban Development	Member
23. Joint Secretary, Ministry of Culture, Tourism and Civil Aviation	Member
24. Representative Members from Reconstruction Donor Agencies (*5)	Member
25. Representative Members from partner organizations, civil society organizations, professional organizations and academia (*5)	Member
26. Bhagawan Aryal, Joint Secretary, Planning and Budget Division, NRA	Member Secretary

NRA - NPC Task Team for Publication:

Chandra Bahadur Shrestha, Executive Committee Member, NRA	Coordinator
Basu Dev Sharma, Joint Secretary, NPC	Member
Lok Bahadur Khatri, Program Director, NPC	Member
Manohar Ghimire, Under Secretary, NRA	Member Secretary

ICNR Secretariat:

1. Chandra Bahadur Shrestha, Executive Committee Member, NRA	Head of Secretariat
2. Bharat Prasad Aryal, Joint Secretary, NRA	Member
3. Deepak Lamichane, Chief Accountant, NRA	Member
4. Sulochana Nepali, World Bank, Representative - Development Partner	Member
5. Manohar Ghimire, Under Secretary, NRA	Member Secretary

Permanent ICNR Secretariat Invitees

1. Janardan Nepal
2. Sandeep Gurung
3. Minar Thapa Magar

Reviewers' List:

Amod Mani Dixit, Ph.D., President, National Society for Earthquake Technology - Nepal (NSET)
Bamadev Paudel, Ph.D., Professor of Economics, Sheridan College, Canada
Bharat Mandal, Ph.D., Associate Professor, Institute of Engineering, Tribhuvan University
Bhishna Bajracharya, Ph.D., Associate Professor, Bond University, Gold Coast, Australia
Bijaya K. Shrestha, Ph.D., Visiting Faculty, Khwopa Engineering College, Bhaktapur
Binod Pokharel, Ph.D., Professor of Anthropology, Tribhuvan University
Bishal Nath Upreti, Ph.D., Professor of geology, Academician, Nepal Academy of Science & Technology (NAST)
Bishnu Prasad Sharma, Ph.D., Associate Professor of Economics, Tribhuvan University
Chandra Kiran Kawan, Associate Professor, Khwopa Engineering College
Dambar Upreti, Ph.D., Visiting Assistant Professor, Department of Economics and Finance, University of North Carolina Wilmington, USA
Danda Pani Adhikari, Ph.D., Professor of Environmental Science, Tribhuvan University
Deepak Chamlagain, Ph.D., Associate Professor of Geology, Tribhuvan University
Dibyashree Lohani, Associate Professor, Department of Civil Engineering, Nepal Engineering College
Dipendra Gautam, Interdisciplinary Research Institute for Sustainability, Kathmandu
Ganesh Kumar Jimjee, Ph.D., National Society for Earthquake Technology - Nepal (NSET)
Gokarna Bahadur Motra, Ph.D., Professor, Institute of Engineering, Tribhuvan University, Nepal
Gopal KC, Ph.D., Professor (Adjunct) of plant pathology, Institute of Agriculture and Animal Science, Tribhuvan University
Govind Prasad Lamichhane, Ph.D., Associate Professor, School of Engineering, Pokhara University
Hari Dahal, Ph.D., Former Secretary, Government of Nepal
Hari Darshan Shrestha, Ph.D., President, Center of Resilient Development (CoRD)
Hari Prasad Bhattarai, Associate Professor of Anthropology, Tribhuvan University
Inu Pradhan Salikhe, Ph.D., Assistant Professor, Institute of Engineering, Tribhuvan University
Jagat Kumar Shrestha, Ph.D., Associate Professor, Institute of Engineering, Tribhuvan University
Janak Rai, Ph.D., Associate Professor of Anthropology, Tribhuvan University
Jharna Joshi, Ph.D., Architect
Kai Weise, ICOMOS Nepal
Kamal Bahadur Thapa, Ph.D., Associate Professor, Institute of Engineering, Tribhuvan University
Kazuo Konagai, Ph.D., Professor Emeritus, University of Tokyo, Japan
Kul Prasad Kapri, Ph.D., Assistant Professor, Rowan University, USA

Madhusudan Subedi, Ph.D., Professor, Department of Community Health Sciences, Patan Academy of Health Sciences

Manjeshwori Singh, Ph.D., Program Coordinator, Nepal Development Research Institute (NDRI), Lalitpur

Manjip Shakya, Ph.D., Department of Earthquake Engineering, Khwopa Engineering College

Hikmat Raj Joshi, Ph.D, Professor, Institute of Engineering, Tribhuvan University

Megh Raj Dhital, Ph.D., Professor of Geology, Tribhuvan University

Nabha Basnyat Thapa, UNESCO Kathmandu Office

Narayan Prasad Bhatta, Ph.D., Expert, Governance and Sustainability in Irrigation Systems

Narayan Prasad Marasini, Ph.D., National Society for Earthquake Technology - Nepal (NSET)

Narbikram Thapa, Ph.D., Professor, Lumbini International Academy of Science and Technology, Lalitpur

Narendra Raj Khanal, Ph.D., Professor of Geography, Tribhuvan University

Nawa Raj Khatiwada, Ph.D., Program Coordinator, Nepal Development Research Institute (NDRI), Lalitpur

Neel Kamal Chapagain, Ph.D., Associate Professor, Centre for Heritage Management, Ahmedabad University, India

Nisha Shrestha, Environment and DRM Expert, National Society for Earthquake Technology - Nepal (NSET)

Prachand Man Pradhan, Ph.D., Associate Professor, Department of Civil Engineering, Kathmandu University

Pratap Kumar Pathak, Former Secretary, Government of Nepal

Prem Bahadur Thapa, Ph.D., Associate Professor of Geology, Tribhuvan University

Raj Kumar Bhattarai, Ph.D., Associate Professor of Management, Tribhuvan University

Rajan Suwal, Ph.D, Associate Professor, Institute of Engineering, Tribhuvan University

Rakesh Dumar, Ph.D., Associate Professor, Nepal Engineering College

Ram C Acharya, Ph.D., Balioghar Construction Pvt Ltd, Kathmandu

Ram Chandra Khanal, Ph.D., Community of Evaluators (CoE) Nepal

Ramesh Guragain, Ph.D., Deputy Executive Director, National Society for Earthquake Technology - Nepal (NSET)

Ramraj Narasimhan, Disaster Risk Management Specialist, United Nations Development Programme (UNDP), Nepal

Ranjan Dhungel, Program Manager-Baliyo Ghar, National Society for Earthquake Technology - Nepal (NSET)

Rekha Shrestha, Ph.D., Visiting Professor, National College of Engineering, Lalitpur

Roshan B. Bhandari, Ph. D., Sessional Lecturer, Master of Emergency and Disaster Management, Charles Darwin University, Australia

Rudra Suwal, Ph.D., Former Deputy Director General, Central Bureau of Statistics, Government of Nepal

Samsung Lim, Ph.D., Associate Professor, School of Civil & Environmental Engineering, UNSW, Sydney, Australia

Sangeeta Singh, Ph.D., Professor, Institute of Engineering, Tribhuvan University.

Santosh Shrestha, Ph.D., Senior Earthquake Resilience Adviser, NHSSP-III, Ministry of Health & Population
Sanjaya Uprety, Ph.D., Associate Professor, Institute of Engineering, Tribhuvan University
Santa Man Rai, Ph.D., Professor (retired) of Geology, Tribhuvan University
Shankar Ghimire, Ph.D., Assistant Professor of Economics, Western Illinois University, USA
Shankar Shrestha, Ph.D., Senior Researcher, Nepal Development Research Institute (NDRI), Lalitpur
Shiva Raj Adhikari, Ph.D., Professor of Economics, Tribhuvan University
Shyam Sunder Kawan, Assistant Professor, Nepal Engineering College
Sirish Bhatt, Conservation Architect
Subik Kumar Shrestha, Department of Architecture, University of Oregon, USA
Subodh Dhakal, Ph.D., Associate Professor of Geology, Tribhuvan University
Suman Narsingh Rajbhandari, Ph.D., Senior Structural Engineer, Creative Design Architect (P.) Ltd. Lalitpur
Suresh Kumar Dhakal, Ph.D., Associate Professor of Anthropology, Tribhuvan University
Surya Narayan Shrestha, Earthquake Risk Management (ERM) Expert, National Society for Earthquake
Technology - Nepal (NSET)
Upendra Aryal, Executive Director, Digital Broadcast Initiative, Equal Access (DBI EA), Lalitpur
Usha Kiran Subba, Ph.D., Professor of Psychology, Tribhuvan University
Vibha Bhattarai Upadhyay, Ph.D., Urban Planning and Heritage Conservation, University of Sydney
Vivek Rawal, Advisor (Housing Reconstruction), United Nations Development Programme (UNDP), Nepal

Language Editor:

Binod Bhattarai

Design and Layout:

Chiran Ghimire

